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Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

Jerome D. Goodrich, Jr.
PRESIDENT

October 4, 1995

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

SUPERSEDED

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed portion of its *Environmental Impact Report* (EIR) for the Crandon Project, together with revisions to previously submitted sections. Those sections of the report with appendices included with this submittal are:

Section 4	Environmental Impacts
Section 5	Mitigation

The additional EIR sections and revisions have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. As noted on the attached distribution list, CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The enclosed information consists of a packet of loose pages and additional bound material. The loose pages need to be inserted into EIR Volumes I and II which were submitted to you in May, 1995. The attached reference list provides information as to where to insert the enclosed report sections in the Volume I and II three ring binders. The list has been prepared to not only facilitate insertion of the additional information, but also to serve as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. If subsequent revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes. The

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additional three ring binders represent Volumes X and XI which are additional EIR appendices.

Also enclosed is a new cover page and binder title for EIR Volume IX. Please insert these in your documents. Also please discard Appendix 4.2.13-1 which is in Volume IX as it is now included in Volume XI with the rest of the appendices for Section 4 of the EIR.

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

Jerome D. Goodrich, Jr.
President
Crandon Mining Company

JDG:mld2

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

Jerome D. Goodrich, Jr.
PRESIDENT

May 22, 1995

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army of Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

RE: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to file the enclosed portion of its *Environmental Impact Report* (EIR) for the Crandon Project, together with supporting appendices. Those sections of the report included with this submittal are:

Section 1	Introduction
Section 2	General Project Description
Section 3	Description of the Environmental Setting
Section 4.2.13	Socioeconomic Impact Analysis

The EIR has been prepared on behalf of CMC by Foth & Van Dyke and Associates Inc. As noted on the attached distribution list, CMC has distributed the document to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The purpose of the EIR is to support the Mine Permit Application for the Crandon Project which has been simultaneously submitted to the WDNR and to the USCOE. The EIR will also support the Federal Clean Water Act Section 404 Permit Application which will be filed with the USCOE. As per previous discussions with the WDNR and the USCOE, CMC is submitting portions of the EIR at this time to allow the WDNR and the USCOE to begin work on the project's *Environmental Impact Statement* (EIS). Work is currently underway on EIR Sections 4 and 5, titled Environmental Impacts and Mitigation of Impacts, respectively. CMC currently anticipates these sections will be completed in July, 1995, at which time they will be submitted to your two agencies. In addition, long term data collection for programs related to baseline air and groundwater quality, waste characterization, and other matters is continuing. Per our discussions with both the WDNR and USCOE, collected data will be forwarded to the agencies periodically through the summer of 1995, in the form of addenda to the EIR.

Telephone: (715) 365-1451 FAX: (715) 365-1457

CMC requests that the WDNR and USCOE initiate the following action on the documents being filed:

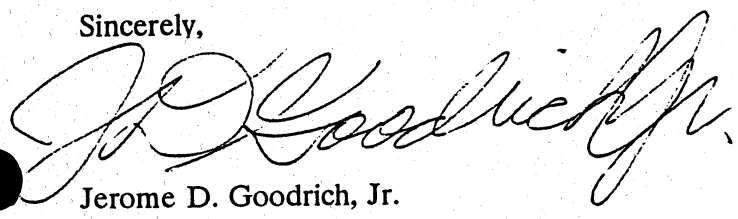
1. Begin preparation of a draft EIS for the proposed project described in the EIR and the Mine Permit Application.

2. Coordinate with appropriate state and federal agencies to assure that the EIS will be responsive to the needs of those agencies that have input regarding the proposed project.

3. Initiate the review of all permit applications, license applications, and similar documents regarding the proposed project that are filed with and require approval of either or both the WDNR and USCOE.

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,



Jerome D. Goodrich, Jr.
President
Crandon Mining Company

JG:jcp

Attachment

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

Jerome D. Goodrich, Jr.
PRESIDENT

January 29, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 4.2.2.1.1, Roads, of the Crandon Project's *Environmental Impact Report* (EIR).

This update has been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. As noted on the attached distribution list, CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes I and II of the EIR according to Items 13 through 15 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 12 on the list were previously submitted in September 1995. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

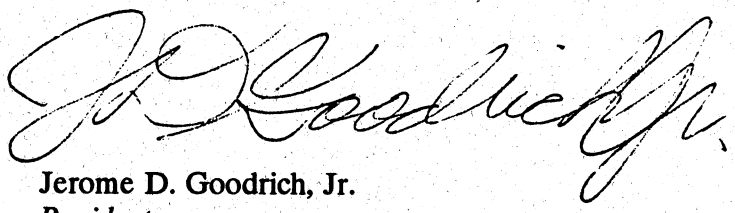
MLD2\93C049\GBAPP\26101\10000

Telephone: (715) 365-1451

FAX: (715) 365-1457

If you or your staff have any questions regarding the EIR or EIR Supplement, please contact me at (715) 365-1450.

Sincerely,



Jerome D. Goodrich, Jr.
President
Crandon Mining Company

JDG:mld2

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

June 13, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 3.4, Climatology, Meteorology and Air Quality, and the new Appendix 3.4-2, of the Crandon Project's *Environmental Impact Report* (EIR).

This update has been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. As noted on the attached distribution list, CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

EIS 40/ 995/
V.1-3

The pages contained in this update need to be inserted into Volumes I and III of the EIR according to Items 36 through 42 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 35 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Also, please note that Comment 14 of the WDNR's July 31, 1995 letter has been addressed by a revision to paragraph 4 of Section 3.4.3.2 (page 3.4-6).

MLD2\93C049\GBAPP\32535\10000

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TEL.: (715) 478-3393 FAX: (715) 478-3641

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

July 31, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 3.7, Surface Water and Bottom Sediments, of the Crandon Project's *Environmental Impact Report* (EIR).

This update has been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. As noted on the attached distribution list, CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes II and IX of the EIR according to Items 43 through 53 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 42 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the following comments from the July 31, 1995 WDNR letter pertaining to CMC's EIR have been addressed:

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P.O. BOX 336 104 W. MADISON
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WDNR Comment Number	See Update
67	Section 3.7.3
68	Section 3.7.1
70	Section 3.7.4.7
71	Section 3.7.5.1
72	Section 3.7.6

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

DM:mld2

Crandon Project Environmental Impact Report
Log of Updates and Additional Information

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
1	10/04/95	3	Log of Updates	Addition (Place Behind Cover Letter)
2	10/04/95	4 through 9	Distribution	Updated (Place Behind Log of Updates and Additional Information)
3	10/04/95	ii - xiv	Executive Summary	Updated to Address Impacts and Mitigation (Remove Existing and Place New Behind the Title Page)
4	10/04/95	xv	Master Table of Contents	Updated
5	10/04/95	1 through 6	List of Contributors	Updated
6	10/04/95	7 through 9	List of Acronyms	Updated
7	10/04/95	4.2.13-1 to -132 & Figures 4.2.13-1 to -8	4.2.13	Delete - Replaced with Section 4 of EIR. Changes to Section consist of added information for Subsection 4.2.13.4.6 on page 4-244 and the deletion of last paragraph in Section 4.2.13.6 on page 4-248.
8	10/04/95	Title Page through 4-300	Section 4	Add Environmental Impact Section
9	10/04/95	Title Page through 5-8	Section 5	Add Mitigation Section
10	10/04/95	—	Appendix 4.2.13-1	Delete from Volume IX. Replaced by Appendix 4.2-8 in Volume XI.
11	10/04/95	Cover & Spine	Volume IX of Appendices	Replace face and spine covers.
12	10/04/95	—	Volumes X & XI	Add Volumes X and XI - Appendices for Section 4
13	01/29/96	3	Log of Updates	Updated
14	01/29/96	4 through 9	Distribution	Updated

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

August 28, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Integrated Science Services
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Appendix 4.2-3, Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin, of the Crandon Project's *Environmental Impact Report* (EIR).

This update has been prepared on behalf of CMC by GeoTrans, Inc. As noted on the attached distribution list, CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes I, X, and XI of the EIR according to Items 54 through 61 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 53 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

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If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

October 31, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David L. Ballman, Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 4.2.13, Socioeconomics, of the Crandon Project's *Environmental Impact Report* (EIR).

This update has been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes I and II of the EIR according to Items 99 through 111 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 98 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this letter and the enclosed update the following comments from Bill Tans' July 31, 1995, and May 3, 1996, letters, and Shannon Fenner's September 9, 1996, letter pertaining to CMC's EIR have been addressed:

MLD2\93C049\GBAPP\36178\10000

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WDNR Comment Number	
116	See Response Below
117	CMC to discuss directly with WDNR
118	See Updated Sections 4.2.13.4.4.1 and 4.2.13.4.4.2
119	See Updated Section 4.2.13.4.2
120	See Response Below
121	See Updated Section 4.2.13.4.2.2
122	See Updated Section 4.2.13.4.4.6
123	See Response Below
124	See Updated Section 4.2.13.4.1 and Figure 4.2.13-6a
185	See Response Below
186	See Response Below
187	See Updated Section 4.2.13.2.1
188	See Updated Section 4.2.13.3.3
189	See Updated Section 4.2.13.4.2
190	See Updated Section 4.2.13.4.4.4
Shannon Fenner Comment #1	See Response Below
Shannon Fenner Comment #2	See Response Below

Responses to Comments from the July 31, 1995 and May 3, 1996 WDNR Letters

Comment 116: In this section the following statement is made: *"Although CMC believes that the statutes provide for a deduction of federal and state income taxes for net proceeds tax calculation, no deduction for these taxes was taken in preparing the net proceeds tax estimates, as there is some disagreement about their deductibility."* Please explain with whom there is a disagreement and provide a little explanation of why there is a disagreement. How much difference is there between being able to use taxes as a deduction and not being able to use them?

Comment 116: *Chief Legal Counsel of the Department of Revenue, Mr. John Evans, has advised CMC that it is the Department's position that Section 70.375(4)(e), Stats., does not permit a deduction for federal and state income taxes. It contends that the phrase "and deductible by corporations in computing net income under s.71.26(2)" applies to all the taxes*

listed in Section 70.375(4)(e). It is CMC's position that such phrase only modifies "other taxes," and that rules of statutory construction and the legislative history for both provisions specifically do permit the deduction of income taxes for purposes of the net proceeds tax. CMC intends to further discuss this issue with the Department of Revenue at a later date. If CMC were able to deduct federal and state income taxes, the estimated $119,000,000 net proceeds tax for the project would decrease by approximately 20 percent.

Comment 120: In view of the apparent differences of opinion on local hires, the uncertainty associated with socioeconomic projections and the critical importance of local hiring, we may require a worst case analysis based on a supportable figure for the percentage of local hiring. If we conduct a worst case local hiring scenario, then that local hiring figure must be used to re-calculate all the appropriate additional socioeconomic impacts which are based on it.

Response 120: *Comment 120 is a statement not requiring a revision to the EIR or a response by CMC.*

Comment 123: 4.2.13.4.1 Population Impacts: A family size factor of 3.01 for each in-migrant was used to estimate total population increase in the study area. In the table projecting increases in the population, several towns show increases of 1 and 2 people. Please explain.

Response 123: *The population change for any given minor civil division (MCD) was determined using the gravity model and a family size factor of 3.01. The gravity model allocated workers to each MCD based on a number of factors such as distance from the mine, amenities and services offered in the MCD, etc. To estimate population increase per MCD, the gravity model allocation was multiplied by the family size factor. For some MCDs the gravity model allocation was between zero and one workers. In these cases, the population change for the MCD was estimated to be the nearest whole number to the product of the gravity model allocation factor multiplied by 3.01.*

Comment 185: On Table 4.2.13-4 (Projected Total Project Expenditures in Wisconsin) are fuel costs included? Does the category electric services include the cost of electricity?

Response 185: *Table 4.2.13-4 on projected expenditures includes the cost of fuel and electricity for the operating period (years 2000-2027). The cost of fuels during this period is captured under the line item titled miscellaneous retail. The cost of electricity during the operating years is shown under electrical services. The fuel expenditures for the construction and reclamation periods are captured as part of the line item costs for equipment, material and services required to construct the facility.*

Comment 186: For the above table, please include a discussion regarding how the distinction was made between projected expenditures that would be made within or outside

of Wisconsin. Please indicate some examples of expenditures that would be made outside of the state and show the percentage of expenditures within and outside of the state.

Response 186: *The point of purchase for major items of equipment was sourced through the "Thomas Register". Equipment manufacturers or material suppliers were either labelled as "local", or "out of state" purchases.*

Bulk materials such as cement, structural steel, architectural items, etc. were designated as state purchased items. In addition items such as motors and generators, electrical controls, tankage, process piping, industrial trucks and tractors, computer equipment, etc. were designated as "local" items. On the other hand, "out of state" purchases included underground production mining equipment, hoists, industrial chemicals, grinding mills and other related concentrator process equipment.

Table 1 is an example of estimated expenditures by a number of sectors. The amount of in-state expenditures has been calculated as a percentage of total dollars to be spent. (Note: Also see the following responses to WDNR's September 9, 1996 letter for additional comments regarding tri-county and Wisconsin expenditures.)

Table 1

Sector	Expenditure (,000$)		% in State $
	In-State	Other	
Metal Mining			
Metal Mining Services	9,578	70,793	12%
Heavy Construction Contractor			
Highway Construction	1,114	404	73%
Prefabricated Metal Products			
Fabricated Metal Buildings	5,569	2,184	72%
Primary Metal Industry			
Pipes, Valves, Fittings	1,934	1,706	53%
Communication			
Communication	1,896	743	72%
Rail Transportation			
Rail and Related Services	4,745	1,698	74%
Inorganic Chemical			
Industrial Chemicals	42	253	14%

Prepared by: KB
Checked by: JWS

Responses to WDNR's September 9, 1996 Letter

Comment 1: Expenditures which will occur in Wisconsin are specified in Table 4.2.13-4 of the Environmental Impact Report. In order to more fully evaluate the socio-economic impacts of the project, it would be useful to understand the methodology which was used in determining the expenditures. Were specific suppliers contacted, or are the amounts based on more general prices?

Response 1: *An analysis was conducted to determine the point of purchase of major items of equipment. Equipment manufacturers or material suppliers were sourced through the Thomas Registry and labelled as "local", "state", or "out of state" purchases depending on their location relative to the project site. The breakdown of equipment and material costs by the standard industrial classification was established by a construction contracting firm experienced in mine construction. Unit costs for mine construction were available through the contractors database coupled with information from CMC records.*

Comment 2: In the May 3 comment letter from Bill Tans to Don Moe, a request was made for the percentage of total expenditures which would occur in Wisconsin. In addition to this information, I would also like to request a further breakdown. What percentage of the Wisconsin expenditures would occur in the tri-county study area?

Response 2: *Table 2 reflects the total project expenditures which would occur in Wisconsin. A split has been made to reflect both estimated local and state expenditures.*

Table 2

Total Project Expenditures in Wisconsin (in 1994 $,000s)

Total Expenditure in Wisconsin	*Total Local[1]*	*%*	*Total State[2]*	*%*
$739,913	*$130,569*	*18%*	*$609,344*	*82%*

[1]Tri-County Area.
[2]Within Wisconsin Outside of Tri-County Area.

Prepared by: KB
Checked by: JWS

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

DM:mld2

cc: EIR Distribution List

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

November 1, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 3.8, Aquatic Biology, of the Crandon Project's *Environmental Impact Report* (EIR).

These updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volume II of the EIR according to Items 112 through 120 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 111 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the comments identified below from the July 31, 1995 WDNR letter pertaining to CMC's EIR have been addressed.

MLD2\93C049\GBAPP\39424\10000

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WDNR Comment Number	See Update
75	See Response Below
76	See Response Below
77	Section 3.8.2.10, Table 3.8-57, See Response Below
78	Section 3.8.3.5
79	Section 3.8.3.6

Comment 75: 3.8.2.9: The fish survey by CMC consultants in 1994 concentrated on searching for threatened and endangered species in areas surrounding the proposed mine site. Data collection and reporting appear adequate to that purpose. However, there is a need for additional fish survey work in the area of the proposed mine site. Past fish survey work by DNR and CMC's consultants during the last permitting process was extensive. Several environmental events including a major drought in 1988-90 and changes in location and extent of beaver dams on area streams may well have contributed to changes in fish communities in the waters previously surveyed. Current (1994) fish survey work by CMC consultants was confined to May and June sampling and focused on threatened and endangered species, and may not have been adequate to detect such changes. While it is not necessary to repeat the entire past survey work, we request that CMC's consultants repeat intensive lake and stream surveys at several selected sites to cross check species composition and relative abundance since the previous surveys. Prior to such sampling, CMC's consultants should contact the Woodruff office so we can provide recommended sampling sites.

Response 75: *Fish sampling efforts conducted by CMC in 1994 in the area of the proposed Crandon mine were strictly for the purposes of evaluating the status of threatened, endangered, or special concern species. The 1994 study was supplementary to previous studies which did not specifically address "listed" species. Therefore, the 1994 data was meant to complete the data set for the Crandon Project.*

As we understand, the WDNR conducted additional fish work in the area in 1995 to duplicate efforts completed during 1979. As we understand, this work was done to provide the data referred to in Comment 75.

Comment 76: The recent proposal to discharge waste water to the Wisconsin River at Hat Rapids raises potential fish sampling needs not addressed to this point. Fish community composition (species presence and relative abundance), growth of selected fish species, length frequencies and fish tissue analysis for metals as was done at the proposed mine site should be measured at a minimum of one site downstream from the proposed discharge site. Please notify fisheries personnel at Woodruff prior to sampling to allow observation of data collection.

Response 76: *CMC understands that the WDNR has an on-going fish inventory program for this section of the river. The WDNR's survey is focused on developing information on the status*

of the fish community from Hat Rapids Dam to Menard Isle, with most of the effort dealing with larger game and forage species. As we also understand, previous fish inventories of the area are, according to WDNR personnel, sufficient for purposes of environmental review and for permitting activities.

Notwithstanding the above, CMC, in an August 5, 1996 letter to Mr. Bill Tans of the WDNR, proposed to supplement the WDNR's program by conducting an intensive survey using shocking and seining techniques to provide additional data on the occurrence of species listed on the Wisconsin Heritage Inventory List that may not have a high likelihood of being encountered using the WDNR's sampling methods. This work was accomplished in late summer of this year (1996). The results of this work are described in an update to Volume IIIa, EIR Supplement: Wisconsin River Wastewater Discharge Pipeline for the Crandon Project, of the CMC Environmental Impact Report that was issued on October 21, 1996.

Comment 77: Table 3.8-57. *Pleurobema sintoxia* and *Pleurobema coccineum* are synonymous, and information for these should be combined under *Pleurobema coccineum*.

Response 77: *Changes to the narrative of Section 3.8.2.10 and Table 3.8-57 have been made in the enclosed EIR update to address WDNR's comment. CMC acknowledges that there has been some confusion relating to this issue. P. coccineum and P. sintoxia are the same species. Don Helms in his 1994 work for CMC listed his findings as P. sintoxia. The only listing of P. coccineum in the data set were of findings of Dave Heath of the WDNR. Mr. Heath has since indicated that the proper classification for the two is P. coccineum.*

The Wisconsin Natural Heritage Inventory (WHI) lists only P. sintoxia. Mr. Heath has indicated that the WHI nomenclature was based on his initial recommendation, and that the new name for the round pigtoe is P. coccineum. As we understand, Mr. Heath is working to revise the name for the round pigtoe as it appears in the WHI to P. coccineum. As we also understand, the reference which is being cited by Mr. Heath relative to the nomenclature of the species is as follows: Turgeon, Donna D., et al., 1988. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Molluscs. AFS Special Publication #16.

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

cc: EIR Distribution List

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

November 4, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed updates to Section 3.10, Wetlands, and Section 3.12, Land Use and Zoning, of the Crandon Project's *Environmental Impact Report* (EIR).

These updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes II and IX of the EIR according to Items 121 through 129 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 120 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the comments identified below from the July 31, 1995 WDNR letter pertaining to CMC's EIR have been addressed. Also note that revisions to wetland acreages addressed in the October 1, 1996 letter to Ms. Cathy Cleland of the WDNR have also been incorporated into the update to Section 3.10.

MLD2\93C049\GBAPP\39277\10000

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WDNR Comment Number	See Update
102	Section 3.10.1
103	Section 3.10.1.1
104	Section 3.10.2 and Appendix 3.10-4 Table 2
105	Section 3.10.4
108	Section 3.12.3.6

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

DM:mld2

cc: EIR Distribution List

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
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December 18, 1996

Mr. Bill Tans
Wisconsin Department of Natural Resources
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Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed updates to Sections 3.2, 4.2.1, and 4.2.14 of the Crandon Project's *Environmental Impact Report* (EIR). Updated Sections 3.2 and 4.2.1 relate to cultural resources. Section 4.2.14 relates to impacts to Native American Communities. The updates to Sections 3.2.2, 3.2.3, 3.2.4, and 4.2.1.2 involve numerous changes to the original text, and therefore are not highlighted. Changes made to all other sections are highlighted.

These updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in these updates need to be inserted into Volumes I, II and III of the EIR according to Items 130 through 137 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 129 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

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Please note that through this update the following comments from the July 31, 1995 WDNR letter and the September 5, 1996 USCOE letter pertaining to CMC's EIR have been addressed:

WDNR Comment Number	See Update
General Comment - 3.2 Cultural Resources	Section 3.2

USCOE Comment Number	See Update
4a	Section 3.2
7a	Section 3.2.1.2.3
8	Section 3.2.1.3.1
10	Section 3.2.1.3.3
11	Section 3.2.2
15	Section 3.2.2
16	Section 3.2.2
17	Section 3.2.2
18	Section 3.2.2
20	Figure 3.2-1 has been removed
21a	Section 3.2.2
21b	Section 3.2.2
23	Section 3.2.2
34	Sections 4.2.13, 4.2.2[1]
48	Figure 3.2-1 has been removed
49	Section 4.2.1.2[2]
57	Figure 3.2-1 has been removed
59	Section 3.2
60	Sections 3.2.2 and 4.2.14
67	Sections 4.2.13.4.3 and 4.2.13.4.2.2

[1]Addressed in update dated October 31, 1996.

[2]The topics addressed in this section were originally contained in Section 4.2.14 of the original version of the EIR.

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
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January 9, 1997

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P.O. Box 7921
Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed updates to Section 3.3, Transportation and Utilities, and Section 3.6, Groundwater, of the Crandon Project's *Environmental Impact Report* (EIR).

The updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes I, VI, VII, and VIII of the EIR according to Items 138 through 177 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 137 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the comments identified below from the July 31, 1995 WDNR letter pertaining to CMC's EIR have been addressed.

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WDNR Comment Number	See Update
13	Section 3.3.5
46	Section 3.6.4.3
51	Section 3.6.4.3
53	Figure 3.6-46
54	Figure 3.6-11
55	Figure 3.6-11
56	Section 3.6.2 and See Response Below
57	See Response Below
58	See Response Below

Comment 56: CMC should continue to attempt to obtain missing information from the domestic water well inventory. This includes continuing to obtain information for wells which no information has been obtained to date as well as filling in missing information from partially-inventoried wells. At some point, it will be necessary for field measurements to be made to obtain the missing information. It is particularly important to obtain information regarding the static water level and pumping water levels for the wells wherever possible. The resulting water levels will determine whether a detrimental effect might occur to a particular well. Otherwise, impact assessments will have to be based upon assumptions regarding a particular well's static and pumping water levels.

Response 56: *As presented in the update to Section 3.6.2 and the January 2, 1997 Addendum No. 1 to the High Capacity Well Permit Application, CMC has collected additional information for the domestic water well inventory.*

Comment 57: CMC has limited its investigation of domestic water well to wells in what were previously identified as Zone 1, the area which was predicted to have a drawdown of 3 feet or more. Because wells could be negatively impacted by a groundwater drawdown of even a foot or two, depending on the characteristics of the well, the pump and groundwater, representative sampling of wells in zone 2 also should be conducted.

Comment 58: Depending upon the final extent of predicted and actual mine dewatering effects it may be necessary to expand the well water inventory into all of Zones 2 and 3. Also, potential water quality impacts to private well users resulting from mine dewatering and other site activities has been largely ignored. Reversals in groundwater gradients and resulting induced infiltration from surface water sources or other contamination sources on the site have a potential to change and/or adversely affect well water quality. Eventually, this potential must be addressed and evaluated together with any mitigative measures that may be implied. Such an evaluation will ultimately require collection of baseline water quality data from private wells. CMC should begin to develop a proposed baseline water quality sampling program for private wells in the mine area and suggest mitigative

measures to be implemented in the event mining activities cause private well water quality or quantity problems.

Response to Comments 57 and 58: *Since these comments were made, CMC has been working with the WDNR to establish reasonable limits for the domestic water well survey. In a September 9, 1996 letter to Mr. Charles Fitzgerald regarding the project's October 1995 High Capacity Well Permit Application (HCWPA), CMC proposed a clarification to the limits. On January 2, 1997 CMC be submitted Addendum No. 1 to its HCWPA providing additional survey information in accordance with that letter.*

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

DM:mld2

cc: EIR Distribution List

Crandon Mining Company

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January 14, 1997

Mr. Bill Tans
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Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 3.5, Geology and Soils, of the Crandon Project's *Environmental Impact Report* (EIR).

The updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in this update need to be inserted into Volumes I and IV of the EIR according to Items 178 through 196 on the attached reference list. This list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 177 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the comments identified below from the July 31, 1995 WDNR letter pertaining to CMC's EIR have been addressed.

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WDNR Comment Number	See Update
16	Table 3.5-1
17	Table 3.5-1
19	Table 3.5-1
20	Table 3.5-1
22	See Response Below
25	See Response Below
26	See Response Below
29	Section 3.5.3.1.4
30	Table 3.5-11
31	Section 3.5.3.4 and See Response Below
32	Section 3.5.3.4 and See Response Below
38	Section 3.5.3.4
40	See Response Below
43	Section 3.5.3.4
48	Section 3.5.3.2.1

Comment 22: Part 3.5.1.5 and Appendix 3.5-13 - A number of drill holes were blind drilled through the saprolite-till contacts and the contact is interpreted. The narrative gives the impression and implies all contacts were picked from recovered intervals. This should be clarified.

Response 22: *This issue was addressed and incorporated into the Groundwater Modeling Report contained in Appendix 4.2-3 of the EIR. The Saprolite Report contained in Appendix A of the Groundwater Modeling Report is preceded by a memorandum that addresses contact interpretations.*

Comment 25: The first round of ABA samples taken in the Spring, 1994, were not incorporated into the EIR. CMC needs to explain why the first ABA rounds were not used or include their results into the EIR.

Response 25: *The subject ABA data was incorporated into the Waste Characterization Update Report submitted to the WDNR and USCOE in December 1995.*

Comment 26: The entire borrow needs for the mine facility are not addressed. In order for the DNR to accurately assess impacts, the entire borrow needs (clay and fill) for the facility need to be addressed in detail. If needed materials would be purchased, even if

from existing commercial sources, it means that another company will develop a borrow site or enlarge an existing one. To do this adequately would involve identification and characterization of potential borrow sites to meet all needs, regardless of whether a third party may be doing the actual development. This is a requirement for the EIR.

Response 26: *As noted in Addendum No. 1 to the May 1995 Crandon Project Tailings Management Area Feasibility Report/Plan of Operation (Feasibility Report), CMC has replaced the native clay in the proposed liner and final cover system for its proposed TMA with a geosynthetic clay liner (GCL). The use of a GCL eliminates the need to import clay to the site for liner construction. A revision to the TMA material balance will be presented in Addendum No. 3 to the Feasibility Report which will be issued shortly.*

General Discussion Relating to Comments 31 through 45

This series of comments relates to soils (topsoil in particular) information as presented in the EIR and other project documents. The organization of the Crandon Project EIR and permit documents has been developed to meet the requirements of the various laws and administrative codes that govern their development and review. For instance, Section 3 of the EIR presents baseline environmental information for the study area. The permit applications explain how the various project features will be constructed and operated in a way to meet the requirements of the prevailing law and administrative code. Section 4 of the EIR takes the baseline information from Section 3 and the information from the permit applications and describes and evaluates the impacts of the project on the affected environment. Given this method of organization, individual comments within the 31 through 45 series pertain to either Section 3.5 (numbers 38 and 43) of the EIR, Section 4 (numbers 43 and 45) of the EIR, or the Mine Permit Application (MPA) or the Tailings Management Area Feasibility Report/Plan of Operation (Feasibility Report) (numbers 33, 34, 35, 36, 37, 39, 41, 42, and 44). Those comments pertaining to Section 3.5 of the EIR are addressed in the update to Section 3.5 enclosed with this letter. The comments pertaining to Section 4 of the EIR and the MPA and TMA Feasibility Report will be addressed in future updates to those documents. Responses to comments 31, 32, and 40 are presented below.

Comment 31: In its current state the EIR does not adequately describe the existing soils environment. There is a varying degree of soils information presented in discrete locations in several documents with no attempt to integrating this information into a comprehensive whole. There is no way to systematically show the baseline condition much less establish that no impacts to soils have occurred. Please integrate the soils discussion into one comprehensive treatment.

Comment 32: There is substantial information on soils and vegetation and that may be relevant that was submitted as part of the Exxon EIR. If past data is no longer relevant, there should be some discussion as to why it is not. What is needed is some processing of available soils information including existing data - along with new SCS data and proper use and integration of old data to portray a graphical (maps, tables) and narrative to allow

the reader to come to some conclusions about the nature, variability, usefulness of the existing resource and how it relates to the kind of topsoil management necessary to assure that reclamation is feasible.

Response 31 and 32: *Section 3.5.3.4, Topsoil, of the enclosed update presents a substantially enhanced discussion of baseline topsoil information for the mine site. The updated section consolidates information collected in the 1980s with data collected in the 1990s along with the 1990s Soil Conservation Service data to define the nature, variability, and usefulness of the existing topsoil resource.*

Comment 40: Please generate a topsoil stripping map. This is necessary to determine if there would be adverse long-term impacts from failing to recover the available soil resource.

Response 40: *It is CMC's intent to recover all the available topsoil resource from the areas of disturbance within the mine site, therefore there is no need to prepare a topsoil stripping map.*

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

DM:mld2

cc: EIR Distribution List

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
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March 13, 1997

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
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Madison, WI 53707

Mr. David Ballman
Ecologist
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - *Environmental Impact Report*

Crandon Mining Company (CMC) is pleased to submit the enclosed updates to the following sections of the Crandon Project's *Environmental Impact Report* (EIR).

Executive Summary
List of Contributors
List of Acronyms
Section 4, Environmental Impacts
Section 5, Mitigation

These updates have been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The pages contained in these updates need to be inserted into Volumes I, II and XI of the EIR according to Items 197 through 225 on the attached reference list. Appendices 4.2-10 and 4.2-11 are included in Volume XII of the EIR which is being issued with this update. The reference list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 196 on the list were previously

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submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update the following comments from the USCOE's September 5, 1996 letter and the July 31, 1995 and May 3, 1996 WDNR letters pertaining to CMC's EIR have been addressed:

USCOE Comment Number	See Update
26a	Section 4.2.2.1.1

WDNR Comment Number	See Update
July 31, 1995 Letter	
36	Section 4.2.4.2
43	Section 4.2.4.2
45	Sections 4.2.4.2
115	Section 4.2.12
May 3, 1996 Letter	
144	See Response Below
145	Section 4.2.3.2
146	See Response Below
147	Section 4.2.4.1.1
148	Section 4.2.4.1.1 and See Response Below
149	See Response Below
150	Section 4.2.4.1.2
151	Section 4.2.4.1.2
152	Section 4.2.4.1.1
153	Figures 4.2.5-1 through 4.2.5-8 and See Response Below
154	Figures 4.2.5-1, 4.2.5-4, and 4.2.5-7

WDNR Comment Number	See Update
155	Figures 4.2.5-2, 4.2.5-5, and 4.2.5-8 and See Response Below
156	Sections 4.2.5.7 & 4.2.6 and See Response Below
157	Section 4.2.5.7 and See Response Below
158	Section 4.2.5.7 and See Response Below
159	Sections 4.2.5.9 and 4.2.6
160	Section 4.2.5 and See Response Below
161	See Response Below
162	See Response Below
163	See Response Below
164	See Response Below
165	See Response Below
166	See Response Below
167	Section 4.2.9.2.2
Section 4.2.6.3.3	Section 4.2.6.3.3
168	Figures 4.2.7-3 & 4.2.7-4 and See Response Below
169	Section 4.2.7 and See Response Below
170	See Response Below
171	Section 4.2.7 and See Response Below
172	See Response Below
173	See Response Below
174	Sections 4.2.7.1.3 and 4.2.9.3.4
175	See Response Below
176	See Response Below

WDNR Comment Number	See Update
177	Tables 4.2.10-2, 4.2.10-4, and 4.2.10-7
178	See Response Below
179	See Response Below
180	Section 4.2.10.2 and Figure 4.2.10-4
181	See Response Below
182	Section 4.2.12
183	Section 4.2.12
184	See Response Below
191	See Response Below
192	See Response Below
Section 5.4	See Response Below

Comment 144: Appendix 4.2-2 details the air quality modeling completed for the proposed project. Figures (e.g., figures 15-24) show the air quality impacts on a grid system, but it is impossible to visualize the impacts relative to the project site, natural landmarks and proposed facilities because none of these are shown on the map. For our EIS, we will need figures illustrating air quality impacts comparable to figures 3-13 and 3-14 in the Exxon Final EIS.

Response 144: *The requested figures have been prepared and forwarded to WDNR for inclusion in the EIS.*

Comment 146: What are the potential air quality emissions from the froth flotation circuits in the mill? Will the mill be vented? Please discuss.

Response 146: *The potential air quality emissions from the froth flotation circuits in the mill are addressed in the project's August 1995 Air Pollution Control Permit Application and are considered to be an insignificant source. Since the processes are wet, no particulate emissions are expected. Furthermore, of the liquid reagents containing volatile materials, the organic compounds are expected to bind with the concentrates or solids and are not expected to be emitted. The flotation processes will have no direct stacks or vents exhausting to atmosphere.*

Comment 148: Please provide a discussion of how "tightly" the stopes would be backfilled, and thus how much space would there be between the top of the backfill and the top of

the stope? How much settling would be expected in stopes filled with cemented and non-cemented tailings? Please address alternatives to more completely fill the stopes to minimize or eliminate underground voids.

Response 148: *A discussion of how "tight" the stopes would be filled is presented in Section 4.2.4.1 of the enclosed update to Section 4 of the Crandon Project EIR. The methods selected to fill the stopes represent the state of the art in backfilling processes. As the discussion in Section 4.2.4.1 indicates, the only voids of any significance that will remain after backfilling will be the small volume immediately below the crown pillar. The effect of these voids on crown pillar stability is addressed in detail in the May 1996 report Hydrologic Stability of the Crown Pillar, Crandon Deposit prepared by Agapito Associates, Inc.*

Comment 149: Please describe the crown pillar in greater detail in terms of what would be left in place, and provide a map indicating the actual (not average) thickness that would remain after mining. Please provide a discussion that indicates the relative strengths of the various rock layers and describes the weathering that has weakened the upper rocks.

Response 149: *The May 1996 report Hydrologic Stability of the Crown Pillar, Crandon Deposit prepared by Agapito Associates, Inc., addresses these issues.*

Comment 153: Figure 4.2.5-1 "Modeling Drawdown (feet) in Layer 2 for BEJ Case" is confusing and should be eliminated. We will need figures showing the groundwater drawdown at its maximum extent based on expected mine inflow and under worst case conditions of mine inflow. If you wanted to produce only one map, then the maximum inflow scenario should be mapped. For reference, the map as figure 3-3 in the Exxon final EIS is a model of what is needed. Flow directions and relative magnitude should be indicated on the map. The figure showing groundwater drawdown should show the extent of the 1-foot drawdown contour and be clearly labeled.

Response 153: *An updated set of figures (4.2.5-1 through 4.2.5-8) addressing the above comments have been added to Section 4.2.5. The figures show drawdown under steady state conditions, since maximum drawdown is achieved at steady state. The regional flow model consisting of seven layers computes drawdown for each layer. Predicted drawdown across the study area is similar for each layer. Since layer 4 (Pre- to Early Wisconsinan Till) is the first continuously saturated layer across the study area, the updated drawdown figures display drawdown for layer 4. It was also requested that flow directions be displayed on the drawdown figures. It should be noted that flow directions can only be displayed on potentiometric surface maps that take into account the predicted drawdown. Potentiometric surface maps for layer 4 are included as part of the series of figures added to Section 4.2.5. The potentiometric surface maps display the regional flow system under pre-mining and mining conditions.*

Comment 155: Another figure is needed to show the groundwater table at full drawdown such as is shown in the final EIS on figure 3-4. Flow directions and relative magnitude should be indicated on the map.

Response 155: *The water table and potentiometric surface maps added to Section 4.2.5 are for steady state conditions and therefore reflect maximum drawdown. The direction of groundwater flow is displayed on calibrated and predicted potentiometric surface maps for layer 4 (Figures 4.2.5-2, 4.2.5-5, and 4.2.5-8). Potentiometric surface maps were selected over water table maps to display the effect on the regional flow system due to mining. Water table maps reflect the connection to area lakes. Since flow from area lakes is predominantly a vertical phenomenon, predicted water table maps are not the most desirable map to display the effect mining has on regional flow, which is principally horizontal. The groundwater modeling report in Appendix 4.2-3 provides profiles of head through Little Sand Lake under mining conditions to demonstrate the effect on vertical flow between the lakes and groundwater system.*

Comment 156: Tables 4.2.5-1 and 4.2.5-3 show changes in groundwater quantity to streams. However, stream impacts will also result from decreases in discharge water to stream-side wetlands. Thus, a full impact analysis to stream segments must show both of the reductions. Please provide a table that shows the complete and realistic impacts to streams in terms of reduced groundwater flows for both the "BEJ" and "PWC" scenarios.

Response 156: *Revised tables in EIR Section 4.2.5 summarizing impacts to streams include the reduction in flow to the discharge creeks and adjoining discharge wetlands as requested. Please note that in the original EIR cumulative impacts (reduction in flow to discharge creeks and to adjoining discharge wetlands) to streams under average and low flow conditions were discussed in Section 4.2.6. Practical worst case summary tables are also provided in revised EIR Sections 4.2.5 and 4.2.6.*

Comment 157: On page 4-25 you state that as a result of mine pumping, there will be a reduced amount of groundwater reaching wetlands and streams and a greater loss from lakes. Of the total reduction in available groundwater, you stated that 60% would be diverted from wetlands, 28% from streams, and 12% from lakes. However, from tables 4.2.5-1 and 4.2.5-2, the total reduction in groundwater to wetlands is given as 0.476 cfs and from streams is 0.55 cfs. Why isn't the wetland loss about twice a large as the stream loss?

Response 157: *Mass balance summaries are more clearly presented in EIR Section 4.2.5 revisions. Referenced percent changes in flow to streams and wetlands in revised Section 4.2.5 are consistent with the summary tables.*

Comment 158: Referring to the above question, about 88% of the reduced groundwater flow results in losses to wetlands and streams. The calculated mine inflow (602 gpm = 1.34 cfs) x .88 = 1.179 cfs which should be lost from streams and wetlands. The two tables indicate reductions in groundwater to wetlands and streams that total 1.026 cfs instead of 1.179. The difference between the calculated loss and the loss indicated in the tables = 0.153 cfs, or about 69 gpm. Why is there a difference?

Response 158: *See response to comment 157.*

Comment 160: Figures 4.2.5-3 and -4 show results of solute transport modeling that are difficult to interpret and should be revised. Please refer to figures 3-5 to 3-12 in the Exxon final EIS as suitable models. The results of the solute transport modeling may have to be shown using different modeling input assumptions.

Response 160: *Section 4.2.5 has been updated to reflect the revised solute transport modeling work. The transport model calculates relative concentrations or concentrations as a percent of the source concentration. Once the tailings studies are complete, constituent specific concentration history plots at the compliance boundary and requested concentration contour plots will be provided.*

Comment 161: Please provide a discussion which demonstrates the expected quality of the leachate over time in the TMA. The discussion should provide an approximate accounting for the compounds added during milling and expected to be added from the wastewater treatment sludge. You have already evaluated the occurrence of arsenic and chromium.

Response 161: *This topic will be addressed in detail in the report to be prepared using data generated from the project's original waste characterization and supplementary kinetic testing programs. The work to be accomplished and methods to be used are outlined in the June 1996 document titled Proposed Oxygen Transport and Source Term Modeling Work Plan for the Crandon Project, which was previously provided to the WDNR and USCOE.*

Comment 162: The model results are presented in relative concentrations. Please discuss in detail the actual contaminants that would reach the groundwater in the leachate, their expected concentrations, and their movement toward the compliance boundary and nearby surface waters.

Response 162: *See response to comment 160.*

Comment 163: Please provide an analysis of the expected water quality in the reflooded mine following mine closure and a rebound of the groundwater. Include in the discussion the effects of oxidation on the exposed rocks in the dewatered, underground mine, the contribution of pollutants from the cemented and uncemented backfill material and the time it will take for reflooding to occur.

Response 163: *A detailed report addressing this issue will be issued shortly.*

Comment 164: CMC concluded that the reflooded mine would not contribute significant amounts of pollutants to the overlying glacial aquifer. We presume this is based on the known conductivity of the overlying strata. However, we believe it is possible that the crown pillar, which is heavily weathered, may have an increased conductivity due to stress from the mined-out space below that could increase micropore conductivity into the glacial aquifer. In view of these concerns, we would like to see additional analysis of the potential for pollutants contribution to the glacial aquifer from the reflooded mine. (These issues

will be more fully discussed by the groundwater technical group during review of the solute transport modeling.)

Comment 164: *Since issuance of the WDNR's comments, CMC has completed additional analysis on stress impacts to crown pillar hydraulic characteristics. Analyses completed by Agapito Associates, Inc. (1996) indicates that stresses placed on the crown pillar during mining will have minimal effects on the hydraulic characteristics of the crown pillar. The revised solute transport model, Numerical Simulation of Potential Solute Transport at the Proposed Zinc and Copper Mine Near Crandon, Wisconsin, prepared by GeoTrans in November 1996, indicates that projected travel times from the reflooded mine to the compliance boundary range from 600 years under practical worst case conditions to over 6,000 years under best engineering judgement conditions.*

Further work is currently underway by Agapito Associates, Inc. to address questions raised by WDNR in their February 4, 1997 letter.

Comment 165: There are a number of alternative methods that could be implemented to reduce or minimize the potential effects of the contaminants from the reflooded mine reaching the glacial aquifer. These include, but are not limited to:

- filling some or all of the underground voids that were planned to remain open in order to reduce mobilization of pollutants;
- if all the underground openings could not be filled, then blocking the drifts and other underground passageways so that transmittal of pollutants would be reduced;
- adding amendments to the upper-most voids to neutralize or precipitate the pollutants to make them less mobile;
- pumping out the initial water for treatment and disposal;
-leaving a thicker crown pillar
-conducting the backfilling in a way that provides for the tightest possible backfilling which would reduce the impacts of eventual collapse.

Please provide a discussion of these and other alternatives that could be used to minimize the effects of contamination from the underground mine.

Response 165: *Since issuance of the WDNR comment letter, CMC has initiated additional studies to further characterize the expected quality of the water in the reflooded mine and studies that will evaluate the effects of tight backfilling of mined out stopes. Comment 165 appears to be based on the assumption that the quality will be inferior, requiring mitigative steps to minimize the potential effect on the glacial aquifer. Before investigating mitigative steps, CMC prefers to complete its analysis of the expected water quality to determine if potential adverse effects are likely.*

Comment 166: Page 4-42 (paragraph 1) refers to the structures such as the access road and railroad crossings for Swamp Creek. When will CMC submit those plans? Were they included with the Chapter 30 permits? The central office did not receive copies of the

chapter 30 permit applications, but we need to see them for evaluation. The Department would greatly prefer span bridges rather than box culverts because the latter result in greater construction impacts and can restrict flow. All bridges and culverts should be designed to pass the 100 year flood waters with no backwater effects.

Response 166: *Plans for the structures needed for the access road and railroad crossings for Swamp Creek are included in the project's June 1996 Water Regulatory Permit Application for the Proposed Crandon Project Mine Site and Treated Wastewater Discharge Pipeline. CMC has taken the Department's comments into consideration regarding a preference for span bridges and as will be outlined in the response to the WDNR's January 10, 1997 comment letter on the water regulatory permit application, CMC intends to use span bridges for the crossings.*

Comment 168: Large scale maps 4.2.7-3 and 4.2.7-4 show BEJ and practical worst case groundwater drawdown contours. The maps are confusing. The drawdown contours are labeled 1,2,3, etc., but it is unclear what the contour interval is and whether the drawdown is in feet or meters. In all future drawdown maps, the contour lines should be clearly labeled. (It is unclear why the groundwater drawdown maps appear in the wetland impact section rather than in the groundwater section.)

Response 168: *Figures 4.2.7-3 and 4.2.7-4 have been revised to include a contour interval designation in the legend. The groundwater drawdown figures are used in the wetland impact section to investigate the potential for drawdown impacts to wetlands. Figures depicting drawdown have also been added to Section 4.2.5 of the EIR as part of the update accompanying this letter.*

Comment 169: There needs to be a better definition of "direct" impacts to wetlands. The features of the project have been delineated on a map and the amount of direct impact appears to be calculated as the number of acres of wetland that fall within the footprints, e.g., the number of wetland acres that would be obliterated. This may make sense from a federal regulatory standpoint, especially when determining compensatory mitigation. However, the EIR needs to recognize that the actual direct impact to wetlands will extend beyond the line of obliteration due to equipment maneuvering at the edges of features (vegetation disruption and compaction), erosion and sedimentation due to the soils disturbance, flow reductions and possibly additional hydrological impacts as well.

Response 169: *This issue was discussed extensively with the WDNR, USCOE and others in early 1996. Those discussion resulted in part in the development of a revision to Section 4.2.7 of the EIR dated April 4, 1996. Addressing the issue of direct versus indirect impacts was one of the primary objectives of the April 4, 1996 revision. For example:*

- *A general discussion regarding measures to minimize erosion and sedimentation and hydrologic impacts to wetlands that will only be partially taken by the TMA is presented in the first paragraph of page 4-62.*

- *Specific discussions are provided for each wetland impacted by construction in Section 4.2.7.1. This includes wetlands that straddle the boundaries of the surface facility footprints (e.g., impacts to the functional values of the portions of wetlands M4, M3, F66 and Z7 that remain after construction is complete are discussed on pages 4-62 and 4-63).*

- *Potential hydrological impacts are discussed in Sections 4.2.7.2 and 4.2.7.3.*

It is CMC's understanding that the April 4, 1996 revision addresses the issues raised in this comment.

Comment 170: Page 4-66 - The determination of "percent of total impact" as reported in Table 4.2.7-3 assumes that the greater the acreage of wetland loss the greater the impact. On the contrary, the focus must be on minimizing impacts to important wetlands, as well as minimizing the numbers of acres filled and disrupted. The fact that more acres of one wetland are filled does not necessarily mean that is the most important impact. Please clarify the relevance of this table.

Response 170: *Table 4.2.7-3 was developed to summarize overall impacts to wetland functional values as a result of construction impacts and was used to define those functional values that are most important to the loss of wetland acreage as a result of the project. This table recognizes that both the aerial extent of impact and the functional values lost must be considered when discussing total wetland impact. For example, the construction impacts to wetland M3 represent 11.7 percent of the total wetland impact during the construction phase of the project. Wetland M3 was assigned a rank of 2 (medium) for the biological function. Wetland T4 represents a smaller percent of total wetland impact during construction as compared to wetland M3 (8.0 percent). Wetland T4, however, was assigned a rank of 3 (high) for the biological function. The weighted score for the biological category presented in Table 4.2.7-3 for wetland T4 is higher than the weighted score for wetland M3 even though a smaller portion of wetland T4 will be impacted. This example shows the analysis recognizes that the aerial extent of impact is only one variable in the equation.*

Comment 171: It seems that the following wetlands could be directly impacted due to erosion/sedimentation, reduction in water, and/or construction machine impacts: plant site- 6, 7, 8, 9, 11, 12, F16, F10, and P2; TMA - M4, M3, F29, 13, 14, and 15. Please discuss.

Response 171: *This comment was addressed in the April 4, 1996 revision of Section 4.2.7 of the EIR. The sediment and erosion control practices proposed during the construction phase of the project are described in Section 4.10 of the May 1995 Mine Permit Application. Additional details specific to the above listed wetlands are discussed on the pages of the updated EIR indicated below:*

Wetland	*EIR Page Number*
6	*4-69, 4-76*
7	*See Paragraph Below*
8	*4-69, 4-75*
9	*4-69, 4-76*
11	*4-69, 4-75*
12	*4-69, 4-75*
F16	*See Paragraph Below*
F10	*See Paragraph Below*
P2	*4-69, 4-75*
M4	*4-72, 4-76*
M3	*4-72, 4-76*
F29	*4-72, 4-77*
13	*4-58, 4-62*
14	*4-58, 4-62*
15	*4-58, 4-62*

Wetlands 13, 14 and 15 will be totally lost during the construction phase of the project, therefore, this comment is not applicable for these wetlands. Further, it is unclear how the suggested impacts will occur to wetlands F10 and F16. Wetland F16 is located approximately 800 feet to the north of the TMA (i.e., the nearest mine facility) and in a drainage basin isolated from the mine facilities. Wetland F10 is located approximately 640 feet south of the mine site (i.e., the nearest mine facility). It may be that wetlands F10 and F16 were listed incorrectly in the WDNR's comments and should have been listed as wetlands 10 and F116. Potential secondary impacts to wetlands 10 and F116 are addressed on page 4-69.

Wetland 7 is located downgradient of wetland 6. Any sedimentation, erosion or hydrologic impacts that would occur in wetland 7 would first occur in wetland 6. Since impacts to wetland 6 were predicted to be minor, impacts to wetland 7 will likely also be minor.

Comment 172: Dave Heath, DNR in Rhinelander, conducted aquatic surveys in the Wisconsin River near the proposed discharge site as part of his dam relicensing work. He located old shells of Bullhead Mussel, a Wisconsin endangered species. He also collected the following rare dragonflies near the proposed discharge site: *Gomphus (Phanogomphus) quadricolor* - State Special Concern, *Gomphus (Gomphurus) lineatifrons* - State Special

Concern, *Gomphus (Gomphus) viridifrons* - State Special Concern, *Ophiogomphus howei* - State Endangered.

Dave's surveys were not intended to provide a comprehensive picture of the Wisconsin River's aquatic biology. The results do, however, provide evidence that conditions are suitable for sensitive species to occur in this stretch of the river. Therefore, CMC should develop a plan to conduct aquatic surveys for mussels and macroinvertebrates at the Wisconsin River discharge site (and downstream) similar in scope and detail to those conducted by CMC for the other portions of the project site. Department staff should review this plan prior to data collection.

Response 172: *A detailed work plan relating to aquatic studies downstream of the Wisconsin River discharge site was prepared and the work conducted in 1996. The work plan was reviewed by the WDNR prior to the initiation of field work. The results of the work have been incorporated into Volume IIIa, Appendix 3-2 of the EIR through an update dated October 21, 1996.*

Comment 173: In a December 27, 1993 letter to Bill West of Foth & Van Dyke (Appendix 3.8-4-1), Ken Tennessen commented that samples of the riffle beetle genus *Stenelmis* had been collected but could not be identified to species due to a lack of male specimens. Dr. Tennessen suggested that additional survey work be completed to determine if either *S. douglasensis* (State Special Concern) or *S. knobeli* (State Endangered) is present in the study area. We could not find mention of this genus in the report narratives or the environmental impact section. Was additional survey work completed as discussed?

Response 173: *Dr. Ken Tennessen and Mr. William West conducted additional field work in the summer of 1994, specifically searching habitat along Swamp Creek for the riffle beetles. The EIR lists the findings of other riffle beetles including Stenelmus crenata, however, neither S. douglasensis nor S. knobeli were collected during the specific search nor were they found during other general macroinvertebrate collection efforts conducted in May and August 1994. When specifically looking for riffle beetles, two other genera were collected including Macronychus and Optioservus, neither genera of which contain listed species.*

Comment 175: Bill Smith, Natural Heritage Inventory Zoologist, was asked to confirm the identification of a dragonfly specimen that was collected by a GLIFWC representative. The specimen, *Ophiogomphus howei*, was reported to have been collected in Swamp Creek. We have yet to receive appropriate documentation to enter this occurrence into the NHI database. It is our understanding that GLIFWC has recently conducted several surveys in the Crandon area. We will be contacting them soon to inquire about the possibility of incorporating their data into the Natural Heritage Inventory.

Response 175: *Comment noted.*

Comment 176: On page 4-97 you mention that a savanna community would be established on the plant site following reclamation. Natural savanna communities in this part of the state are limited to pine barrens or open barrens on very sandy soils, and these must be maintained with the use of fire to keep them open. What is the proposed plant composition of the savanna and how would a savanna community be maintained (managed) on the plant site?

Response 176: *As indicated in Table 5-7, Page 202 of the Mine Permit Application, the species to be used in the savanna "type" planting will be primarily indigenous hardwoods and a mix of indigenous evergreens. The primary idea is to plant savanna copses of hardwoods that will begin the process of reclamation and reforestation. The grasses and forbs will help to control erosion and will reduce in number over time as the canopy begins to close and woodland herbaceous plants move in. This succession should lead to a similar composition of plant materials that now exist on site.*

As stated on Page 203 of the Mine Permit Application, in Section 5.6.4.2 and 5.6.4.3 - The restored native plant communities will be maintained on an as needed basis to allow development in a manner consistent with similar naturally occurring plant communities. The grasses and forbs will initially be mowed or burned on an as needed basis. Volunteer native species will be left to develop.

Comment 178: Please discuss the potential vibrations and noise that could be emitted from the large grinding mills and crushers in the mill.

Response 178: *The impact analysis in Section 4.2.10.1.2 discusses operational noise. The grinding mills have been included in this noise assessment since they are located in the concentrator building. Since ore will be crushed underground, there will be no crushers in the mill building. A temporary crusher will be located in the construction material storage area for the crushing of ore or waste rock during the later year of construction and during the first year of operation. There will be no vibration from the grinding mills outside the mill building area as the foundation design and grinding mill installations are specifically designed to minimize vibration and protect the equipment bearings.*

Comment 179: On page 4-112 you make reference to the CHABA Work Group 84 (ANSI, 1986; NRC, 1981). If you have these two references, could you please provide us with a copy of each for our review?

Response 179: *Copies of the articles were forwarded to Mr. William Tans of WDNR on February 20, 1997.*

Comment 181: CMC plans to replace the lands purchased from the Forest County forest with other wooded lands. Please provide information to us on the replacement lands so we can make a comparison between them and the lands in the project site to be removed from the County Forest system.

Response 181: *In February 1995, Forest County identified 1,396 acres in the Towns of Argonne, Lincoln, and Crandon in Forest County as replacement acreage for the 1,000 acres it had, or was negotiating, to option to CMC. CMC purchased the 1,396 acres in March 1995 and subsequently entered into a Timber License and Option Agreement with Forest County which allows the county to harvest timber from the lands and provides for the sale of the lands to the County at the time that CMC exercises its options on the 1,000 acres after the receipt of required mine permits. Legal descriptions for all properties are provided in Attachment 1 for reference.*

Comment 184: CMC has stated it was negotiating for timber rights on Spirit Hill and other properties optioned by the company. Please update us on the results of those negotiations.

Response 184: *As indicated in a letter to Chairman Arlyn Ackley of the Sokaogon Chippewa Community (Attachment 2), CMC has no plans to log Spirit Hill. This fact is also clearly stated in Section 5.1 of the EIR. CMC has acquired a purchase option for Spirit Hill specifically to prevent logging of these lands. CMC undertook this initiative to protect the area because of the Sokaogon Chippewa Community's stated concerns about the spiritual significance of Spirit Hill.*

Comment 191: Following completion of groundwater modeling and prediction of groundwater drawdown, we will assume that every water well within the area of the 1-foot groundwater drawdown area, under the maximum inflow scenario, could be affected. The impacts to each well in this area depend on the individual well construction characteristics, and not all wells would be impacted. CMC will provide "potable" water for each potentially affected water well. How will potable be determined? What is the schedule for providing potable water? Will some wells have to be deepened into the bedrock to provide potable water? What water quality testing will be done to each well after measures are taken to provide better service? Please elaborate on the well water mitigation plan.

Response 191: *This topic is addressed in Section 4.1 of the project's October 1995 <u>High Capacity Well Permit Application</u> and in Response 5 of the January 2, 1997 <u>High Capacity Well Permit Application Addendum No. 1</u>. It is also addressed in Section 8.2.1 of the project's May 1995 <u>Mine Permit Application</u>.*

Potable water will be water that meets the definitions provided in Chapter NR 809.04(47), Wis. Admin. Code. The schedule for providing potable water will be that schedule as outlined in Section 144.855(4)(c), Wis. Stats. Potential methods to provide potable water are outlined in the references stated in the above paragraph. After measures are taken to provide substitute water, a sample of the substitute water will be collected and analyses performed to verify the water meets the standards specified in Chapter NR 809.11, Wis. Admin. Code.

Comment 192: CMC will be required to monitor the water quality of certain wells in the impact area, assuming it can get the necessary access, according to the conditions

established as part of the high capacity well plan approval. What is proposed for frequency of monitoring? What parameters would be tested for in private wells?

Response 192: *As outlined in Response 6 in CMC's January 2, 1997 High Capacity Well Permit Application Addendum No. 1, background water chemistry for wells in the vicinity of the mine will be defined prior to the start of mine dewatering activities. During construction and operations, CMC anticipates monitoring these private wells semi-annually. The parameters to be tested will be those that are included on the normal plant site and TMA groundwater quality monitoring programs as outlined in Section 7.1.4 of the project's May 1995 Mine Permit Application.*

General Comment: 5.4 Surface Water Mitigation - Our review of the surface water mitigation section will not be complete until the groundwater model is finished and we have final estimates of the surface water impacts. However, we will be looking at all significantly impacted streams, lakes, springs and some wetlands as potential mitigation sites. In particular, Hoffman Springs, Hoffman Creek (permanent brook trout population), and Creek 12-9 (likely through the lake mitigation) are potential mitigation waters in addition to Skunk Lake.

Response to General Comment: *Comment noted.*

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

cc: Current EIR Distribution List

Crandon Mining Company

7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161

August 7, 1997

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Integrated Science Services
101 South Webster Street
Madison, WI 53703

Mr. David Ballman
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - Environmental Impact Report

Crandon Mining Company (CMC) is pleased to submit the enclosed update to Section 3.5.5, Waste Characterization, of the Crandon Project's *Environmental Impact Report* (EIR). The update has been prepared on behalf of CMC by Foth & Van Dyke and Associates, Inc. The update involves numerous changes to the original text, and therefore is not highlighted. Changes made to other portions of Section 3.5 provided to support this update are highlighted.

With this filing, CMC has now answered all of the outstanding questions on the EIR Section 1, Introduction; Section 2, Project Description; and Section 3, Environmental Setting. Any future work by CMC is considered by CMC to be of a confirmatory nature, and not required for impact analysis. CMC is aware that the WDNR or other interested parties may have future questions on the groundwater model and the solute transport model.

CMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

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The pages contained in these updates need to be inserted into Volumes I, V, and VI of the EIR according to Items 234 through 254 on the attached reference list. The reference list serves as a log and reference identifying changes made to the EIR by CMC throughout the permitting process. Items 1 through 233 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

Please note that through this update Comment 24 of the July 31, 1995 WDNR letter pertaining to CMC's EIR has been addressed as follows.

Comment 24: Part 3.5.5.[2].1, Page 3.5-74, First Paragraph - During verification, it was our understanding that 3" samples were taken every 2 feet for whole core and a 6" sample taken every 2 feet for split core. The EIR narrative states 2" core samples were taken every 2 feet. We need to resolve this discrepancy.

Response 24: *WDNR's understanding is correct. The discrepancy has been corrected in the update to Section 3.5.5.2.1 and in Appendix 3.5-32 Figure 1.*

If you or your staff have any questions regarding the EIR, please contact me at (715) 365-1450.

Sincerely,

D. E. Moe

Don Moe
Technical/Permitting Manager
Crandon Mining Company

Nicolet Minerals COMPANY

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Web Site: www.crandonmine.com

July 23, 1998

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Integrated Science Services
101 South Webster Street
Madison, WI 53703

Ms. Char Hauger
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101-1638

Dear Mr. Tans and Ms. Hauger:

Re: Crandon Project - Environmental Impact Report

Nicolet Minerals Company (NMC) is pleased to submit the enclosed updates to Appendix 4.2-3, Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin, and Appendix 4.2-12, Crandon Project Tailings Management Area Groundwater Quality Performance Evaluation, of the project's *Environmental Impact Report* (EIR). The updates have been prepared on behalf of NMC by Foth & Van Dyke and Associates, Inc. The updates consist of revisions to page 2-11 (EIR page 4.2-3-39) and Table 2.7 (EIR page 4.2-3-52) of Appendix 4.2-3, which correct the citations for the source of the data listed in Table 2.7; and revisions to Tables 2-8 and 2-12 (EIR pages 4.2-12-28 and 4.2-12-38) of Appendix 4.2-12, which correct the upper bound estimates for barium and silver to correctly reflect equilibrium modeling results.

NMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties according to the current EIR distribution list. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

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The pages contained in this update need to be inserted into Volumes X and XI of the EIR according to Items 276 through 280 on the attached reference list. The reference list serves as a log and reference identifying changes made to the EIR by NMC throughout the permitting process. Items 1 through 275 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

If you or your staff have any questions concerning this update, please contact me at (715) 478-3393.

Sincerely,

Gordon Reid
Manager of Engineering
Nicolet Minerals Company

GR:cer1

Attachments

Nicolet Minerals COMPANY

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Web Site: www.crandonmine.com

EIS 40

September 17, 1998

Mr. Bill Tans
Wisconsin Department of Natural Resources
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101 South Webster Street
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Ms. Char Hauger
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St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Ms. Hauger:

Re: Crandon Project - Environmental Impact Report

Nicolet Minerals Company (NMC) is pleased to submit the enclosed updated pages for Appendix 4.2-13, Reflooded Mine Source Term, of the Crandon Project's *Environmental Impact Report* (EIR).

These updates have been prepared on behalf of NMC by Steffen Robertson and Kirsten (Canada) Inc. (SRK). NMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the updates to their appropriate staff members.

The enclosed pages are considered to be an update to the Project's EIR according to Items 284 through 287 on the attached reference list. The reference list serves as a log and reference identifying changes made to the EIR by NMC throughout the permitting process. Items 1 through 283 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

If you or your staff have any questions regarding these updates, please contact me at (715) 478-3393.

Sincerely,

Gordon Reid
Manager of Engineering
Nicolet Minerals Company

GR:cer1

Enclosures

cc: EIR Distribution List (dated September 3, 1998)

process. Items 1 through 287 on the list were previously submitted. If additional revisions are made, they will be added to the attached list in sequential order and the list will be forwarded with the changes.

If you or your staff have any questions regarding these updates, please contact me at (715) 478-3393.

Sincerely,

Gordon Reid
Manager of Engineering
Nicolet Minerals Company

GR:cer1

Enclosures

cc: EIR Distribution List (dated September 3, 1998)

Nicolet Minerals COMPANY

Rhinelander Office: 7 N. Brown Street, 3rd Floor • Rhinelander, WI 54501-3161 • Ph: 715.365.1450 • Fax: 715.365.1457
Crandon Office: 104 W. Madison Street, P.O. Box 336 • Crandon, WI 54520-0336 • Ph: 715.478.3393 • Fax: 715.478.3641
Web Site: www.crandonmine.com

June 17, 1998

Mr. Bill Tans
Wisconsin Department of Natural Resources
Bureau of Integrated Science Services
101 South Webster Street
P.O. Box 7921
Madison, WI 53707-7921

Mr. David Ballman
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul, MN 55101

Dear Mr. Tans and Mr. Ballman:

Re: Crandon Project - Tailings Management Area Feasibility Report/Plan of Operation

Nicolet Minerals Company (NMC) is pleased to provide you with the report titled *Addendum No. 4 to the May 1995 Crandon Project Tailings Management Area Feasibility Report/Plan of Operation*. Addendum No. 4 should be added to the three-ring notebook provided with Addendum No. 3 submitted in January 1997. Also enclosed are a new cover and spine reflecting the addition of Addendum No. 4 to the volume.

Addendum No. 4 has been prepared on behalf of NMC by Foth & Van Dyke and Associates, Inc. As noted on the attached distribution list, NMC has distributed the information to appropriate state and federal agencies, to local officials, and to various interested parties. It is our understanding that the Wisconsin Department of Natural Resources (WDNR) and the U.S. Army Corps of Engineers (USCOE) will be responsible for distribution of the document to their appropriate staff members.

The primary purpose of Addendum No. 4 is to present TMA design changes made as a result of the recently completed geosynthetic clay liner (GCL) compatibility tests. GCL compatibility testing has been performed by NMC in response to Comment 12 of the WDNR's September 26, 1997, TMA Completeness Determination. The information

presented in Addendum No. 4 and the GCL compatibility test report appended to the document constitute NMC's response to Comment 12.

If you or your staff have any questions regarding Addendum No. 4, please contact me at (715) 478-3393.

Sincerely,

Gordon Reid
Manager of Engineering
Nicolet Minerals Company

GR:mld2

Distribution

No. of Copies	Sent To
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1	Wisconsin Geological & Natural History Survey Mr. Tom Evans 3817 Mineral Point Road, Room 108 Madison, WI 53705

Attachment 1

EXHIBIT A
LEGAL DESCRIPTIONS

880-ACRE PARCEL

Section 29; and the Southwest one-quarter (SW¼) of the Southwest one-quarter (SW¼) of Section 28; and the Northeast one-quarter (NE¼), and the Northeast one-quarter (NE¼) of the Northwest one-quarter (NW¼) of Section 30; Township 35 North, Range 13 East, Forest County, Wisconsin.

120-ACRE PARCEL

The North one-half (N½) of the Southwest one-quarter (SW¼) and the Southeast one-quarter (SE¼) of the Southwest one-quarter (SW¼) of Section 28, Township 35 North, Range 13 East, Forest County, Wisconsin

1,396-ACRE PARCEL

Parcel #1.
The Southeast Quarter of Southeast Quarter (SE 1/4 SE 1/4) of Section One (1), Township Thirty-six (36) north, Range Twelve (12) East.

Parcel #2.
The Northeast Quarter of Northeast Quarter (NE 1/4 NE 1/4) of Section Eleven (11), Township Thirty-six (36) North, Range Twelve (12) East.

Parcel #3.
The entire Northeast Quarter (NE 1/4); the entire Northwest Quarter (NW 1/4); the Northeast Quarter of Southwest Quarter (NE 1/4 SW 1/4); and the West one-half of Southeast Quarter (W 1/2 SE 1/4) of Section Twelve (12), Township Thirty-six (36) North, Range Twelve (12) East.

Parcel #4.
The entire Northeast Quarter (NE 1/4); the entire Northwest Quarter (NW 1/4); the entire Southwest Quarter (SW 1/4); and the North one-half of Southeast Quarter (N 1/2 SE 1/4) of Section Six (6), Township Thirty-six (36) North, Range Thirteen (13) East.

Parcel #5.
The North one-half of Northwest Quarter (N 1/2 NW 1/4) and the Southwest Quarter of Northwest Quarter (SW 1/4 NW 1/4)

of Section Seven (7), Township Thirty-six (36) North, Range Thirteen (13) East.

Parcel #6.
The Northwest Quarter of Southwest Quarter (NW 1/4 SW 1/4); the South one-half of Southwest Quarter (S 1/2 SW 1/4); and the South one-half of Southeast Quarter (S 1/2 SE 1/4) of Section Thirty-one (31), Township Thirty-seven (37) North, Range Thirteen (13) East.

Parcel #7.
A perpetual non-exclusive easement 2 rods width for road and travel purposes across the NW 1/4 NE 1/4 of Section 7, Township 36 North, Range 13 East, as described in Volume 86 Deeds page 174.

Parcel #8.
A perpetual non-exclusive easement 2 rods in width for road and travel purposes across the W 1/2 NE 1/4 of Section 11, Township 36 North, Range 12 East, as described in Volume 86 Deeds page 268.

All in Forest County, Wisconsin.

Attachment 2

Crandon Mining Company

August 28, 1996

Chairman Arlyn Ackley, Sr.
Sokaogon Chippewa Community
Mole Lake Band
Rt 1, Box 625
Crandon, WI 54520-9635

Dear Chairman Ackley:

I am writing in response to your August 6, 1996, letter to DNR Secretary George Meyer in which you express concern that Crandon Mining Company "intends to log Spirit Hill".

Let me assure you that CMC has no plans to log Spirit Hill. As CMC indicated in our October 1995 EIR submittal (page 4-254 and page 5-2), CMC has acquired purchase options for Spirit Hill specifically to prevent logging on these lands. We undertook this initiative to protect the area because of the Sokaogon Chippewa Community's stated concerns about the spiritual significance of Spirit Hill.

During the summer and fall of 1995, CMC became aware that part of the Spirit Hill area was to be selectively logged by one of the owners of the property. We believed that logging in the area was not in the best interest of CMC or the Sokaogon Chippewa Community. To prevent logging in this area and to secure a more controllable land position, CMC acquired purchase options for 120 acres comprising the majority of the Spirit Hill area (W1/2 of NE1/4 Section 35, and SW1/4 of SE1/4 Section 26). In compensation for the standing timber, CMC agreed to let one of the current land owners cut timber on other CMC properties away from Spirit Hill.

CMC would plan to exercise the purchase options on the 120 acres associated with the Spirit Hill area upon receipt of permits. If the purchase options are not exercised by CMC within ten years, all rights, including timbering, revert back to the current land owners.

In summary, CMC has no plans to log the Spirit Hill area now or in the future and has in fact acted to prevent logging in the area.

(con't)

RHINELANDER BUSINESS OFFICE
7 N. BROWN ST., 3RD FLOOR
RHINELANDER, WI 54501-3161
TEL.: (715) 365-1450 FAX: (715) 365-1457

ENVIRONMENTALLY RESPONSIBLE

CRANDON FIELD OFFICE
P.O. BOX 336 104 W. MADISON
CRANDON, WI 54520-0336
TEL.: (715) 478-3393 FAX: (715) 478-3641

Chairman Arlyn Ackley

August 28,1996

As you may know, I am new to the Crandon Mining project and was disappointed to find that we have not established an open dialogue between ourselves and the Sokaogon Chippewa Community. Misunderstandings such as this one could be resolved easily if we talked on a regular basis.

I will call you in the next week to request a meeting so that I can introduce myself and we can discuss issues of mutual concern.

Sincerely,

Rodney A. Harrill
President

cc: George Meyer, Secretary Wisconsin Department of Natural Resources
William Tans, Wisconsin Department of Natural Resources
Col. J.M. Wonsik, U.S. Corps of Engineers
John Anfinson, Army Corps of Engineers
Ben Wopat, Army Corps of Engineers
Dave Ballman, Army Corps of Engineers
Richard Dexster - SHPO, State Historical Society
Druscilla Null, Advisory Council on Historic Preservation
John Teller, Chairman of the Menominee Tribe
Phillip Shopodock, Chairman of the Forest County Potawatomi Tribe
Daniel J. Cozza, U.S. Environmental Proection Agency
Herb Nelson, U.S. Bureau of Indian Affairs
Mark Kuester, U.S. Bureau of Indian Affairs

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
97	10/22/96	3.9-6-1 through 3.9-6-11	Appendix 3.9-6	New appendix (Volume IX)
98	10/22/96	3.9-7-1 through 3.9-7-12	Appendix 3.9-7	New appendix (Volume IX)
99	10/31/96	9	Log of Updates	Updated (Volume I)
100	10/31/96	iv, viii, ix, x	Secton 4 Table of Contents	Updated (Volume II)
101	10/31/96	4-125	Section 4.2.13.2.1	Updated discussion on labor costs
102	10/31/96	4-132	Table 4.2.13-4	Corrected table
103	10/31/96	4-157 and 4-158	Section 4.2.13.3.3	Updated discussion on seasonal/recreational housing
104	10/31/96	4-194	Section 4.2.13.4.1	Added reference to new figure
105	10/31/96	4-201	Sections 4.2.13.4.2	Added discussion on economic base impacts
106	10/31/96	4-202a through 4-202e	Section 4.2.13.4.2.1	New subsection; updated discussion on employment impacts
107	10/31/96	4-203 and 4-203a	Section 4.2.13.2.2	Added subsection on tourism impacts
108	10/31/96	4-213 and 4-216	Sections 4.2.13.4.4.1 and 4.2.13.4.4.2	Updated discussion on Badger Fund
109	10/31/96	4-231	Section 4.2.13.4.4.4	Updated discussion on property values
110	10/31/96	4-235 and 4-235a	Section 4.2.13.4.4.6	Updated discussion on tax revenues, new Table 4.2.13-53a
111	10/31/96	—	Figure 4.2.13-6A	Added new figure
112	11/1/96	9-10	Log of Updates	Updated (Volume I)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
113	11/1/96	3.8-78	Section 3.8.2.4.6	Corrected misspelling (Volume II)
114	11/1/96	3.8-107	Section 3.8.2.6	Updated discussion on aquatic macrophyte investigations
115	11/1/96	3.8-134	Section 3.8.2.10	Updated discussion on mussel collection activities
116	11/1/96	3.8-139	Table 3.8-57	Updated table
117	11/1/96	3.8-144	Section 3.8.3.2	Updated discussion of macroinvertebrate findings
118	11/1/96	3.8-148	Section 3.8.3.5	Updated discussion of mussel findings
119	11/1/96	3.8-149	Section 3.8.3.6	Updated discussion of summary of findings
120	11/1/96	3.8-155	Section 3.8.4	Updated reference list
121	11/4/96	10	Log of Updates	Updated (Volume I)
122	11/4/96	i through 3.10-14	Secton 3.10	Updated; replace entire section (Volume II)
123	11/4/96	—	Figure 3.10-1	Updated figure (Volume II)
124	11/4/96	—	Appendix 3.10-1	Updated title sheet (Volume IX)
125	11/4/96	3.10-1-11 through 3.10-1-19	Appendix 3.10-1	Added 1992 wetland data from Fugro-McClelland (Volume IX)
126	11/4/96	3.10-4-6	Appendix 3.10-4	Updated Functional Values Table 2 (Volume IX)
127	11/4/96	i	Section 3.12 Table of Contents	Updated (Volume II)
128	11/4/96	5	Section 3.12.3	Updated discussion on special land use category (Volume II)
129	11/4/96	11	Section 3.12.3.6	Added new subsection and discussion on special land use category (Volume II)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
130	12/3/96	11	Log of Updates	Updated (Volume I)
131	12/3/96	ii through iv 3.2-1 through 3.2-119	Section 3.2	Updated, replace entire section (Volume I); remove Figure 3.2-1
132	12/3/96	3.2-13-9 through 3.2-13-22	Appendix 3.2-13	Additional pages (Volume III)
133	12/3/96	—	Appendices 3.2-15 and 3.2-16	New Appendices (Volume IIIb)
134	12/3/96	ii through xi	Section 4 Table of Contents	Updated (Volume II)
135	12/3/96	4-3, 4-4, 4-4a through 4-4q, 4-5	Section 4.2.1	Updated (Volume II)
136	12/3/96	4-249 through 4-266	Section 4.2.14	Updated: new pages 4-249 through 4-262, remove pages 4-263 through 4-266 (Volume II)
137	12/3/96	4-289 through 4-299	Section 4.4, Bibliography	Updated (Volume II)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
130	12/3/96	11	Log of Updates	Updated (Volume I)
131	12/3/96	ii through iv 3.2-1 through 3.2-119	Section 3.2	Updated, replace entire section (Volume I); remove Figure 3.2-1
132	12/3/96	3.2-13-9 through 3.2-13-22	Appendix 3.2-13	Additional pages (Volume III)
133	12/3/96	—	Appendices 3.2-15 and 3.2-16	New Appendices (Volume IIIb)
134	12/3/96	ii through xi	Section 4 Table of Contents	Updated (Volume II)
135	12/3/96	4-3, 4-4, 4-4a through 4-4q, 4-5	Section 4.2.1	Updated (Volume II)
136	12/3/96	4-249 through 4-266	Section 4.2.14	Updated: new pages 4-249 through 4-262, remove pages 4-263 through 4-266 (Volume II)
137	12/3/96	4-289 through 4-299	Section 4.4, Bibliography	Updated (Volume II)
138	1/9/97	11 through 14	Log of Updates	Updated (Volume I)
139	1/9/97	3.3-3	Sections 3.3.4 and 3.3.5	Updated (Volume I)
140	1/9/97	ii through vi	Section 3.6 Table of Contents	Updated (new page vi) (Volume I)
141	1/9/97	3.6-3 through 3.6-9	Table 3.6-1	Updated (Volume I)
142	1/9/97	3.6-15	Section 3.6.1.3.1	Updated figure reference (Volume I)
143	1/9/97	3.6-22 and 3.6-23	Section 3.6.1.6.2	Updated (Volume I)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
144	1/9/97	3.6-26	Section 3.6.1.8	Updated (deletion) (Volume I)
145	1/9/97	3.6-28 through 3.6-33	Section 3.6.2 & Subsections, Table 3.6-5	Updated section designations, added new subsection 3.6.2.2, and updated table (Volume I)
146	1/9/97	3.6-33a	Section 3.6.3.1	Updated (new page) (Volume I)
147	1/9/97	3.6-34 and 3.6-35	Table 3.6-6	Updated (Volume I)
148	1/9/97	3.6-36	Section 3.6.3.1	Updated (Volume I)
149	1/9/97	3.6-44	Section 3.6.4.2.1	Updated (Volume I)
150	1/9/97	3.6-56 through 3.6-56e	Section 3.6.4.2.1, Tables 3.6-11a and 3.6-11b	Updated, two new tables (Volume I)
151	1/9/97	3.6-73, and 3.6-80 through 3.6-82	Sections 3.6.4.3 and 3.6.4.3.1	Updated (Volume I)
152	1/9/97	3.6-85 through 3.6-85e, and 3.6-86	Sections 3.6.4.3.1 and 3.6.4.3.2	Updated (Volume I)
153	1/9/97	3.6-94	Section 3.6.5.2	Updated (Volume I)
154	1/9/97	3.6-97 through 3.6-99	Table 3.6-25	Updated (Volume I)
155	1/9/97	3.6-100 through 3.6-104	Section 3.6.5.3 and Tables 3.6-26 & 3.6-27	Updated (Volume I)
156	1/9/97	3.6-105 and 3.6-106	Table 3.6-28	Updated (Volume I)
157	1/9/97	3.6-107 through 3.6-109	Section 3.6.6	Updated (Volume I)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
158	1/9/97	—	Figure 3.6-2a	New figure (Volume I)
159	1/9/97	—	Figures 3.6-3, 3.6-8, and 3.6-9	Updated (Volume I)
160	1/9/97	—	Figure 3.6-10a	New figure (Volume I)
161	1/9/97		Figure 3.6-11	Updated (Volume I)
162	1/9/97		Figures 3.6-27 and 3.6-28	Updated (Volume I)
163	1/9/97		Figures 3.6-28a through 3.6-28c	New figures (Volume I)
164	1/9/97	—	Figure 3.6-29a	New figure (Volume I)
165	1/9/97	—	Figures 3.6-36a through 3.6-36h	New figures (Volume I)
166	1/9/97	—	Figures 3.6-45 and 3.6-46	Updated (Volume I)
167	1/9/97	—	Figure 3.6-47	New figure (Volume I)
168	1/9/97	3.6-4-2a and 3.6-4-4a	Appendix 3.6-4	New pages (Volume VI)
169	1/9/97	3.6-8-2, -3, -4, -7, -10, -13, -16, -19, -22, -25, -28, -31, -34, -37, -40, -43, -46, -49, -52, -55, -58, -61, -64, -67, -68 through -74, -74a, -76, and -146 through -148	Appendix 3.6-8	Updated (Volume VII)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
170	1/9/97	—	Appendix 3.6-9a	New appendix (Volume VII)
171	1/9/97	—	Appendix 3.6-9b	New appendix (Volume VII)
172	1/9/97	—	Appendix 3.6-11 Title Sheet	Updated (Volume VIII)
173	1/9/97	3.6-11-347 through 3.6-11-387	Appendix 3.6-11	New pages (Volume VIII)
174	1/9/97	3.6-12-5, -9, -11, -15, -16, -18, -20	Appendix 3.6-12	Updated (Volume VIII)
175	1/9/97	—	Appendix 3.6-13 Title Sheet	Updated (Volume VIII)
176	1/9/97	3.6-13-5, -9, -11, -15, -16, -18, -20	Appendix 3.6-13	Updated (Volume VIII)
177	1/9/97	3.6-15-1 through 3.6-15-34	Appendix 3.6-15	New appendix (Volume VIII)
178	1/14/97	14 through 15	Log of Updates	Updated (Volume I)
179	1/14/97	ii through viii	Section 3.5 Table of Contents	Updated (Volume I)
180	1/14/97	3.5-1	Section 3.5.1	Updated section reference (Volume I)
181	1/14/97	3.5-4 through 3.5-11	Table 3.5-1	Updated (Volume I)
182	1/14/97	3.5-12 through 3.5-21	Table 3.5-2	Updated (Volume I)
183	1/14/97	3.5-29 and 3.5-30a	Sections 3.5.1.5 through 3.5.1.7	Updated Section 3.5.1.5; new Sections 3.5.1.6 and 3.5.1.7, and Table 3.5-4a (Volume I)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
184	1/14/97	3.5-31 through 3.5-33	Sections 3.5.1.8 through 3.5.1.10.2	Updated section numbering; updated 1994-1996 test pit programs (Section 3.5.1.8) (Volume I)
185	1/14/97	3.5-45 through 3.5-48	Sections 3.5.3.1.4, 3.5.3.1.5, and 3.5.3.2	Updated (Volume I)
186	1/14/97	3.5-59 and 3.5-59a	Section 3.5.3.2.1	Updated (Volume I)
187	1/14/97	3.5-62	Table 3.5-11	Updated mapping of soil unit 20 (Volume I)
188	1/14/97	3.5-65 through 3.5-65u	Sections 3.5.3.3 and 3.5.3.4 and Subsections	Updated discussion on soil units and topsoil (Volume I)
189	1/14/97	3.5-110	Section 3.5.6	Updated bibliography (Volume I)
190	1/14/97	—	Figure 3.5-5	Updated (Volume I)
191	1/14/97	—	Figure 3.5-10	Updated (Volume I)
192	1/14/97	—	Figures 3.5-25, and 3.5-27 through 3.5-31	Updated geologic cross sections (Volume I)
193	1/14/97	—	Figures 3.5-47a through 3.5-47d	New figures (Volume I)
194	1/14/97	—	Appendix 3.5-13a	New Appendix (Volume IV)
195	1/14/97	—	Appendix 3.5-13b	New Appendix (Volume IV)
196	1/14/97	3.5-14-123 through 3.5-14-134	Appendix 3.5-14	New cover sheet and new pages to be inserted at the end of the appendix (Volume IV)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
197	3/13/97	16-18	Log of Updates	Updated (Volume I)
198	3/13/97	19-24	Distribution List	Updated (Volume I)
199	3/13/97	ii through xiv	Executive Summary	Updated to reflect results of additional studies and updates to the EIR (Volume I)
200	3/13/97	1 through 6	List of Contributors	Updated (Volume I)
201	3/13/97	7 through 9	List of Acronyms	Updated (Volume I)
202	3/13/97	ii through xi	Section 4 Table of Contents	Updated (Volume II)
203	3/13/97	4-6 through 4-9	Section 4.2.2.1.1, Tables 4.2.2-1, 4.2.2-2, and 4.2.2-3	Updated to reflect change in truck traffic due to the proposed use of a geosynthetic clay liner in lieu of native clay (Volume II)
204	3/13/97	4-11	Table 4.2.3-1	Updated secondary standards for carbon monoxide (Volume II)
205	3/13/97	4-14	Section 4.2.3.2	Updated discussion on erosion control methods for particulate emissions due to wind erosion (Volume II)
206	3/13/97	4-15 through 4-15d	Section 4.2.4.1	Updated discussion on geology; Added new subsections relating to backfilling, underground collapse, and subsidence (Volume II)
207	3/13/97	4-15d through 4-15h	Section 4.2.4.2	Updated discussion on soils; Added new Table 4.2.4-1 (Volume II)
208	3/13/97	4-17 through 4-18, and 4-20 through 4-38	Section 4.2.5	Updated discussion to reflect additional groundater modeling work performed in 1995 and 1996; Added new Tables 4.2.5-1a, 4.2.5-2a, 4.2.5-3a, and 4.2.5-4a (Volume II)
209	3/13/97	4-39 through 4-56	Section 4.2.6	Updated surface water impacts based on additional groundwater modeling work; Added new Tables 4.2.6-2a and 4.2.6-5 (Volume II)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
210	3/13/97	4-57 through 4-59, 4-62 through 4-68, and 4-70 through 4-78d	Section 4.2.7	Updated wetland impacts based on additional groundwater modeling work (Volume II)
211	3/13/97	4-80 through 4-104	Sections 4.2.8 and 4.2.9	Update aquatic and terrestrial biology impacts (Volume II)
212	3/13/97	4-105 through 4-116	Section 4.2.10 Tables 4.2.10-2, 4.2.10-4, and 4.2.10-7	Updated estimated increases (Volume II)
213	3/13/97	4-117	Section 4.2.10.2	Updated discussion on vibration (Volume II)
214	3/13/97	4-118	Sections 4.2.11 and 4.2.11.1	Updated discussion on land use (Volume II)
215	3/13/97	4-119 through 4-122	Section 4.2.12	Updated discussion on aesthetics (Volume II)
216	3/13/97	4-262, 4-267, and 4-268	Section 4.2.15	Updated impact summary (Volume II)
217	3/13/97	4-289 through 4-299	Section 4.4	Updated bibliography (Volume II)
218	3/13/97	—	Figures 4.2.5-1 through 4.2.5-13	Updated Figures 4.2.5-1 through 4.2.5-6; New Figures 4.2.5-7 through 4.2.5-13 (Volume II)
219	3/13/97	—	Figures 4.2.6-1 through 4.2.6-4	New Figures 4.2.6-1 through 4.2.6-3; renumbered Figure 4.2.6-4 (Volume II)
220	3/13/97	—	Figures	The following figures have been updated: 4.2.7-2, 4.2.7-3, 4.2.7-4, 4.2.12-1, 4.2.12-2, and 4.2.12-3; New Figure 4.2.10-4 (Volume II)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
221	3/13/97	4.2-4-1 through 4.2-4-124	Appendix 4.2-4	Updated (Volume XI)
222	3/13/97	4.2-5- through 4.2-5-238	Appendix 4.2-5	Updated (Volume XI)
223	3/13/97	4.2-10-1 through 4.2-10-123	Appendix 4.2-10	New appendix (Volume XII provided)
224	3/13/97	4.2-11-1 through 4.2-11-105	Appendix 4.2-11	New appendix (Volume XII provided)
225	3/13/97	ii, and 5-1 through 5-7	Section 5	Updated mitigation discussion (Volume II)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
221	3/13/97	4.2-4-1 through 4.2-4-124	Appendix 4.2-4	Updated (Volume XI)
222	3/13/97	4.2-5- through 4.2-5-238	Appendix 4.2-5	Updated (Volume XI)
223	3/13/97	4.2-10-1 through 4.2-10-123	Appendix 4.2-10	New appendix (Volume XII provided)
224	3/13/97	4.2-11-1 through 4.2-11-105	Appendix 4.2-11	New appendix (Volume XII provided)
225	3/13/97	ii, and 5-1 through 5-7	Section 5	Updated mitigation discussion (Volume II)
226	5/15/97	18	Log of Updates	Updated (Volume I)
227	5/15/97	19 through 24	Distribution List	Updated (Volume I)
228	5/15/97	Section 4, pages iii, vii, and xi	Table of Contents	Updated (Volume I)
229	5/15/97	4-33 through 4-37a	Section 4.2.5.10	Updated discussion on solute transport modeling (Volume II)
230	5/15/97	4-292, 4-293, and 4-296	Section 4.4	Updated bibliography (Volume II)
231	5/15/97	—	Appendix 4.2-12	Added new appendix (Volume XII)
232	5/15/97	—	Appendix 4.2-13	Added new appendix (Volume XII)
233	5/15/97	—	Appendix 4.2-14	Added new appendix (Volume XII)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
234	8/7/97	19-20	Log of Updates	Updated (Volume I)
235	8/7/97	21-27	Distribution List	Updated (Volume I)
236	8/7/97	ii-viii	Section 3.5 Table of Contents	Updated (Volume I)
237	8/7/97	3.5-70 through 3.5-125	Section 3.5.5	Updated to reflect on-going waste characterization work (Volume I)
238	8/7/97	3.5-126 through 3.5-131	Section 3.5.6	Updated bibliography (Volume I)
239	8/7/97	3.5-132	Figure Title Sheet	Renumbered page (Volume I)
240	8/7/97	—	Figures 3.5-48 through 3.5-66	Updated and New Figures (Volume I)
241	8/7/97	—	Appendix 3.5-31 Title Sheet	Updated title sheet to reflect changes to appendix (Volume V)
242	8/7/97	3.5-31-1 through 3.5-31-5y	Appendix 3.5-31	New Table 1, renumbered Table 1a (Volume V)
243	8/7/97	—	Appendix 3.5-32 Title Sheet	Updated title sheet to reflect changes to appendix (Volume V)
244	8/7/97	3.5-32-35a through 3.5-32-35w	Appendix 3.5-32	New pages, add to appendix (Volume V)
245	8/7/97	3.5-32-36a and 3.5-32-36b	Appendix 3.5-32	New pages, add to appendix (Volume V)
246	8/7/97	3.5-32-47a and 3.5-32-47b	Appendix 3.5-32	New pages, add to appendix (Volume V)
247	8/7/97	3.5-32-54a and 3.5-32-54b	Appendix 3.5-32	New pages, add to appendix (Volume V)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
248	8/7/97	3.5-32-55	Appendix 3.5-32	Updated (Volume V)
249	8/7/97	3.5-32-77 through 3.5-32-168	Appendix 3.5-32	New pages, add to appendix (Volume V)
250	8/7/97	—	Appendix 3.5-33 Title Sheet	Update to reflect changes to appendix contents (Volume VI)
251	8/7/97	3.5-33-1 through 3.5-33-109	Appendix 3.5-33	Updated, replace existing pages, remove pages 3.5-33-110 through 3.5-33-338 (Volume VI)
252	8/7/97	3.5-33-361 through 3.5-33-370	Appendix 3.5-33	New pages, add to appendix (Volume VI)
253	8/7/97	3.5-34-1 through 3.5-34-162	Appendix 3.5-34	Updated, replace title sheet and entire appendix (Volume VI)
254	8/7/97	3.5-35-1 through 3.5-35-144	Appendix 3.5-35	Updated, replace title sheet and entire appendix (Volume VI)

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
272	5/8/98	22	Log of Updates	Updated (Volume I)
273	5/8/98	—	Appendix 4.2-10 Title Sheet	Updated title sheet to reflect addition of the update to the Solute Transport report (Volume XII)
274	5/8/98	4.2-10-124 through 4.2-10-291	Update to Appendix 4.2-10	New pages: add to appendix (Volume XII)
275	5/8/98	4.2-14-1 through 4.2-14-10	Update to Appendix 4.2-14	Updated: replace existing pages (Volume XII)
276	7/23/98	22	Log of Updates	Updated (Volume I)
277	7/23/98	1-7	Distribution List	Updated (Volume I)
278	7/23/98	4.2-3-39	Appendix 4.2-3	Updated: replace existing page (Volume X)
279	7/23/98	4.2-3-52	Table 2.7 of Appendix 4.2-3	Updated to correct citation of data source (Volume X)
280	7/23/98	4.2-12-28 and 4.2-12-38	Table 2-8 and Table 2-12 of Appendix 4.2-12	Updated to correct upper bound barium and silver estimates (Volume XII)
281	9/3/98	22	Log of Updates	Updated (Volume I)
282	9/3/98	1-6	Distribution List	Updated: remove page 7 (Volume I)
283	9/3/98	4.2-3-1466 through 4.2-3-1888	Appendix 4.2-3	Addendum No. 2 to Appendix 4.2-3 (Volume Xa)
284	9/15/98	22	Log of Updates	Updated (Volume I)
285	9/15/98	4.2-13-16	Appendix 4.2-13	Updated to correct conversion explanation (Volume XII)
286	9/15/98	4.2-13-18	Table 2.4 of Appendix 4.2-13	Updated to correct Sample Content for SO_4 (Volume XII)
287	9/15/98	4.2-13-23	Table 2.8 of Appendix 4.2-13	Added footnote to table (Volume XII)

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Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
272	5/8/98	22	Log of Updates	Updated (Volume I)
273	5/8/98	—	Appendix 4.2-10 Title Sheet	Updated title sheet to reflect addition of the update to the Solute Transport report (Volume XII)
274	5/8/98	4.2-10-124 through 4.2-10-291	Update to Appendix 4.2-10	New pages: add to appendix (Volume XII)
275	5/8/98	4.2-14-1 through 4.2-14-10	Update to Appendix 4.2-14	Updated: replace existing pages (Volume XII)
276	7/23/98	22	Log of Updates	Updated (Volume I)
277	7/23/98	1-7	Distribution List	Updated (Volume I)
278	7/23/98	4.2-3-39	Appendix 4.2-3	Updated: replace existing page (Volume X)
279	7/23/98	4.2-3-52	Table 2.7 of Appendix 4.2-3	Updated to correct citation of data source (Volume X)
280	7/23/98	4.2-12-28 and 4.2-12-38	Table 2-8 and Table 2-12 of Appendix 4.2-12	Updated to correct upper bound barium and silver estimates (Volume XI)

Log of Updates *(Continued)*

Entry Number	Date Revision Issued	Page(s)	Document/ Section Number	Description
288	10/6/98	23	Log of Updates	Updated (Volume I)
289	10/6/98	4.2-13-23	Table 2.8 of Appendix 4.2-13	Updated to correct Cemented Unoxidized Pore Volume value (Volume XII)
290	10/6/98	4.2-13-57	Table 7.1 of Appendix 4.2-13	Updated to correct Volume Weighted Average Estimated Volume value (Volume XII)
291	10/6/98	4.2-3-1527a	Addendum No. 2 to Appendix 4.2-3	Updated to incorporate Table 4.7 (Volume Xa)

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In addition to the regular distribution, the following people received the August 7, 1997 update to Section 3.5.5 of the EIR.

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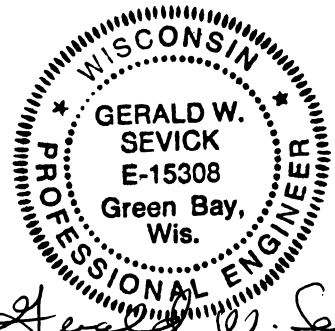

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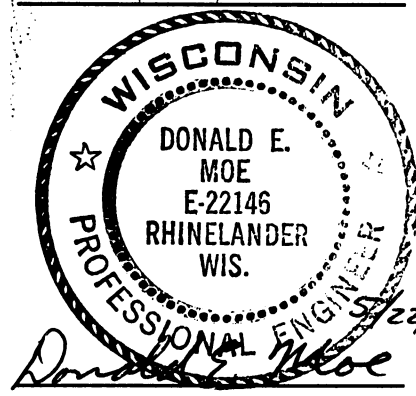

5/22/95

Environmental Impact Report for the Crandon Project

93C049

Prepared for
Crandon Mining Company
Rhinelander, Wisconsin

Prepared by
Foth & Van Dyke and Associates Inc.

May 1995

Foth & Van Dyke 1995
2737 S. Ridge Road, P.O. Box 19012, Green Bay, Wisconsin 54307-9012, 414/497-2500, FAX: 414/497-8516

Executive Summary

Filings

This Environmental Impact Report (EIR) has been prepared in support of a proposal by the Crandon Mining Company to develop an ore body to extract metals. The ore body, known as the Crandon deposit, was discovered in the mid-1970s and is located approximately five miles south of the city of Crandon, Wisconsin. Early exploration and verification of the ore body was carried out through a combination of airborne geophysical sensing methods and exploratory drilling. The size and quality of mineralization has been determined by core holes drilled from the surface. The deposit contains primarily zinc and copper ore, with lesser amounts of lead, silver and gold.

In 1978, Exxon Minerals Company (EMC) submitted a Notification of Intent to the Wisconsin Department of Natural Resources (WDNR) to collect data to support a mining permit application. During the mid-1980s, EMC submitted the following major documents and applications to the WDNR: Environmental Impact Report (EIR), Mine Waste Disposal Facility Feasibility Report, Mine Permit Application, Air Permit Application, Wisconsin Pollutant Discharge Elimination System Permit Application, High Capacity Well Approval Applications, Mine Refuse Disposal Facility Feasibility Report, Chapter 30 and 31 permit applications, and supporting documents. Additional permit applications and plan approvals were submitted by EMC to the Wisconsin Department of Transportation (WisDOT) and local units of government, and to the Public Service Commission of Wisconsin (PSC) by Wisconsin Public Service Corporation (WPSC). In late 1986, the WDNR issued a Final Environmental Impact Statement regarding the proposed project. Subsequently, EMC informed the WDNR that it wished to withdraw from the permitting process due to depressed metal prices.

In the fall of 1993, subsidiaries of Exxon Corporation formed a general partnership with subsidiaries of Rio Algom Limited and created Crandon Mining Company (CMC), a Wisconsin general partnership, with the intent to permit and develop the Crandon Project. The deposit will be mined in a similar fashion to that proposed in the 1980s, with the exception that the expected production rate is now set at 5,500 tons per day. The current project design has also been updated to meet or exceed current environmental standards.

The baseline information portion of the Crandon Project EIR was one of three major documents originally submitted in May of 1995 to the WDNR, U.S. Army Corps of Engineers (USCOE) and others in support of the project. The other documents also submitted in 1995, which compliment the EIR by providing design details, are the *Mine Permit Application* (MPA) and the *Tailings Management Area (TMA) Feasibility Report/Plan of Operation*. Both documents provide engineering details pertaining to the construction and operation of the mine, plant site and tailings facilities. The remaining two sections of the EIR, which address project impacts and mitigation of impacts, are part of the submittals forwarded to the WDNR, USCOE and others along with a series of additional permit applications relating to air, wastewater, wetlands, etc. during July, August, September, and October, 1995. Since the time these documents were originally submitted in 1995, numerous updates or addenda have been prepared by CMC and forwarded to the reviewers in response to questions or requests for additional information.

Project Description

The Crandon deposit is of volcanic origin and consists of sulfide minerals. The ore body is approximately 4,900 feet long east/west and averages 100 feet wide north/south. It will be mined by underground mining methods. After an initial three-year site preparation period, mining will be conducted for 28 years. Annual ore production is anticipated at two million tons, with a total ore production of 55 million tons.

The surface facilities will consist of the plant site, tailings management area, tailings and return water pipeline corridor, access road, railroad spur and wastewater treatment and discharge system. The plant site consists of all mining, processing, concentrating, wastewater treatment, administrative, and storage facilities.

After the ore is mined, and hoisted to the surface, it will be processed resulting in zinc, lead, and copper concentrates and a waste product called tailings. The concentrate will be shipped via railroad to smelting facilities located out of state. One half of the tailings will be re-introduced into mined-out stopes as backfill, with the remaining 50 percent pumped to the TMA for permanent placement. Water used in the milling process will be recycled. Any additional water needed for mill operations will be supplied from mine inflow. A wastewater treatment plant will treat all contact water to WDNR water quality standards prior to discharge to the Wisconsin River. The discharge will average about 560 gallons per minute. By contrast, the Wisconsin River's average flow in the vicinity of the discharge point is 400,000 gallons per minute, and the average seven-day low flow is 135,000 gallons per minute.

The facility will operate continuously seven days/week. Employment levels will peak at 750 during the construction of the plant and TMA facilities, and be sustained at 402 to 526 for the duration of the mining operation. At the conclusion of the mining operation, the entire project site will be reclaimed by implementation of a four-year restoration project. The objective of the reclamation effort is to restore the site to a long-term environmentally stable condition, and to leave the site for beneficial and recreational uses.

Environmental Studies

An important aspect relating to the development of the project in a manner that does not adversely affect the environment is to accurately measure and record environmental conditions prior to project development. The investigation of the comprehensive environmental/ecological setting within the project area provides the baseline against which (1) facility design and operations methods can be developed to avoid negative environmental consequences, (2) permit requirements will be established by regulatory agencies, and (3) the post-production reclamation plan will be developed.

Under Wisconsin law, a mine may be issued a permit only if it:

1. complies with all applicable federal and state regulations;
2. protects lands with historical value or critical ecological importance;
3. protects public health, safety and welfare;
4. has a net positive socioeconomic impact;
5. conforms to local zoning regulations; and
6. includes suitable plans for reclamation.

The baseline investigations and studies completed for this EIR also incorporate the voluminous technical data developed during the late 1970s and 1980s mine permitting efforts. The advantage

to using historical data, particularly for the establishment of background environmental conditions, is the comfort of having data which reflects site conditions more than one decade in the past. These data have been extensively supplemented with additional data collected since 1993.

Location

The project site is located in northern Wisconsin within the Wolf River-Lake Winnebago-Fox River-Green Bay drainage basin. The area is characterized by northern hardwood forest, lakes, and wetlands. Land use includes forestry, recreation, residential, agricultural, and transportation. Approximately 18 percent of the land in the region is publicly owned. A majority of residences in the area are in the City or Town of Crandon or along lake shores. There is an airport four miles northwest of the project site, and the Wisconsin Central Limited Railroad passes four miles east of the site in a north-south direction.

Cultural Resources

As part of project baseline studies over 5,000 acres of land have been archaeologically surveyed. As a result of these surveys a small number of archaeological sites have been identified. All of the sites are either outside the areas of planned project activities or in areas where adverse impacts can be avoided with the exception of the Keith's Siding site located northeast of the plant site. The Keith's Siding site may represent a significant set of historic resources that may be eligible for listing on the National Register of Historic Places. A traditional cultural properties (TCP) investigation that includes both Native American and Euro-American communities was carried out.

The Sokaogon Chippewa Community has reported that they believe burial sites lie within the project's proposed construction area. CMC has requested that the Sokaogon Chippewa Community provide information as to the locations of such potential burials. To date no such information has been received by CMC. CMC field work has shown no evidence of any potential burials in the project's proposed construction area. If at a future date this information is provided, CMC will address it in accordance with accepted archaeological practices.

Transportation/Utilities

Updated transportation data were collected on the roadways serving the study area. The data were obtained from WisDOT and through traffic counts at selected points in January 1994. Electrical service to the site will be provided by WPSC from an existing substation near Monico, Wisconsin. Natural gas will be provided via a pipeline to be constructed from an existing WPSC pipeline located one-half mile north of Crandon, Wisconsin.

Air/Methodology

Field and laboratory methods were used to evaluate the existing air quality and meteorological conditions of the area surrounding and including the proposed mine site. The methods included monitoring for parameters such as wind speed, wind direction, temperature, relative humidity, precipitation, total suspended particulate, and particulate matter less than 10 microns in diameter. In addition, particulate characterization and trace metal analyses were conducted. The project is expected to be classified under the Federal Clean Air Act as a minor source of air emissions.

The climate of the region is continental, modified slightly by Lake Michigan, 80 miles to the east, and Lake Superior, 93 miles to the north. The region has moderately warm summers with prevailing westerly winds and long cold winters.

Geology

Crandon deposit minerals were deposited during the Precambrian era, about 900 to 2,500 million years ago. The ore bearing deposits were formed on the ocean floor by a volcanic system. Some of the materials deposited by the volcanic system were mineral laden fluids. The mineral laden fluids were heavier than sea water so they accumulated in low spots on the ocean floor. Continued accumulation of other volcanic materials and sedimentary rock materials occurred. Later in geologic time, a mountain building phase occurred in the region, tilting the layers to a near vertical position and lifting them above the ocean floor. Next, erosion of the rock layers by wind and water occurred. Finally, in the more recent geologic past, the rock layers were covered by unconsolidated materials of glacial origin.

The host rock north and south of the ore body consists of a series of volcanic rocks such as tuffs (solidified volcanic ash), debris flows (ocean floor and volcanic-derived sediments), breccia (blocky, angular particles) and lapilli (sand and gravel sized volcanic material). Above the host rock and ore body is a sequence of unconsolidated glacial deposits. The rock in contact with the unconsolidated glacial overburden is weathered in some areas. The amount of weathering varies from staining along fractures of the rock to a reduction of the rock to a clay-like material called saprolite.

The glacial overburden consists of interbedded and intermixed glacial till, which is material deposited directly by the glacier, and glacial outwash deposited by streams emanating from the glacier. Glacial deposits are found in various thicknesses in this area ranging from 75 to over 250 feet thick.

The ability of the glacial deposits and bedrock to convey water (hydraulic conductivity) were investigated using different laboratory and field studies. Bedrock hydraulic conductivities were studied in the field through the use of packer tests at over 40 locations in existing exploration holes. The hydraulic conductivity of lake beds was tested in the laboratory on actual samples of lake bed material and in the field using wells installed for that purpose. A full scale pump test was performed in 1994 to determine the degree of connection between the bedrock and overlying glacial soils.

Four major groups of potential waste materials--waste rock, tailings, overburden/and wastewater treatment/reclaim pond solids--have been tested for their leaching characteristics under conditions approximating those where the materials will be used or stored. This testing helped determine what steps are needed to handle and store these materials in ways that protect the environment. The results of the studies indicate that about 50 percent of the waste rock generated during mine development activities can be used in direct contact with site soils. Those that cannot will be backfilled in the mine or placed in the TMA. The TMA, described fully in the *TMA Feasibility Report/Plan of Operation* and addenda, is designed to keep tailings in an environmentally benign condition for the long term.

Groundwater

Groundwater occurs primarily in the glacial materials and to a lesser extent in the upper zones of weathered bedrock. Regional groundwater flow is generally from east to west. A stratified layer of glacial outwash consisting of sands and gravels is the primary aquifer used in the area for local

potable water sources. This layer is typically located below a surficial till layer, and in most locations is separated from the bedrock by a layer of less permeable material which may be a glacial till or a saprolite.

Groundwater quality in the region has been described as being derived primarily from coarse grained glacial deposits and being hard to very hard with locally high iron. Investigations performed during the 1977 to 1980 and May 1994 to January 1995 periods substantiated these findings.

Additionally, background measurements were made for 29 parameters in the groundwater, these include both those which are typically at elevated concentrations, such as iron, and those which are associated with the chemistry of the ore body. The investigations established that iron, manganese, arsenic, lead, aluminum, antimony and alkalinity occur naturally at high concentrations in groundwater at the project site.

Surface Water/Bottom Sediments

Surface water studies focused on the collection of baseline information on water flow and chemistry in order to evaluate the quality and quantity of surface water resources existing in the study area. These investigations concentrated on the lotic and lentic systems within the Swamp Creek and Pickerel Creek drainage basins which, in turn, are located entirely within the larger Wolf River drainage basin. The water bodies studied within the Swamp Creek system included Oak, Ground Hemlock and Rice Lakes and Hemlock, Outlet, Hoffman and Swamp Creeks. Those evaluated within the Pickerel Creek system included Pickerel, 11-4 and 12-9 Creeks, as well as Rolling Stone, Little Sand, Duck, Deep Hole, Skunk, Mole, Walsh, and St. John's lakes. Monitoring was also conducted in the Wolf River itself.

Results of collections and measurements made over a 12-month period beginning in November 1993 indicated that the study area is characterized by small perennial streams and lakes of four types: drainage, seepage, spring, and drained. In general, the lakes and rivers studied contained soft to moderately hard, neutral to slightly acidic water. Metal concentrations within the study systems were generally observed to be low, although various metals were detected at several sites in trace amounts using low level metals analysis techniques.

Within the study area, there is a close relationship between the groundwater from the main area aquifer and the surface water in the streams and spring lakes. This is indicated by similarities in surface and groundwater chemistry. The study area drainage, seepage, and drained lakes for the most part are isolated from the groundwater and therefore reflect surface runoff which contains softer water of lower pH.

Baseline studies were also conducted in an effort to evaluate the areas' bottom sediment composition and quality. Bottom sediment core samples were collected from various sites in 11 water bodies within the study area. These samples, comprised of the upper one foot of substrate, were analyzed for various constituents of metallic and organic composition. Results indicate that the area's general sediment composition is diverse ranging from firm sand bottom lakes to muck substrate in some reaches of stream. Considerable variability in the concentrations of various metals in stream and lake sediment samples was observed between individual sampling sites as well as between duplicate samples at each river station exemplifying the heterogeneity of sediment deposition within a riverine environment. In general, metals concentrations were observed within ranges expected in typical non-industrial sediment samples.

Biology

The flora and fauna existing within a 30 square mile area surrounding the proposed Crandon Project site were inventoried. Specific studies were carried out for mammals, birds, reptiles and amphibians, butterflies, terrestrial and aquatic plants, fish, aquatic macroinvertebrates, dragonflies, and mussels. Previous studies summarized in the 1986 *Environmental Impact Report* focused on a general characterization of the biologic environment and on common species, while the studies commissioned by CMC in 1993, 1994, and 1995 focused on endangered, threatened, and special concern species and provided an update of the previous work. The resulting inventory is a result of thousands of field hours (over 6,000 between 1993-1995 alone) spent from the late 1970s to the present. The 1993-1995 biology team consisted of up to 25 biologists, including many of the most respected researchers in Wisconsin. Few, if any, areas in Wisconsin have been studied as intensively as the area surrounding the proposed mine. The presence of woodland ponds, bogs, lowland conifer swamps, lakes and streams, together with extensive forested habitats, provide a favorable mix of wet and upland habitats and a relatively high diversity of terrestrial wildlife species. These habitats are common across Northeastern Wisconsin.

The aquatic biology studies included an investigation of the Swamp Creek and Upper Pickerel Creek drainage systems and the Wolf River upstream and downstream of the confluence with Swamp Creek. The aquatic survey results are not indicative of a particularly diverse aquatic community. No endangered or threatened species were observed. A number of special concern species were found in the study area. The study area lakes (Skunk, Little Sand, Duck, Deep Hole, and Oak) are generally low in productivity. Algal-leaved pondweed (*Potamogeton confervoides*), a stated-listed threatened species, exists in Duck Lake.

As a result of the intense studies of the land and water environment, a total of five endangered, five threatened, and 78 special concern species were observed. By comparison, the Wisconsin Natural Heritage Working list of threatened, endangered and special concern species includes more than 400 species. Crandon Project researchers specifically looked for those species most likely to be found in the area. The existence of any of these species will not be threatened by the proposed project. For example, of the five threatened and five endangered species identified in the study area, only one, the state endangered goblin fern, was found on land that would be directly affected by mining. The studies found a number of populations of this plant in 1994, including three populations far from the proposed mine site in the Nicolet National Forest. Further studies of the goblin fern and its range in Northeastern Wisconsin conducted in 1995 documented a large number of additional sites bringing the total goblin fern sites in Wisconsin to 48. This indicates that goblin fern may be more widespread than previously thought, especially since the plant's habitat is not uncommon in Northeastern Wisconsin.

The flora and aquatic fauna along the Wisconsin River downstream from the planned Hat Rapids Dam discharge point were surveyed in 1996. The survey for rare vascular plants was conducted from the Hat Rapids Dam to Menard Island and to lesser extent, downstream of Menard Island to County Trunk Highway (CTH) A. All fully aquatic species were carefully considered during the survey and the standard practice was to identify any unknown species such that unexpected rare species were not overlooked. The study area for aquatic fauna investigations included those areas of the Wisconsin River from the Hat Rapids Dam downstream to Menard Island, a distance of about 7 miles. The primary objective of these investigations was to provide field data on federal or state listed threatened, endangered, or special concern species, i.e., species "listed" by the Wisconsin Natural Heritage Inventory.

No endangered or threatened vascular plant species were previously known to exist within the area of the study, and none were found during the study. The special concern species, *Epilobium palustre* (marsh willow-herb) had been reported from within the area, but was not encountered in the survey, although the similar *E. leptophyllum* was found in the boggy marsh near Highway A. With the exception of Odonata, no threatened, endangered, or special concern species of aquatic macroinvertebrates were collected from the study area. Four special concern and one endangered Odonata were collected from the study area. These include *Ophiogomphus howei* (endangered), *Gomphus lineatifrons, G. ventricosus, G. viridifrons* and *G. quadricolor*. In general, habitat for state-listed species of Odonata appears to be abundant between Hat Rapids Dam and Menard Island. Although similar habitat occurs throughout the entire reach, species diversity and abundance is significantly greater from Camp 10 Landing to Menard Island.

No threatened or endangered mussels were encountered during the study. One special concern specie, *Lasmigona compressa*, was collected at the two downstream sites but not at the site immediately downstream of Hat Rapids Dam. The fishery of the Wisconsin River below Hat Rapids Dam is a moderately diverse and healthy community. Records provided by the WDNR indicated that one greater redhorse (threatened) was identified within the study area. During CMC's field survey which concentrated mainly on areas of swift water with rock substrates (i.e., redhorse habitat), neither of the target species, greater redhorse or black redhorse, were observed. Despite the sampling results and very limited historical records of occurrence, the greater redhorse may occur in very low numbers in this stretch of the Wisconsin River. However, the black redhorse was not documented during either the WDNR or CMC's fish surveys.

Wetlands

Within an approximate 18 square mile study area surrounding the proposed Crandon Project site, a total of 256 wetlands were inventoried and mapped with functional values assessed for 180 wetlands. By far, conifer swamp is the most common wetland habitat existing in the study area followed by emergent marsh/wet meadow, deciduous swamp, bog, and shrub swamp. In general, this is representative of the region. As with the study area and the region, conifer swamp represents over half of the wetlands of the approximate 29 acres of wetlands existing within the footprint of the proposed project facilities. The storm and floodwater storage and water quality maintenance functions are the most important wetland functional values associated with this 29 acres. The entire mining project has been designed to minimize impacts on wetlands.

Noise

A baseline noise survey was conducted to augment data originally collected in the 1970s and 1980s. Survey locations were established within an approximate three-mile radius around the plant site and TMA. The study showed that the background noise environment in the area is controlled mainly by birds, animals and nearby and distant traffic on the roads. Based on the study, typical ranges of background noise were assigned based on types of land use.

Land Use

Land use was studied within a 100 square mile area surrounding the project area. The study showed that approximately 77 percent of the land is forested; 12 percent is recreational, including water bodies; six percent is residential; and five percent is agricultural. Of the 64,000 acres in the study area, approximately 9,000 acres are devoted to recreation. This 9,000 acres is less than three percent of the publicly owned lands in Forest County alone.

Aesthetics

A visual impact assessment was prepared for the surface facilities at the proposed Crandon Project site. This assessment focused on the three facilities likely to be the most visible; the headframe, tailings pond embankments, and the railroad spur. Thirty five viewpoints were selected to identify visually sensitive areas or areas of intense land use, including roadways, residential housing, public access areas, areas of topographic elevation, and locations of sizable forest openings.

The regional landscape encompassing the plant site and surrounding area is primarily forested upland with lesser amounts of forested wetland, and an abundance of lakes and streams. The natural features currently dominate the views in the area and are anticipated to continue to do so after the mine facility is constructed.

Socioeconomics

The socioeconomic study concentrated on assessing impacts to the people who live within the Forest, Langlade, and Oneida County area, as well as impacts on Wisconsin's economy as a whole. Background information was collected on population, employment, housing, government structure and public finances, public facilities and services, as well as Native American communities within the three county area. The socioeconomic study found that the three county area economy is less diversified than Wisconsin as a whole. The study also found that unemployment rates in Northern Wisconsin historically are higher than the state as a whole.

Environmental Impacts

This section of the EIR presents the expected effects of the Crandon mine on the biological, physical and socioeconomic environment. The project is designed to avoid and minimize environmental impacts. Where those impacts are unavoidable and likely to be significant, CMC will take appropriate mitigation measures as described in Section 5 of the EIR and in the project's *Mine Permit Application*. In addition, CMC will implement contingency plans in the unlikely event that environmental impacts are greater than expected. The impacts projected below are based on scientific judgement drawn from an extremely thorough environmental and socioeconomic study.

Cultural Resources

An archaeological study of more than 5,000 acres in the project area found only one possible historically significant site likely to be affected. The 1910 era Keith's Siding logging camp will be affected by construction of the mine's railroad spur. CMC has proposed to recover artifacts from the site if it is found to be of historical significance. A final Memorandum of Agreement developed per the Section 106 process will outline the final methods to be used to protect this site. No Euro-American TCPs were identified in the study area and, as such, no impacts on such properties are anticipated. As discussed in Section 3.2 of the EIR, numerous Native American cultural sites were identified in the study area and vicinity from archival and other public sources. Most of these sites are associated with Sokaogon Chippewa occupation and utilization of the region, and almost all (i.e., greater than 90 percent) are located beyond the area of project construction and operation activities. Some of the cultural sites identified may be potential TCPs, but this can only be determined with so far unavailable primary source data from the local Sokaogon Chippewa and Forest County Potawatomi (FCP) populations. TCP studies have been conducted with the Menominee Tribe of Wisconsin, although the results have yet to be released by the Menominee Tribal Legislature.

Transportation/Utilities

Traffic studies show that roads and highways in the area are adequate to handle mine-related traffic. The studies indicate that a southbound bypass lane and a northbound right turn lane on State Highway 55 at the intersection with the mine access road would aid traffic flow when the mine is constructed.

Air Quality

Estimated air quality around the project site will be better than all federal and state standards during both the construction and operations phases. Both underground and surface operations will use effective dust-control technologies and practices. Mobile diesel vehicles will have exhaust scrubbers. The mine air heating system and the back-up electric power generators will be fueled with clean-burning natural gas.

Geology, Soils and Topography

The total area disturbed by the mine will be approximately 540 acres. Construction of the plant site, access road and railroad spur will require the clearing of approximately 195 acres. During this process, reseeding, landscaping and other erosion-control practices will be used. Because the site will be fully reclaimed, no significant long-term effects on soils or topography are expected. TMA and surrounding facility construction will affect approximately 345 acres. Long-term physical effects will be minor because reclamation will create new grades, drainage patterns and vegetation that are similar to those of existing landforms.

Groundwater

Mine inflow and groundwater drawdown. Groundwater will seep into the mine at an estimated 700 gallons per minute based on extensive geological data and groundwater modeling. The resulting decline in groundwater levels will be limited to the immediate area of the mine and will reach its peak in about ten years. At that point, any measurable effect will be limited to an area within about 1.9 miles of the ore body.

Private wells. Only 12 private water supply wells may be affected by the estimated decline in water levels due to mine dewatering. CMC will monitor groundwater elevations around the site and will deepen or replace, at its expense, any wells if monitoring indicates a pending impact from the mine.

Groundwater quality. The mine's engineered tailings cells will provide long-term protection of the groundwater quality. Groundwater will always meet WDNR quality standards at a compliance boundary 1,200 feet from the cells. CMC groundwater studies show this will hold true even in the highly unlikely event the geomembrane bottom liner would fail completely, leaving only the geosynthetic clay liner and 12-inch bottom layer of low permeable soil.

Surface Waters

Lake water levels. Skunk Lake, a 6-acre lake on the mine property with a maximum depth of five feet, no fish population and no cottages is estimated to experience a lowering of 0.53 feet of its water level due to mine dewatering. Of the other four lakes nearest the mine, there will be no effect on Oak Lake and insignificant (See Table 1) effects — less than one inch — on Little Sand, Duck and Deep Hole lakes. Water level changes on Rice and Rolling Stone lakes will be too small to measure. There will be no change at all in water levels on Lucerne, Metonga,

Ground Hemlock, Mole, Crane, Pickerel, St. Johns, Walsh, Kimberly, Clark or any other lakes more than two miles from the mine.

Table 1

Effect of Mining on Lake Levels

	Changes in Water Level (Inches)		
Lake	Expected Case	Practical Worst Case	Natural Variation
Duck	0.1	1.3	31.7
Deep Hole	0.2	4.7	26.8
Little Sand	0.8	5.8	31.9
Skunk	6	7	56.0

Stream flows. When compared with seasonal variations, effects on local stream flows will not be significant. Minor to moderate flow reductions in five creeks (see Table 2) will not affect public uses, and mitigation is not expected to be necessary.

Table 2

Effect of Mining on Stream Flows

	Changes in Flow Rate (Cubic Feet per Second)		
Stream	Expected Case	Practical Worst Case	Low[1] to High[2]
Swamp Creek (STH 55)	0.90	1.5	8 to 228
Hemlock Creek	0.31	0.52	2.4 to 53
Hoffman Creek	0.15	0.26	NA to 5
Creek 12-9	0.36	0.62	1.1 to 42
Upper Pickerel Creek	0.16	0.28	0.4 to 23

[1]Low = $Q_{7,10}$ from Table 4.2.6-2 of the EIR.
[2]From available recorded data.
NA: Data not available.

Surface water quality. The mine will fully protect the quality of all surface waters in the area. The mine's water treatment plant will use a lime/sulfide process to neutralize and remove metals. The treated water will be discharged to the Wisconsin River at an average of 560 gallons per minute by way of a 38.3-mile buried pipeline. The water will be discharged to the turbine intakes

at the Hat Rapids Dam. The quality of the water will consistently be better than standards set by the WDNR. There will be no adverse effects on the Wisconsin River.

Surface water quality also will be protected from runoff. During construction, effective erosion control practices will be employed. During operations, runoff from ore production and storage areas will be collected and processed in the project's water treatment plant.

Wetlands

Construction of mine facilities will directly affect approximately 29.3 acres of wetlands, about 1.4 percent of the wetlands in the project study area. These wetlands will be replaced by restoration of 57 acres of high-quality wetlands in the Fox-Wolf River watershed. The restoration site is a natural wetland that was converted to farmland. Indirect effects on wetlands will be minor. Lowered water levels and changes in surface water runoff patterns in the immediate area of the mine will cause some changes in the types of vegetation, mainly at the margins of wetlands. However, these wetlands will retain their functional values and almost all will revert to current existing conditions after the mine is closed and groundwater levels recover, within about ten years after mine closure.

Aquatic Biology

Minor reductions in lake levels and stream flows will cause some loss of aquatic habitat, but effects on fish and other aquatic life are expected to be minimal. Flow reductions in Hoffman Creek and Hoffman Springs could affect small populations of brook trout and some potential brook trout spawning areas. CMC will monitor conditions in these waters and will implement mitigation measures if necessary. A state threatened aquatic plant, algal-leaved pondweed, grows in Duck Lake, but it will not be affected because the change in the lake's water level will be insignificant.

Terrestrial Biology

Effects on land-dwelling plants, birds and animals are expected to be negligible. Although project studies found nine terrestrial threatened or endangered species on a 30-square-mile area around the mine site, only the state endangered goblin fern is on land that would be directly affected by mining. Populations of goblin fern were found on the proposed site of the tailings management area. However, to date, a total of 48 populations of the fern have been found in Northeastern Wisconsin and Upper Michigan. The state threatened calypso orchid was found at the site, two in areas unaffected by the mine and one in the Swamp Creek Cedars, which may be affected by groundwater drawdown. CMC will monitor both water levels and the calypso orchid in the Swamp Creek Cedars. If stress to these plants is observed, appropriate mitigation measures will be implemented.

Noise and Vibration

Based on a conservative analysis, the effects of noise from the mine are expected to be minimal. Noise from mine operations will not be noticeable from most residential areas. During mine construction, the increase in noise in residential areas will be below levels considered noticeable, based on U.S. Environmental Protection Agency guidelines. During tailings cell construction, residents within one mile of the tailings management area may notice an increase in noise. CMC will minimize this noise by limiting construction work to daylight hours and selecting low-noise equipment for mine operations.

Vibration caused by underground mine operations will generally be undetectable outside the mine property.

Land Use

The mine will convert about 540 acres of land from mainly forestry and recreational uses. This effect is not significant because of the vast area of forest and recreational land in Forest, Oneida and Langlade counties. Following reclamation, the plant site will be reclaimed to a savannah/forest environment while the TMA will be reclaimed to a northern prairie environment. Indirect effects on land use will be minimal and will be related to changes in population and the local business community that will develop due to the presence of the mine.

Aesthetics

The visual effects of the mine are expected to be minor. Forests and topography will effectively screen mine facilities from view. To further minimize aesthetic effects, CMC will use low-intensity, downward-directed lighting on outside buildings at the plant site and on interior roads and the parking area. Selective tree plantings will provide additional screening for the railroad spur.

Socioeconomics

Employment. Construction employment will peak at about 550, about 20 percent expected to be local hires. Long-term operations employment is conservatively estimated to average 400, of which about 70 percent are expected to be hired locally. Indirect employment in businesses that serve the mine and its employees is estimated at 320 to 400.

Mine purchases. Total construction spending, in 1994 dollars, is estimated at $287 million, about $43 million spent locally for goods and services. Mine operations costs including payroll will vary form $50 million to $78 million per year. Total mine purchases in Wisconsin are projected at $740 million.

Population and housing. During the peak year of construction, the mine is expected to add about 1,174 more people (2.2 percent) to the tri-county area than if no mine were built. During 28 years of operations, the project would add 750 people (1.5 percent) to the area population. The existing housing supply in the tri-county area is adequate for this modest population growth.

Taxes. The mine will add $110 million (1994 dollars) to the local tax base during its peak year, to the benefit of the Town of Lincoln, Town of Nashville, Forest County and the Crandon School District. Net Proceeds Taxes paid by the mine are projected at $119 million, of which $72 million will be available to locally offset mine-related impacts.

Public facilities. The mine will not create a need for any new public facilities. No schools will have to be built or expanded because of the mine.

The only mitigation measures potentially required for socioeconomic effects relate to housing for construction workers and measures to address a temporary suspension or premature closure of the mine. CMC can mitigate short-term housing needs during mine construction by encouraging contractors to hire workers from the local area, thus minimizing the need for in-migrant workers.

Unemployment compensation would provide an income "buffer" for workers affected by a temporary mine shutdown. Effects of premature mine closure can be mitigated by effective

economic planning starting even before the mine opens. Such planning may include efforts by local communities and the state to attract new industry to the area, and use of available resources, such as net proceeds tax revenue, to create alternative, long-term job opportunities.

Native American Communities

CMC has evaluated potential impacts to Native American tribes by considering many factors, including impacts to reservation environments, exercise of treaty rights, culture, social integrity, and tribal government and economic development goals. Because CMC's efforts to consult and exchange information with the tribes have met with limited success to date, the company has had to evaluate the project's effects on Native American communities based largely on previously published studies and other available information.

These studies indicate that the mine is compatible with the protection of Native American resources, economies, cultures, traditions and ways of life. The Sokaogon Chippewa, Forest County Potawatomi, and Menominee tribes have expressed strong opposition to the project, claiming the construction and operation of the mine will have significant and irreversible, social, economic, and cultural impacts on their way of life as practiced over many generations. CMC continues to seek assistance from the tribes in addressing these matters. In the meantime, CMC pledges its best efforts to design, build, operate and reclaim the mine in accord with the following principles:

- Respect for sovereignty, culture, traditions, heritage and diversity of the tribes.
- Compliance with the letter and spirit of all applicable laws covering Native American rights.
- Active efforts to evaluate, understand, avoid, minimize and mitigate potential adverse effects of the mine on Native American tribes, their members, and their natural resources.
- Exploration of possible employment, service, supplier and other business relationships that could mutually benefit the tribes and the company.

Environmental Impact Report
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List of Contributors

A. Companies, Institutions and Independent Consultants

Following is a list of companies, institutions, and individuals who have directly contributed in a significant way to the development of the *Environmental Impact Report* (EIR) for the Crandon Project. A significant number of other parties have contributed indirectly to the EIR via project work completed in the past. These contributors can be found listed in the bibliography at the end of each major section of the report.

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Thomas C. Erdman University of Wisconsin-Green Bay Department of Natural and Applied Sciences Green Bay, WI 54311-7001	Terrestrial Biology
Gary A. Fewless University of Wisconsin-Green Bay Department of Natural and Applied Sciences Green Bay, WI 54311-7001	Terrestrial Biology
Foth & Van Dyke 2737 South Ridge Road P.O. Box 19012 Green Bay, Wisconsin 54307-9012	Climatology, Meteorology and Air Quality Geology Groundwater Surface Water and Bottom Sediments Aquatic/Terrestrial Biology Wetlands Ambient Vibrations Land Use Aesthetics Socioeconomics
Fugro-McClelland, Inc. 6 Maple Street Northborough, Massachusetts 01532	Wetlands
GeoSyntec Consultants One Park Place 621 NW 53rd Street, Suite 650 Boca Raton, FL 33487	HDPE Long-Term Performance
GeoTrans, Inc. 1080 Holcomb Bridge Road Building 200, Suite 305 Roswell, Georgia 30076	Groundwater Modeling
Great Lakes Archaeological Research Center 1659 North Jackson Street Milwaukee, WI 53202	Historical and Archaeology
Helms & Associates 118 South Riverview Bellevue, Iowa 52031-1339	Aquatic Biology

Dr. Robert W. Howe University of Wisconsin-Green Bay Department of Natural and Applied Sciences Green Bay, WI 54311-7001	Terrestrial Biology
Dr. Jack Huddleston 1718 Weber Drive Madison, Wisconsin 53713	Socioeconomics
Hydro-Geo Consultants, Inc. 165 South Union Boulevard, Suite 400 Lakewood, Colorado 80228	Bedrock Hydraulic Conductivity
Inman-Foltz 8612 Highway 51 North Minocqua, WI 54548	Surveying
IPS Environmental and Analytical Services Integrated Paper Services, Inc. 101 West Edison Avenut, Suite 250 Appleton, WI 54912-0446	Bioassays
Dr. Richard W. Lawrence Lawrence Consulting Limited 103-2298 West 1st Avenue Vancouver, B.C. Canada V6K 1G1	Waste Characterization
Market Access International 200 Union Boulevard, Suite 430 Lakewood, CO 80228	Pyrite Recovery Study
Prairie Restorations, Inc. P.O. Box 327 Princeton, MN 55371	Reclamation
Resource Management Group, Inc. 926 Willard Drive, Suite 218 Green Bay, WI 54304	Terrestrial Biology
Steffen Robertson & Kirsten (Canada), Inc. 580 Hornby Street, Suite 800 Vancouver, B.C. Canada V6C 3B6	Tailings Management Area Waste Characterization Reflooded Mine and TMA Source Term Derivation Oxygen Diffusion Modeling
Steffen Robertson & Kirsten (US), Inc. 3232 South Vance Street Lakewood, Colorado 80227	Tailings Management Area

Steigerwaldt Land Services 856 North Fourth Street Tomahawk, WI 54487	Forest Inventory
Dr. Mark Stewart University of South Florida Geology Department SCA 203 4202 East Fowler Avenue Tampa, Florida 33620-5200	Lakebed Geophysics
Subsurface Detections Investigations, Inc. 7381 114th Avenue North, Suite 405B Largo, Florida 34643	Lakebed Geophysics
TD Drilling, Inc. 7391 South Porcupine Road Lena, WI 54139	Soil Borings/Monitoring Well Installation
Dr. Kenneth Tennessen 1949 Hickory Avenue Florence, AL 35630	Aquatic Biology
Thresher & Son, Inc. 2828 Regent Street Madison, Wisconsin 53705	Waste Characterization Geology
Woods Cultural Research, Inc. 32654 Showshoe Road Evergreen, CO 80439	Traditional Cultural Properties
WTD Environmental Drilling 101 Alderson Schofield, WI 54476	Soil Borings/Monitoring Well Installation

B. Laboratories

Laboratories providing recent analytical services for various phases of the environmental investigations to support this EIR are listed below. The primary environmental laboratory was ETC Santa Rosa, which became PACE, Incorporated, Minnesota following a merger of PACE, ETC and Coast to Coast. Northern Lake Service, Inc. was the primary laboratory for the supplemental kinetic test work.

Battelle Marine Sciences Laboratory
1529 West Sequim Bay Road
Sequim, WA 98382

Chemex Labs, Inc.
212 Brooksbank Avenue
North Vancouver, BC Canada V7J 2C1

Controls for Environmental Pollution, Inc.
1925 Rosina Street
Santa Fe, NM 87501

ETC Santa Rosa
320 Tesconi Circle, Suite G
Santa Rosa, CA 95401

EnChem, Inc.
1795 Industrial Drive
Green Bay, WI 54302

Enviroscan Corporation
303 West Miliary Road
Rothschild, WI 54474

HES, Inc.
525 Science Drive
Madison, WI 53711

Lakefield Research
A Division of Falconbridge Limited
185 Concession Street, P.O. Box 4300
Lakefield, Ontario Canada
K0L 2HO

Northern Lake Service, Inc.
400 North Lake Avenue
Crandon, WI 54520

PACE, Incorporated
5930 McIntyre Street
Golden, CO 80403

PACE, Incorporated
Minnesota Laboratory
1710 Douglas Drive North
Minneapolis, MN 55422

Superior Testing
410 Banks Avenue
Superior, WI 54880

Thresher & Son, Inc.
2828 Regent Street
Madison, WI 53705

Woodward-Clyde
2135 South 116th Street
Milwaukee, WI 53227

C. Geologists, Groundwater Hydrologists and Hydrological Engineers

Geologists, groundwater hydrologists and hydrological engineers who contributed to the various recent phases of the geological and hydrological investigations for this EIR are listed below:

Individual	Firm
Lanette L. Altenbach, CPG	Foth & Van Dyke
Peter F. Andersen, P.E.	GeoTrans, Inc.
Carl E. Brechtel	Agapito Associates, Inc.
Richard Cote'	Rio Algom, Ltd.
Stephen V. Donohue	Foth & Van Dyke
Scott A. Effner	Hydro-Geo Consultants, Inc.
A. J. Erickson, Jr.	Exxon Coal and Minerals Company
Dr. Charles Faust, Ph. D.	GeoTrans, Inc.
Garrett Hollands, P.G.	Fugro-McClelland, Inc.
Michael D. Liebman, P.E.	Foth & Van Dyke
Erik A. Silvola	Foth & Van Dyke
Dr. Mark Stewart, P.G., Ph. D.	University of South Florida
Vladimir Straskraba	Hydro-Geo Consultants, Inc.
John E. Thresher, Jr. , Ph. C.	Thresher & Son, Inc.
Robert J. Windshauer, P.G.	Subsurface Detection Investigations, Inc.
Dr. Marek Zaluski, Ph.D.	Foth & Van Dyke

List of Acronyms

The following are acronyms commonly used in the EIR:

ADT	Average Daily Traffic
AADT	Average Annual Daily Traffic
ABA	Acid Base Accounting
ACR	Access Road
AFDC	Aid to Families with Dependent Children
AIRFA	American Indian Religious Freedom Act
ANSI	American National Standards Institute
AP	Acid Potential
APE	Area of Potential Effect
ARC	Area Research Center
ARD	Acid Rock Drainage
ASTM	American Society for Testing and Materials
ATV	All Terrain Vehicle
BACT	Best Available Control Technology
BEJ	Best Engineering Judgement
BOD	Biochemical Oxygen Demand
BP	Before Present
BTU	British Thermal Unit
CAA	Clean Air Act
CCRG	Commonwealth Cultural Resources Group, Inc.
CDM	Camp, Dresser & McKee
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMC	Crandon Mining Company
CPCN	Certificate of Public Convenience & Necessity
CSMRI	Colorado School of Mines Research Institute
CTH	County Trunk Highway
CWA	Clean Water Act
dB	Decibel
dBA	A - Weighted Decibel
DILHR	Wisconsin Department of Industry Labor and Human Relations
DO	Dissolved Oxygen
DRI	Denver Research Institute
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EMC	Exxon Minerals Company
EMS	Emergency Medical Service
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
FCP	Forest County Potawatomi
FAA	Federal Aviation Administration
FCTR	Forest County Tax Rolls
FEIS	Final Environmental Impact Statement
GLARC	Great Lakes Archaeological Research Center
GLIFWC	Great Lakes Indian Fish & Wildlife Commission

gpd	gallons per day
gpm	gallons per minute
HDPE	High Density Polyethylene
HES	Hazelton Environmental Services
HUD	United States Department of Housing and Urban Development
IEP	Interdisciplinary Environmental Planning, Inc.
IGWMC	International Ground Water Modeling Center
Ldn	Day-Night Average Sound Level
L_{eq}	Equivalent Sound Level
M	Million
MCD	Minor Civil Division
MIFB	Mining Impact Fund Board
MILIF	Mining Investment and Local Impact Fund
MILIFB	Mining investment and Local Impact Fund Board
MITW	Menominee Indian Tribe of Wisconsin
mL	Milliliter
MME	Metallic Mineral Exploration
MSHA	Mine Safety and Health Administration
MSL	Mean Sea Level
MWDF	Mine Waste Disposal Facility
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NCWRPC	North Central Wisconsin Regional Planning Commission
NHPA	National Historic Preservation Act
NLS	Northern Lake Service
NNP	Net Neutralization Potential
NOI	Notice of Intent to Collect Data
NP	Neutralization Potential
NPC	Normal Portland Cement
NPT	Net Proceeds Tax
NRHP	National Register of Historic Places
ORW	Outstanding Resource Water
pcf	pounds per cubic foot
PM	Particulate Matter
PM10	Particulate Matter less than 10 microns in diameter
PS	Plant Site
PSC	Public Service Commission of Wisconsin
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PVC	Polyvinyl Chloride
PWC	Practical Worst Case
RFRA	Religious Freedom Restoration Act
RRS	Railroad Spur
SCC	Sokaogon Chippewa Community
SCIP	Small County Improvement Program
SCS	Soil Conservation Service
SDII	Subsurface Detection Investigations, Inc.
SHPO	Wisconsin State Historical Preservation Office
SIC	Standard Industrial Classification
SOS	Scope of Study

SPCS	State Plane Coordinate System
STH	State Trunk Highway
STS	STS Consultants, Ltd.
TCP	Traditional Cultural Properties
TCPI	Traditional Cultural Properties Investigation
TDS	Total Dissolved Solids
tpd	Tons Per Day
TSP	Total Suspended Particulate
TDEM	Time Domain Electromagnetic
TMA	Tailings Management Area
TPC	Tailings Pipeline Corridor
USCOE	U.S. Army Corps of Engineers
USCS	Unified Soil Clarification Systems
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USR	United States Route
UW-SP	University of Wisconsin-Stevens Point
VES	Visual Encounter Surveys
VOC	Volatile Organic Compounds
WAC	Wisconsin Administrative Code
WCRI	Woods Cultural Research, Inc.
WCS	Wetland Compensation Site
WDNR	Wisconsin Department of Natural Resources
WDOA	Wisconsin Department of Administration
WDOR	Wisconsin Department of Revenue
WisDOT	Wisconsin Department of Transportation
WGNHS	Wisconsin Geological and Natural History Survey
WPDES	Wisconsin Pollutant Discharge Elimination System
WPSC	Wisconsin Public Service Corporation
WWDC	Wisconsin River Wastewater Discharge Corridor

Glossary of Terms

The following technical terms used in the EIR for the Crandon Project have the following definitions:

Term	Definition
A-Weighted	Refers to a filtering of the noise signal to emphasize frequencies in the middle of the audible spectrum and to deemphasize low and high frequencies in a manner corresponding to the way the human ear perceives sound.
Acoustical	Pertaining to hearing or sound.
Algae	A class of plants including microscopic, single-celled, and more complex, multi-celled organisms, such as seaweed, occurring in water or on land.
Alluvium	Deposits of sedimentary material like clay, silt, sand, gravel, or similar detrus laid down in river beds, flood plains, lakes or at the foot of mountain slopes.
Amphibian	Cold-blooded vertebrate animals with gilled larvae but air-breathing adults.
Anaerobic	The absence of oxygen.
Aneurin	Frogs and toads. An order of amphibians "without tails".
Annulus	The space between the wall of a borehole or inner casing and the outside of the monitoring well casing or well screen.
Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs. As used in this report, it includes both fine and coarse grained stratified drift.
Archaeology	The study of historic or prehistoric areas or peoples by analysis of their artifacts and other remains.
Artifact	An object made by man to be used for some purpose.
Argillite	A compact rock, derived either from mudstone (claystone or siltstone) or shale, that has undergone a somewhat higher degree of induration than is present in mudstone or shale but that is less clearly laminated than, and without the fissility of, shale, or that lacks the cleavage distinctive of slate.
Argillization	Development of clay minerals in rock adjacent to mineral veins.
Asbestiform	Mineral that is fibrous, like asbestos.

Assay — To analyze a material or mineralization for the purpose of determining constituents.

Avian — Pertaining to birds.

Basalt — A general term for dark-colored mafic igneous rocks, commonly extrusive but locally intrusive (for example, as dikes) composed chiefly of calcic plagioclase and clinopyroxene; the fine grained equivalent of gabbro.

Basal till — Glacial till deposit found on the bedrock surface.

Batholith — A large, generally discordant plutonic mass that has more than 40 square miles of surface exposure and no known floor. Its formation is believed by most investigators to involve magmatic processes.

Bedrock — Solid rock forming the earth's crust, frequently covered by overburden or water.

Benchmark — A permanent natural or artificial object with a known elevation. Used by surveyors to determine other elevations.

Benthic — All bottom terrain, from a shoreline to the greatest depth of a water body.

Boomshocking — Use of an electric shocking device, mounted on a long pole, to collect live fish.

Breccia — A coarse grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine grained matrix, originating by igneous, or volcanic processes.

C-Weighted Scale — A frequency network which corresponds to the C Scale on a standard sound level meter. The C Scale provides even responses through the entire audible spectrum.

Carnivorous — Flesh-eating.

Chert — A hard, extremely dense or compact, dull to semi-vitreous, microcrystalline sedimentary rock, consisting dominantly of interlocking crystals of quartz; it may contain amorphous silica (opal). It may be an original organic or inorganic precipitate or a replacement product.

Cherty — Containing chert (for example, "cherty" limestone).

Chlorite — A group of platy, monoclinic, usually greenish minerals of the general formula (Mg, Fe^{+2}, Fe^{+3}) $6A1Si_3O_{10}(OH)_8$. It is characterized by prominent ferrous iron and by the absence of calcium and alkalis. Chromium and manganese may be present. Chlorites are associated with and resemble the micas. They may also be considered as clay minerals.

Chloritic — Containing chlorite.

Colluvial	Consisting of rock fragments and soil.
Colluvium	(a) A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downward creep, usually collecting at the base of gentle slopes or hillsides. (b) Alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope.
Concentrate	A product containing the valuable minerals and from which most of the waste material in the ore has been eliminated.
Concentrator	A particular type of milling plant that produces a concentrate of valuable minerals.
Core	A long cylinder of rock one inch or more in diameter that is recovered by diamond drilling.
Crosscut	A small passageway driven at right angles to a main entry to connect it with a parallel entry or air course.
Crusher	A machine for crushing rock or other materials.
Decibels	A logarithmic unit which expresses the ratio between two sound pressures. A ratio of 10 in root-mean-square pressure corresponds to a difference of 10 decibels.
Demographics	Population statistics.
Development	The underground work carried out for the purposes of reaching and opening up a mineral deposit. It includes shaft sinking, cross cutting, drifting and raising.
Diamond Drilling	The act or process of drilling boreholes using bits inset with diamonds as the rock-cutting tool.
Dike	A discordant tabular body of igneous rock that was injected into a fissure when molten, that cuts across the structure of the adjacent country rocks, and which usually has a high angle of dip.
Dip	The angle that a structure surface (for example, a bedding or fault plane) makes with the horizontal, measured perpendicular to the "strike" of the structure and in the vertical plane.
Discharge Water Body	A body of water that receives a portion of its flow from the groundwater system.

Dolomite (a) A common rock-forming rhombohedral mineral: $CaMg(CO_3)_2$; commonly is white, colorless, or tinged yellow, brown, pink, or grey. Part of the magnesium may be replaced by ferrous iron and less frequently by manganese. (b) A carbonate sedimentary rock more than 50 percent by weight of the mineral dolomite or approximating the mineral dolomite.

Drift (Geology) A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. Drift includes unstratified material (till) that forms moraines, and stratified deposits that form outwash plains, eskers, kames, glaciofluvial sediments, etc.

Drift (Mining) A horizontal passage underground that follows along the length of a vein or rock formation.

Drumlin A low, smoothly rounded, elongate oval hill, mound, or ridge of compact glacial till or, less commonly, other kinds of drift (sandy till, varved clay), built under the margin of the ice and shaped by its flow, or carved out of an older moraine by readvancing ice. Its longer axis is parallel to the direction of movement of the ice. It usually has a blunt nose pointing in the direction from which the ice approached, and a gentler slope tapering in the other direction.

Endangered Species Species, listed by a federal or state agency, that are in danger of extinction throughout all or significant portions of their ranges.

Esker A long, narrow, sinuous, steep-sided ridge composed of irregularly stratified gravel and sand that was deposited by a subglacial or englacial stream flowing between ice walls or in an ice tunnel of a stagnant or retreating glacier, and was left behind when the ice melted. It may be branching and is often discontinuous, and its course is usually at a high angle and to the edge of the glacier.

Eutaxitic Refers to the banded structure of certain volcanic rocks, which results in a streaked or blotched appearance.

Evapotranspiration Loss of water from a land area through plant transpiration and soil evaporation.

Flotation A milling process by which selected mineral particles are induced to become attached to bubbles that float. In this way valuable minerals are concentrated and separated from the worthless gangue.

Flow (a) A mass movement of unconsolidated material that exhibits a continuity of motion and a plastic or semi-fluid behavior resembling that of a viscous fluid. Water is usually required for most types of flow movement. (b) The mass of material moved by a flow.

Fold A curve or bend of a planar structure such as rock strata, bedding planes, foliation, or cleavage. A fold is usually a product of deformation although its definition is descriptive and not generic and may include primary structures.

Footwall The underlying side of an ore body or mine working.

Fracture The character or appearance of a freshly broken surface of a rock or a mineral.

Gabbro A group of dark-colored, basic intrusive igneous rocks composed principally of basic plagioclase (commonly labradorite or bytownite) and clinopyroxene (augite), with or without olivine and orthopyroxene; also, any member of that group. It is the approximate intrusive equivalent of basalt.

Galena A lead sulfide.

Gangue The worthless minerals associated with valuable minerals in an ore deposit.

Geology The science concerned with the study of rocks which compose the earth.

Glacial Outwash See outwash.

Glacial Till Non-sorted, non-stratified sediment deposited directly by a glacier.

Gneiss A foliated rock formed by regional metamorphism, in which bands or lenticles of granular materials alternate with bands or lenticles in which minerals having flaky or elongate prismatic habits predominate. Generally less than 50 percent of the minerals show preferred parallel orientation. Although a gneiss is commonly feldspar - and quartz-rich, the mineral composition is not an essential factor in its definition.

Gossan Oxidized sulfide.

Granitic Pertaining to or composed of granite.

Granodiorite A group of coarse grained plutonic rocks intermediate in composition between quartz diorite and quartz monzonite, containing quartz, plagioclase, and potassium feldspar, with biotite, hornblende, or, more rarely, pyroxene, as the mafic components; also, any member of that group; the approximate intrusive equivalent of rhyodacite.

Greenstone Belt Term applied to elongate or beltlike areas within Precambrian shields that are characterized by abundant "greenstone", which are any compact dark-green altered or metamorphosed basic igneous rock that owes its color to the presence of chlorite, actinolite, or epidote.

Greywacke	An old rock name that has been variously defined but is now generally applied to a dark grey firmly indurated coarse grained sand that consists of poorly sorted angular to sub-angular grains of quartz and feldspar, with a variety of dark rock and mineral fragments imbedded in a compact clayey matrix having the general composition of slate and containing an abundance of very fine grained illite, sericite, and chloritic minerals.
Groundwater Table	The subsurface boundary between the saturated and unsaturated zones.
Grouting	The act or process of injecting grout into crevices of a rock, usually through a borehole drilled into the rock to be grouted.
Habitat	The environment which supplies the life needs of a plant or animal.
Hanging Wall	The overlying side of an ore body or mine working.
Hoist	A drum on which hoisting rope is wound in an engine house.
Host Rock	The wall rock of an epigenetic ore deposit.
Hydraulic Gradient	The rate of change of total groundwater head per unit of distance of flow in a given direction.
Hydric	Refers to a soil subject to relatively consistent saturation.
Hydrophydic	Pertaining to a plant that grows in water or in wet soil conditions.
Intermittent	Alternately ceasing and starting again. A stream or lake where water flows only part of the time.
Intrusion	The process of emplacement of magma in pre-existing rock; magmatic activity; also, the igneous rock mass so formed within the surrounding rock.
Jaw Crusher	A primary crusher designed to reduce large rocks or ore to sizes capable of being handled by any of the secondary crushers.
Kame	A low mound, knob, hummock, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a superglacial stream in a low place or hole on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice.
Kame Terrace	A terracelike ridge consisting of stratified sand and gravel formed as a glaciofluvial or glaciolacustrine deposit between a melting glacier or a stagnant ice lobe and a higher valley wall or lateral moraine, and left standing after the disappearance of the ice. A kame terrace terminates a short distance downstream from the terminal moraine; it is commonly pitted with kettles and has an irregular ice-contact slope.

Kettle (Geology)	A depression in glacial outwash, formed by the melting of a detached block of ice which was buried in the outwash.
Lacustrine	Pertaining to lakes. As used in this report, it refers to both glacial and recently deposited soil, usually fine grained, deposited at the bottom of lakes.
Lapilli	Volcanic ejecta that may be either essential, accessory, or accidental in origin, of a size range from 4 to 32 mm (0.16 to 1.25 inches).
L_{dn}	The L_{dn} is the time average of all A-weighted levels for a 24-hour period with a 10dB upward adjustment added to the night time levels (2200 to 0700). This adjustment is an effort to account for the increased sensitivity to night time noise events.
Leaching	The extraction or selective removal of soluble constituents from an ore or rock by slowly percolating water.
L_{eq}	The L_{eq} is the equivalent steady-state A-weighted sound level that would contain the same acoustical energy as the time-varying A-weighted sound level during the same time interval.
Lithology	The character of a rock formation.
Littoral	Occurring near the shoreline.
L_n	The statistical A-weighted noise level exceeded a given percentage of the time.
Macrophyte	Large vascular plants.
Macroinvertebrates	Macroscopic animals without backbones.
Mean	Average.
Metallurgy	The science and technology of metals.
Metric Tonne	A metric tonne equals 1,000,000 grams. Its approximate U.S. equivalent is 1.1 tons.
Mill	An establishment for reducing ores by other means than smelting. A place or machine in which ore or rock is crushed.
Mineralization	The process taking place in the earth's crust resulting in the formation of valuable minerals or ore bodies.
One Hundred Year Flood	The flood elevation of a river, such that the level is encountered, on the average, only once every 100 years.

Ore	A natural mineral compound of the elements of which at least one is metal.
Ore body	A volume of rock containing extractable mineral commodities which can be mined and sold at a profit.
Ore reserves	The term usually restricted to ore of which the grade and tonnage have been established with reasonable assurance by drilling and other means.
Ornithology	The study of birds.
Outwash	(a) Stratified detritus, chiefly sand and gravel, removed or "washed out" from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of an active glacier. The coarser material is deposited nearer to the ice. (b) The meltwater from a glacier.
Overlap	A general term referring to the extension of marine, lacustrine, or terrestrial strata beyond underlying rocks whose edges are thereby concealed or "overlapped," and to the unconformity that commonly accompanies such a relation; especially the relationship among conformable strata such that each successively younger stratum extends beyond the boundaries of the stratum lying immediately beneath.
Oxidation	A reaction in which the atoms in an element lose electrons and the element's valence is correspondingly increased.
Palustrine	Pertaining to material deposited in a swamp environment.
Perched	Water separated from an underlying groundwater table, or phreatic surface, by an unsaturated zone.
Perched Lake	A lake separated from the underlying groundwater table, or phreatic surface, by an unsaturated zone.
Permeability	The capacity of rock or soil to transmit water.
pH	The unit used to indicate the acidic-basic balance of a substance.
Piezometer	A special type of groundwater observation well, finished so as to permit the measurement of the water level in a particular stratum or zone. Groundwater observation well sealed into a particular soil or rock stratum used to measure groundwater head or hydrostatic pressure.
Pillar	An area of coal or ore left to support the overlying strata or hanging wall in a mine.
Pitted Outwash Deposits	Deposits of outwash (see outwash) with pits or kettles, produced by the partial or complete burial of glacial ice by outwash and the subsequent thaw of the ice and collapse of the surficial materials.

Pleistocene	A period starting about one million years ago, characterized by widespread glacial ice and the appearance of humans.
Porphyritic	Refers to the texture of an igneous rock in which large crystals (phenocrysts) are set in a finer grained ground mass, which may be crystalline or glassy or both. Also, said of a rock with such texture, or of the mineral forming the phenocrysts.
Potentiometric Surface	An imaginary surface representing the total head of groundwater and defined by the level to which water will rise in a well.
Potentiometric Surface Map	Subsurface contour map showing the elevation of the potentiometric surface.
Precambrian	Pertaining to the earliest era in which the earth's crust was formed.
Prehistoric	Prior to recorded history.
Pyrite	Iron disulfide, (FeS_2).
Pyroclastics	A general term for a deposit of pyroclasts. A pyroclast is an individual particle ejected during a volcanic eruption. It is usually classified according to size.
Raise	A vertical or inclined opening driven upward from a level to connect with the level above, or to explore the ground for a limited distance above one level.
Raptor	A species of predator birds with claws and bills adapted for seizing their prey.
Recharge Water Body	A body of water that supplies water to the groundwater system.
Recovery	The amount of metal per ton which is obtained from the treatment of ore.
Riffle	A shallow extending across a stream bed; a short rapid.
Rift	A long, narrow continental trough that is bound by normal faults.
Riverine	Pertaining to a river.
Saprolite	A soft, earthy, clay-rich, thoroughly decomposed rock.

Sericite	A white, fine grained potassium mica occurring in small scales and flakes as an alteration product of various aluminosilicate minerals, having a silky luster, and found in various metamorphic rocks (especially in schists and phyllites) or in the wall rocks, fault gouge, and vein fillings of many ore deposits.
Sericitic	Pertaining to or composed of sericite.
Shaft	An excavation of limited area compared with its depth, made for finding or mining ore or coal, raising water, ore, rock or coal, hoisting and lowering men and material, or ventilating underground workings.
Short Ton	A short ton equals 2,000 pounds and its metric equivalent is 0.907 metric tonne.
Skip	A guided steel hopper usually rectangular with a capacity from four to 10 tons and used in vertical or inclined shafts for hoisting ore or waste rock.
Stockpile	The ore and waste rock accumulated at the surface.
Stockwork	A mineral deposit consisting of a three-dimensional network of planar to irregular veinlets closely enough spaced that the whole mass can be mined.
Stope	An excavation from which ore has been excavated in a series of steps.
Stratified Drift	Synonymous with glacial outwash.
Strike	The direction or trend taken by a structural surface (for example, a bedding or fault plane) as it intercepts the horizontal.
Subcrop	The top of bedrock immediately beneath the glacial overburden.
Sulfide	A compound of sulfur with more than one element.
Tailings	Ground rock remaining after the removal of metals from ore.
Terminal Moraine	The end moraine, extending across a glacial valley as an arcuate or crescentic ridge, that marks the farthest advance or maximum extent of a glacier or ice sheet. It is formed at or near a more or less stationary edge, or at a place marking the cessation of an important glacial advance.
Thickener	A vessel or apparatus for reducing the proportion of water in a slurry.
Threatened Species	Species, listed by a federal or state agency, which are likely to become endangered unless measures are taken to restore the population.

Till	A very poorly sorted mixture of gravel, sand, silt, and clay that was deposited by glacial ice without reworking by meltwater or gravity flow. Dominantly unsorted and unstratified drift, generally unconsolidated, deposited directly by the underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.
Tremie Pipe	Usually a small diameter pipe used to conduct bentonite or grout into the borehole annulus.
Tuff	A rock formed of compacted volcanic fragments, generally smaller than 4 mm (0.16 inch) in diameter.
Type I Waste Rock	Waste rock that will not produce acid rock drainage and will leach only minute quantities of substances.
Type II Waste Rock	Waste rock that will produce acid rock drainage and/or will leach greater quantities of substances.
µg/g	Microgram per gram; equivalent to parts per million (1/1,000,000).
µg/L	Microgram per liter; equivalent to parts per billion (1/1,000,000,000).
Varves	A series of thin layers of soil representing seasonal sedimentation typically found in lacustrine deposits.
Watershed	The contained area which drains by gravity into a given river.
Watertable	See Groundwater Table.
Weathering	The group of processes, such as the chemical action of air and rainwater and of plants and bacteria, and the mechanical action of changes of temperature, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.
Wetlands	An area were water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions.

Crandon Mining Company

Environmental Impact Report

Section 1

Introduction

Crandon Mining Company
Environmental Impact Report

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1 Introduction 1

Crandon Public Library
104 South Lake Avenue
Crandon, WI 54520

Forest County Board
County Clerks Office
200 East Madison Street
Crandon, WI 54520

Forest County Potawatomi
P. O. Box 340
Crandon, WI 54520-0340

Lincoln, Town of
Route 2, P. O. Box 9
Crandon, WI 54520-0009

Menominee Indian Tribe of Wisconsin
P.O. Box 910
Keshena, WI 54135

Nashville, Town of
Star Route, P. O. Box 52
Pickerel, WI 54465-0052

Sokaogon Chippewa Community
Mole Lake Band
Route 1, P. O. Box 625
Crandon, WI 54520-0625

U.S. Army Corps of Engineers
St. Paul District
190 5th Street East
St. Paul, MN 55101

Wisconsin Department of Justice
Public Inventor's Office
123 West Washington Avenue
Madison, WI 53703

The EIR is organized into four major sections in addition to the Introduction (Section 1). These are Section 2, Project Description; Section 3, Description of the Environmental Setting; Section 4, Environmental Impacts; and Section 5, Mitigation of Impacts. Raw data and other supportive data bases are included in extensive appendices which are referenced in each section. Details of the EIR organization are included in the Table of Contents.

References used in the compilation of this EIR are included in a standard bibliographic format at the end of each major subsection. References generally available in the scientific literature are given as such. Reports written by consultants working on the EIR are generally referenced

as appendices attached to the EIR. Unpublished materials not attached as appendices to the EIR have been placed into the Crandon Project file at the WDNR, Madison, Wisconsin. Those referenced documents that were submitted to regulatory agencies, et.al., as part of the February 1994 NOI/SOS are identified in the bibliography by their NOI/SOS file reference number (e.g., CMC-NOI-1, etc.).

EIR appendices are ordered by section. The appendix identification number has been assigned by typically giving it the second level section number followed by a number to designate the individual appendix. For example, the first appendix to Section 3.5 (Geology and Soils) is Appendix 3.5-1; the second is Appendix 3.5-2, and so on. Tables generated from new data collected for the project in 1993, 1994 and 1995 are labeled numerically. For instance, the first table in Appendix 3.5-1 is labeled as Appendix 3.5-1 Table 1.

A glossary of commonly used terms, abbreviations and acronyms is provided in the front of the report, immediately preceding Section 1, Introduction.

Numbering of figures and tables is similar to that described above for appendices. Identification numbers have been assigned to figures and tables by giving them their second level section number followed by another number to designate the individual figure or table. For example, the first figure in Section 3.5 (Geology and Soils) is Figure 3.5-1; the second is Figure 3.5-2, and so on. Numbering of tables is the same as for figures. The first table in Section 3.5 is Table 3.5-1, etc. Figures are located at the end of each major section for ease of access.

CMC requests that the WDNR and USCOE initiate the following action on the documents being filed:

1. Begin preparation of a draft EIS for the proposed Crandon Project described in the EIR and Mine Permit Application.

2. Coordinate with appropriate federal and state agencies to assure that the EIR will be responsive to the needs of those agencies that have input regarding the proposed Crandon Project.

3. Review and approve all relevant permit applications, license applications, and similar documents regarding the proposed Crandon Project that are filed with and require approval of either or both the WDNR and USCOE.

Crandon Mining Company

Environmental Impact Report

Section 2

General Project Description

Crandon Mining Company
Environmental Impact Report

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1 Introduction

The Crandon deposit was discovered in the mid-1970s using airborne geophysical techniques and exploratory drilling. The deposit is located approximately five miles south of Crandon, Wisconsin. Its size and quality of mineralization has been determined by core holes drilled from the surface.

In 1978, Exxon Minerals Company (EMC) submitted to the Wisconsin Department of Natural Resources (WDNR) a Notification of Intent (NOI) to collect data to support a mining permit application for its Crandon zinc and copper deposit. During the mid-1980s, EMC or its successor company submitted the following major documents or applications to the WDNR: EIR, Mine Waste Disposal Facility Feasibility Report, Mine Permit Application, Air Permit Application, Wisconsin Pollutant Discharge Elimination System Permit Application, High Capacity Well Approval Applications Mine Refuse Disposal Facility Feasibility Report, Chapter 30 and 31 permit applications, and supporting documents. Additional permit applications and plan approvals were submitted by EMC to the Wisconsin Department of Transportation (WisDOT) and local units of government, and to the Public Service Commission of Wisconsin (PSC) by Wisconsin Public Service Corporation. In late 1986, the WDNR issued a Final Environmental Impact Statement (FEIS) regarding the proposed project. Subsequently, EMC withdrew its permit applications due to depressed metal pieces.

In the fall of 1993, subsidiaries of Exxon Corporation and Rio Algom Limited formed Crandon Mining Company (CMC), a Wisconsin general partnership, with the intent to permit and develop the Crandon Project. As described in greater detail in Section 2 of this document, the deposit will be mined and reclaimed in a similar fashion to that proposed in the 1980s, with the exception that the production rate will be reduced to 5,500 TPD. The current project has been modified to meet or be better than current day environmental standards and to incorporate design changes to improve environmental protection.

In February 1994, CMC filed its *Notice of Intent to Collect Data and Detailed Scope of Study* (NOI/SOS) with the WDNR in accordance with NR 132.05. The scope of study that was included in the NOI/SOS outlined the breath of existing information to be used and the proposed scope of additional environmental studies planned for the project. The WDNR invited and received extensive written comments on the NOI/SOS, and conducted a public hearing in Crandon on April 23, 1994. Subsequent to the public hearing, the WDNR issued comments on the proposed scope of study. Additionally the U.S. Army Corps of Engineers (USCOE) collected written comments and held two scoping meetings (January 31 and February 7, 1995) to gather public input on the Project. All comments have been carefully evaluated by CMC, and the project's scope of study has been modified to address the comments as appropriate.

This EIR is a compilation of relevant past and current environmental studies and related investigations pertaining to the permitting of the Crandon Project. It has been prepared in order to fulfill the requirements of the mine permitting process in the state of Wisconsin as defined in NR 132 and NR 150 of the Wisconsin Administrative Code (WAC) and to support the permit application submitted to the USCOE, St. Paul District, which has been requested to grant a permit under Section 404 of the Federal Clean Water Act. This EIR provides the environmental information that the St. Paul District needs to meet its responsibilities under the National Environmental Policy Act.

In addition to the EIR, CMC is filing a Mine Permit Application to the WDNR pursuant to NR 132 which provides a detailed description of the proposed mining operation. Other major permit applications and documents being submitted in connection with this mining proposal, and in accordance with the applicable portions of the Wisconsin and federal regulations, include, but are not limited to, the following:

- Air Pollution Control Permit Application
- Industrial Wastewater Treatment Plant Permit Application
- Wisconsin Pollutant Discharge Elimination System Permit Application
- Groundwater Withdrawal Permit Application
- Water Regulatory Permits under Wisconsin Statutes Chapters 30 and 31
- Water Regulatory Permit under Section 404 of the Federal Clean Water Act
- Feasibility Report and Plan of Operation for the Tailings Management Area

Each of these documents provides information concerning the proposed project as it pertains to the particular permit or approval referenced. This EIR is intended to provide background and supplementary environmental information that will be useful to the public and the regulatory agencies in their decision-making process regarding all of the above permits and approvals. These documents cross-reference each other where necessary. For these reasons, the EIR and the above-referenced documents should be reviewed together as a comprehensive presentation of the scope of the entire project.

Additional, other background documents and file information are available to the regulatory agencies and the public. These documents and file information were previously provided to the WDNR and USCOE as part of the February 1994 NOI/SOS submittal. The files are available for review at the following locations:

Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
101 South Webster Street
Madison, WI 53707

Wisconsin Department of Natural Resources
107 Sutcliff Avenue
Rhinelander, WI 54501

Ainsworth, Town of
Audrey Viola, Clerk
N10446 Hwy 55
Pearson, WI 54462

Antigo Public Library
404 Superior Street
Antigo, WI 54409

Crandon, City of
601 West Washington Street
Crandon, WI 54520

2 General Project Description

The main elements of the Crandon Project consist of an underground mine; ore concentrating facilities; water treatment facilities; a tailings management area; a water discharge pipeline and ancillary facilities such as an access road, a railroad spur line, and service and support facilities. An extensive description of the project is included in the Mine Permit Application. Following is a brief overview describing the entire project. The overview discusses the location of the mining facilities, the geology of the ore body, the mining process and the major project components which will be developed to operate and reclaim the proposed project in a manner which protects public health, safety, and the environment. The relative location of the project is shown on Figure 2-1.

The anticipated rate of production, project life and projected employment requirements for the project are shown in Table 2-1. As with any industrial operation, the life of the facility could change based on economic conditions.

Table 2-1

Anticipated Production and Operation Data

Daily Ore Production	5,500 tons
Annual Ore Production	2,000,000 tons
Total Ore Production	55,000,000 tons
Total Estimated Project Life	35 years
Preproduction	3 years
Mining	28 years
Reclamation	4 years
Production Schedule	7 days/week
Employment (estimates)	
Construction (Peak)	750
Operations	402-526

Prepared by: PAE
Checked by: JWS

Within this section there are numerous references to the "project area", "mine site", "plant site" and the "tailings management area". These terms have specific meanings as follows.

- Project Area - The project area is defined by the boundaries delineated on Figure 2-2.
- Mine Site - The mine site is defined by the limits of disturbance of project facilities within the project area.

- Plant Site - The plant site is generally defined as the area within the mine site that includes all mining, processing, concentrating, water treatment, administrative, and storage facilities; portions of the railroad spur in the vicinity of the plant site; portions of the access road in the vicinity of the plant site; ventilation raises; and the project's water supply well and its accompanying pipeline corridor. The plant site also includes all surface water runoff and storage basins constructed in its vicinity.

- Tailings Management Area (TMA) - The "TMA" is defined as the area within the "mine site" that includes the project's four tailings cells and berms, the reclaim pond, the tailings and reclaim water pipeline and access road corridors, and contiguous borrow and storage areas. The TMA also includes all surface water drainage facilities constructed in its vicinity.

Two additional areas located outside of the project area include the narrow corridor from the intersection of the site access road and State Trunk Highway (STH) 55 to the Wisconsin River in which the project's treated water discharge line is to be located, and the project's wetland mitigation site located off-site in Shawano and Oconto Counties. Design information for the discharge pipeline to the Wisconsin River is included as part of the water treatment system engineering report prepared pursuant to Wisconsin Administrative Codes. Design information relative to the wetland mitigation site is included as part of the Federal Clean Water Act Section 404 permit application. For completeness the description of the environmental aspects associated with these areas are included in the project's EIR.

The boundaries of the project area, plant site and TMA are shown on Figure 2-2. The plant site and the TMA are approximately 128 acres and 355 acres in size, respectively. The total area of disturbance, including the access road and railroad spur, is approximately 550 acres.

2.1 Site Location

The Crandon ore body is located in Forest County, Wisconsin. The civil land survey location is Section 25, Township 35 North, Range 12 East, Town of Nashville, and Section 30, Township 35 North, Range 13 East, Town of Lincoln. The project area is located five miles south of the City of Crandon and two miles east of STH 55 and the Mole Lake Indian Reservation. The plant site is approximately one-quarter mile north of Little Sand Lake and one mile south of Swamp Creek. The primary mine surface facilities, e.g., plant site, will be located north of the ore body. The proposed plant site layout is shown in Figure 2-3. Access to the plant site will be along a new access road from STH 55 northwest of the site. A railroad spur line serving the site will be connected northeasterly to the existing Wisconsin Central Limited Railroad. The project's TMA will be located approximately one mile southeast of the plant site.

The project area shown in Figure 2-2 includes those portions of property which CMC has purchased, leased, optioned for purchase or obtained by easements for use in the development of the plant site, TMA, access roads, railroad spur line and buffer areas.

2.2 Geology

The Crandon deposit is composed of two distinct mineralization types, zinc ore and copper ore. The minerals were deposited during the Precambrian era, about 900 to 2,500 million years ago.

The deposit was formed at and just below the ocean floor by mineral bearing fluids of volcanic origin. Some of the material deposited by this volcanic system was sulfide minerals which accumulated in low spots on the ocean floor. Continued accumulation of other volcanic materials and sediments occurred which buried the sulfide deposit. Deep burial, 33,000 to 50,000 feet, resulted in lithification and metamorphism which hardened and solidified both the host rock and the sulfide deposit over time. Later, a mountain building phase occurred in the region, tilting the volcanic layers and the deposit to a near vertical position. Thereafter, the deposit may have been covered by younger sediments, however weathering and erosion have removed these later rocks. The more recent geological process which has affected the deposit is related to Pleistocene glaciation which left the bedrock buried under unconsolidated glacial overburden deposits.

The Crandon ore body is long and tabular with an approximate width of 100 feet, north-south, and a strike length of 4,900 feet, east-west. Based on the results of drilling, the ore body extends to an approximate depth of 2,200 feet. The interpreted geologic stratigraphy and ore body configuration are shown on Figures 2-4 and 2-5 respectively.

The bedrock in the hanging wall and in the footwall of the ore body consists of a series of fragmental volcanic rocks, fine tuffs (solidified volcanic ash), debris flow (ocean floor and volcanic-derived sediments), breccia (blocky, angular particles), lapilli tuffs (gravel sized volcanic material) and flows. Overlying the bedrock is a sequence of unconsolidated glacial sands, clays, and gravels. The rock in contact with the unconsolidated glacial overburden is weathered to varying degrees. The amount of weathering ranges from simple staining to extreme weathering near the surface which reduced the rock to a clay-like material called massive saprolite. The glacial overburden consists of interbedded and co-mingled glacial till, which is material deposited directly by the glacier, and glacial outwash deposited by streams emanating from the glacier. These glacial deposits are found in various thicknesses in the area ranging from 75 feet to over 250 feet thick.

2.3 Key Project Elements

2.3.1 Mine Development

Access to the mine will be through a main production/service shaft located north of the ore body. The first of two ventilation shafts will be located east of this main production shaft. Underground lateral development drifts will access the ore body from the main shaft at 300 foot vertical intervals. These level development drifts are designed to provide access to the ore body. The lateral extent of a mine level at a given point in time will depend upon the need for access to mining blocks, ore passes, and ventilation raises. A schematic longitudinal section showing a typical main level plan is shown on Figure 2-6.

An underground ramp will also connect mine levels to allow for movement of mobile equipment, supplies, and personnel throughout the mine. This centrally-located ramp is also shown schematically on Figure 2-6.

Mine development will be divided into the following phases:

1) Site preparation and the sinking of the main production shaft and the east ventilation shaft. This phase is expected to take 18 months to complete.

2) The development of the underground ore handling and crushing system, the development of the dewatering system, lateral development into the ore horizons and development of the initial mining blocks (stopes). An internal mobile equipment access ramp will connect the main production ore levels. This phase of mine development is also expected to take 18 months to complete.

As shown on Figure 2-6, mine development and production will begin in areas chosen to avoid weathered bedrock which are expected to be the primary conduits for water inflow into the mine workings.

2.3.1.1 Phase I Development

Phase I development primarily includes simultaneous construction of two vertical shafts in the hanging wall rocks. Each shaft will be concrete lined through the overburden and the weathered subcrop rock. Collar construction through the glacial overburden will include stabilization and hydraulic control by ground freezing or other suitable techniques, followed by the excavation and concrete lining of the shaft into bedrock. If required, inert grout will be pumped under pressure through holes in the collar into the rock and glacial formations to provide a watertight seal. When the collar section of the main shaft and east ventilation shaft are completed, a headframe structure will be erected over each shaft. Conventional shaft sinking by drilling and blasting techniques will then commence at the main shaft and the east shaft concurrently.

During shaft development, it is estimated that the drainage water from both shaft sinkings will be controlled to less than ten gallons per minute (gpm) by grouting. All shaft water will be pumped to the surface water storage ponds.

2.3.1.2 Phase II Development

Because the east shaft is smaller than the main shaft, it will be completed sooner. Upon its completion, horizontal level development will consist of driving a horizontal opening in the hanging wall rock to connect the east shaft to the main shaft (Figure 2-6). After the two shafts are connected, level development can commence to access the ore body.

The underground ore handling facilities will be constructed near the main production shaft during this period. These facilities will consist of: (a) coarse ore and waste rock storage bins, (b) crusher facilities, (c) ore handling systems, and (d) a loadout facility.

2.3.2 Mine Operations

Level development from the main production shaft to the stoping areas will be driven at 300-foot vertical intervals. The primary mining method will be blasthole open stoping with delayed backfill. However, other mechanized variations, such as sublevel mining or cut-and-fill stoping methods may also be used. Stopes (Figure 2-7) will average approximately 300 feet high by 75 feet long, and will vary with the width of the ore body. Ore will be drilled in a stoping block, then blasted and removed. Top hammer or down-the-hole drills will be used to drill approximately four to six inch diameter blastholes on approximately 12-foot by 12-foot center spacing for production stope blasting. Broken ore will be removed from the drawpoints at the bottom of each stope using mechanized mining equipment which will then transfer the ore to the

crushing level below by means of ore pass raises. Primary crushed ore, at a top size of eight inches, will be conveyed to a skip loading pocket and hoisted to the surface.

A typical stope will contain approximately 250,000 tons of ore. At a 2,000,000-ton annual production rate, approximately eight stopes will be mined out each year, which exposes less than five percent of the footwall and hanging wall area of the ore body at any one time. Exact production parameters will be based on the grade of the ore in the mined stope; the mechanical characteristics of the rock in the stoping block; and the potential for inflow of water.

A permanent bridge, or crown pillar, of bedrock directly beneath the glacial overburden will be purposely excluded from mining activity. This bedrock barrier, averaging approximately 100 feet thick, along with the routine backfilling of mined-out stopes, will maintain surface stability and prevent subsidence.

In the uppermost mine levels where the ore and host rock may have been moderately weakened by surficial weathering, mechanized cut-and-fill mining may be employed. This method is commonly used by the industry and involves removal of horizontal lifts of ore of variable thicknesses. The void created by each horizontal mining pass is backfilled prior to mining the next upper lift. Less than 10 percent of the ore body may require use of this mining method.

The planned mining methods provide for backfilling all stopes following ore extraction. These practices, combined with the fact that five to 10 percent of the potentially minable ore will be left in place as pillars throughout the mine, will provide perpetual stability of the mine area bedrock and glacial overburden. Backfilling will also result in the reduction of pathways for water migration as mining progresses.

Mine backfilling will begin with the start of milling operations and after the first stope is depleted. The backfill will consist of mill tailings 10 to 15 micron or greater in size, supplemented with coarse waste rock retained underground. Uncemented tailings backfill will have a hydraulic conductivity on the order of 0.028 feet per day. The hydraulic conductivity of cemented tailings backfill will be lower. Backfill slurry containing approximately 60 to 70 percent solids will be pumped underground through boreholes fitted with distribution pipes. The backfilling operations will normally be conducted to coincide with the mining schedule.

Waste rock material from mine development will be used in the stope backfilling process and will be placed before or during the placement of hydraulic tailings fill. The hydraulically-placed fill will flow into and fill the voids between the rock fragments.

Cement will be added to the backfill when needed to provide stability so that the column of fill will stand unsupported and enable complete removal of the ore in the adjacent stope. Approximately one-third to one-half of the total backfill placed in the mine will contain cement.

2.3.3 Mine Dewatering and Groundwater Inflow Control

Groundwater inflow will vary during the different stages of mine construction and operation. The proposed mining plan for the Crandon Project avoids entry into weathered zones during the initial operations, therefore deferring maximum and steady state inflow rates. During the initial operations, groundwater inflow is expected to be minimal and localized, occurring through isolated bedrock fractures that have limited capacity to move water. During this period,

exploration holes will be advanced into the weathered bedrock areas to dewater them. The water removed in this fashion will primarily be stored water which will be withdrawn at rates that can be effectively managed at the project's water treatment plant. A more detailed description of this process follows.

As mine development progresses upward from the original mining areas (Figure 2-6), diamond drilling techniques will be used to identify active underground water courses prior to advancing the mine face. Diamond drill holes will be used throughout the mine to drain stored water. Flows encountered on the uppermost active mine level will be captured by interceptor drill holes and contained to avoid contamination by mining operations on levels below and to reduce pumping head. A conceptual cross-section of the groundwater interceptor system showing the collection methodology is presented in Figure 2-8. Standard rock grouting techniques, typically using neat cement, may also be used for local inflow control during the early mine years to limit total mine pumpage.

Typically, groundwater interception holes will form conical fans in the weathered rock above the development openings, thus increasing the radius of the drains. As is common practice in other mines, the drill hole collars will be fitted with valves to allow controlled water removal.

Groundwater collected from exploration drilling or other drill holes placed specifically for inflow interception will be routed directly to a clean water sump and pump station near the main shaft in the upper mine level. The collected groundwater will typically be pumped to the water treatment plant on the surface. However, a portion of the water may be retained underground for distribution as mine utility water.

Groundwater seepage that is not captured by the interceptor system will infiltrate the mine workings and ultimately be recovered in the main sumps along with the mine potable, utility and backfill drainage water. Normal mine drainage collection will begin on each mine level where groundwater seepage, utility water and backfill drainage will be ditched to small local sumps excavated in the drift wall. Decant water from the local mine level sumps will be piped or drained through boreholes or ditched to the main mine sumps located adjacent to the production shaft at the lowest level.

The main mine sumps and pump station will generally be arranged as indicated on Figure 2-9. Sumps will consist of downgrade excavations in the wall rock adjacent to the pump station. These will function as pumping reservoirs with an outlet end bulkhead containing the pump suction pipes.

2.3.4 Ore Processing

Ore mined from the Crandon deposit will be physically concentrated at the plant site by adding water to the crushed ore and grinding it to the size of fine sand particles. After grinding, the ore slurry will be pumped to a series of flotation circuits where reagents are added for separating metallic minerals from the ground-up ore. During this process, minerals will be selectively "floated" to the top of the flotation cells and removed. The remaining material, which is called tailings, will be either used as backfill in the mine or hydraulically transported to the TMA. Different flotation circuits require different reagents to concentrate specific individual minerals. A schematic of the ore processing circuits is shown on Figure 2-10. Separate concentrates of

zinc, copper and lead minerals will be recovered by the flotation process. The concentrate from these processes will be thickened and filtered to an eight to 10 percent moisture content.

The tailings will range in size from sand to very fine particles. The coarser tailings from the mineral separation circuits will be used to backfill the mined-out stopes. The finer fraction will be sent to the TMA.

In the TMA, the tailings will settle to the bottom of the lined basin. Excess water will then be pumped from the TMA basin to a reclaim pond for reuse in the ore processing facility. The ore concentration process, TMA, and reclaim pond are designed to operate as a closed circuit. The concentration process normally requires the continuous addition of "makeup" water. Water in this circuit will not require treatment because a discharge will not normally take place. The water treatment system will be designed to treat tailings pond waters for discharge, if necessary.

2.4 Infrastructure

Infrastructure features to support the mine and milling operations include a water treatment plant, ore and waste rock storage facilities, mining waste management facilities, access road, railroad spur line, electric power transmission lines, a natural gas pipeline, a treated water discharge pipeline, and ancillary buildings and storage facilities. A discussion of each follows.

2.4.1 Water Treatment

A water treatment plant will be constructed as part of the project facilities. It will treat mine water and, if needed, process water prior to discharge. Intercepted groundwater is expected to be representative of natural groundwater quality. If the monitoring of this groundwater indicates that the water quality is not suitable for direct discharge, it will be routed through the water treatment plant. Groundwater that bypasses the interceptor system and comes in contact with mining activities will be commingled with other mine drainage water, such as the water used to cool the drill bits while drilling the blast holes. All of these "contact waters" will be routed through the water treatment plant.

The water treatment plant will include a lime and sulfide precipitation system with filtration and pH adjustment. Treatment solids from this facility will be placed along with the ore processing tailings in the TMA. Mine water will be treated to meet WDNR Water Quality Standards before being discharged to the Wisconsin River via a discharge pipeline installed primarily along the U.S. Route 8 corridor (Figure 2-11).

The treatment system is designed with two holding ponds to retain the treated water so it can be sampled prior to discharge. This will ensure all water meets discharge standards, prior to discharge.

Sanitary water will also be generated at the facility. Sanitary water will be handled separately through a package sanitary water treatment plant. The treated effluent from this plant will be pumped to the TMA.

2.4.2 Mining Waste Management

Crandon Project mining wastes will include waste rock, tailings, refuse, water treatment plant solids, and laboratory wastes.

Over 50 percent of the waste rock generated by the project will be left in the mine to be used as backfill for mined-out stopes. Limited quantities of waste rock will be brought to the surface during preproduction and managed as discussed in Section 2.4.3 below. As discussed in Section 2.4.4 below, approximately 50 percent of the tailings generated by the project will be returned to the mine as backfill, with the remaining 50 percent placed in the TMA.

During the mining operations on-site laboratories will be used to conduct metallurgical testing for mining grade control and for production quality assurance testing related to milling operations. Wastes generated from the performance of these tests will be placed in the TMA. Approximately 900 cubic yards of general refuse such as office wastes will be generated at the facility each year during the 35 years of construction, operation and reclamation. The reclaimable portion of this waste will be recycled in accordance with state law. The remaining waste materials will be disposed of by a contractor in an approved off-site landfill.

Solids will be generated from the treatment of project generated waters. These solids will be placed in the TMA with the tailings.

2.4.3 Preproduction Ore/Waste Rock Storage Areas

Two storage areas will be located to the north of the main production shaft to store ore and waste rock hoisted to the surface during pre-production mine development. Prior to the commencement of underground crushing and the start of mill operations, approximately 1,050,000 tons of uncrushed ore and waste rock of a maximum size of 24-inches will be placed on the two separate areas. One storage facility which will be lined will be used to store approximately 350,000 tons of ore and about 100,000 tons of Type II waste rock. The remaining 600,000 tons of Type I waste rock will be deposited on an unlined area located east of the lined storage area. Type I waste rock is material that has a very low potential to leach, while Type II waste rock has a higher leaching potential. The lined area is designated as the preproduction ore storage area on Figure 2-3. The unlined area is referred to as the construction material storage area on the same figure. Both storage areas have been designed to accommodate the maximum potential amount of waste rock and ore hoisted from underground during the preproduction period and will occupy a total area of approximately 18 acres.

For the preproduction ore storage area a central ridge will divide the facility on its north-south axis. Each side of the lined pad will slope away from the center. The pad will be bounded by berms with runoff collection ditches which will route water to a lined water storage basin. The base of the pre-production ore storage area will consist of a compacted layer of existing soil overlain by a geomembrane liner. A till cushion will be placed over the geomembrane. Water from this area will be drained to a water storage basin. The location of the basin is sized to hold the volume of water from a 25-year, 24-hour storm event. Water from this basin will be either pumped to the TMA for use in ore processing or to the project's water treatment plant.

The base of the construction material storage area will consist of a compacted layer of existing on-site soil. The base will be sloped to drain toward another of the site's surface water runoff

basins. Water from this runoff basin will be discharged to natural site drainage ways. Following commencement of mill operations, the ore stored in the preproduction storage area will be processed. Type II waste rock stored in this area will be hauled by truck to the TMA for disposal or for use as riprap for TMA internal sidewalls. Type I waste rock will be used as construction material.

2.4.4 Tailings Management Area

All tailings produced by ore processing that are not used for mine backfill, hoisted Type II waste rock, water treatment plant solids and the small amount of laboratory wastes will be placed in the TMA. The TMA has been designed to provide long-term, environmentally-safe containment. Tailings and treatment plant solids will be pumped to the TMA through a high density polyethylene (HDPE) pipeline. Waste rock will be transported to the TMA by truck.

As shown on Figures 2-12 and 2-13, the TMA will consist of four cells, each of which will be lined and include a leachate collection system. The four cells, referred to as TMA1 through TMA4 will each be constructed and operated in two stages. TMA1 and TMA2 are designed to contain the tailings from processing the zinc ore. TMA3 and TMA4 will be used for the copper ore tailings. The approximate capacities and site lives for each cell are shown in Table 2-2.

Table 2-2

Approximate Tailings Management Area Capacity

TMA Cell	Capacity (in millions of cubic yards)	Approximate Site Life (years)
TMA 1	4.0	6
TMA 2	7.8	10
TMA 3	3.9	6
TMA 4	4.8	6
Total	20.5	28

Prepared by: PAE
Checked by: JWS

TMA cell construction and operation will first involve constructing and filling Stage 1 of TMA1. As the tailings in Stage 1 approach the design elevation, Stage 2 of TMA1 will be built. When approximately one to two years of capacity remain in TMA1, construction of Stage 1 for TMA2 will begin. When TMA1 is full, tailings placement in TMA2 will start. After consolidation, reclamation of TMA1 will begin, while filling in TMA2 progresses. The same process will continue for TMA3 and TMA4.

The tailings slurry will be transported from the concentrator building to the TMA through an approximate 16-inch inside diameter HDPE aboveground pipeline. The location of the pipeline is shown on Figure 2-2. The pipeline will lie above ground in a lined ditch. A 22-foot wide access road will be located next to the pipeline for service and maintenance. Pumps used for pumping the tailings slurry in the pipe will be located in the concentrator building. The pipeline ditch will be sloped to lined sumps located at the plant site and approximately midway between the plant site and the TMA to collect tailings and water in the event of leakage or to provide storage if the pipe must be drained.

The tailings slurry will be deposited in the active TMA cell using spigots. The spigot discharge point(s) will be regularly moved around the inner perimeter of the active cell to facilitate even distribution of tailings and to keep the tailings saturated. The excess water that drains from the slurry after the tailings have settled will flow to an area in the center of the cell and will be pumped to the reclaim pond. Water in the reclaim pond will be retained for a short time and then pumped to the mill for reuse in the process circuit. The tailings operating system is designed to maximize tailings density.

The TMA cells have been designed to meet the standards contained in applicable state statues and administrative codes which are written to protect the public health and welfare. Key TMA design features include:

- An average 43-foot separation from the base of the TMA to groundwater.
- A minimum 1,250-foot separation from the nearest lake or stream.
- A composite liner consisting of a low-permeability soil member and a geomembrane liner.
- A leachate collection system over the bottom of each cell and partially up the interior sidewalls of each cell.
- A reclaimed final cover consisting of the following components from top to bottom.
    - topsoil
    - rooting layer
    - drainage layer
    - geomembrane liner
    - low permeability soil liner
    - grading layer
- Surface water control structures designed to accommodate a 100-year, 24-hour storm event.

2.4.5 Access Roads

A site access road will be constructed from STH 55 to the plant site. A second access road will be constructed from the plant site to the TMA. The site access road will be approximately three miles long and consist of bituminous concrete with gravel shoulders. The treated water discharge

line will be buried in the right-of-way of the site access road. The TMA access road will be approximately one mile long and will be gravel-surfaced. Pipelines for tailings disposal and reclaim water will be sited adjacent to the TMA access road in a lined ditch.

2.4.6 Railroad Spur

A 2.7-mile railroad spur line will be constructed from the plant site to the Wisconsin Central Limited Railroad located to the northeast. The spur line will consist of a single track along most of its corridor. A side track will be located near the point where the spur line connects with the main railroad line. The sidetrack will be used for switching and rail car staging. The spur line will be used to bring cement, lime and other materials to the plant, and to ship concentrates to market. Concentrate will be shipped in enclosed cars or containers.

2.4.7 Utilities

Electrical service to the project site will be provided by Wisconsin Public Service Corporation (WPSC) by an electric transmission line constructed between an existing substation near Monico, Wisconsin, and a new substation to be located at the plant site. The substation near Monico will be upgraded by WPSC as part of the extension of electrical power for the project.

The WPSC area distribution system, which will likely be located near the south end of Lake Metonga, will supply natural gas for the project via a pipeline installed to the plant site. The pipeline route will follow existing county roads, cross Swamp Creek north of the plant site, and then follow the main plant access road into the site.

2.4.8 Other Facilities

In addition to the project elements discussed above other site facilities as listed below will be constructed and used as part of the project:

- Administrative offices
- Changehouse facilities
- Explosive storage areas
- Gate house
- Core logging and storage
- Covered storage area
- Truck weigh scale
- Fencing
- On-site roads
- Area lighting
- Surface maintenance shops
- Potable water supply and distribution system
- Fire protection systems
- Lubricant storage
- Bulk fuel storage
- Lay-down areas
- Railroad weigh scale
- Mobile equipment fuel station
- Parking areas
- Material storage areas

2.4.9 Surface Water Controls

Precipitation falling within the limits of the plant site will be collected and directed to one of a number of water storage basins. Contact runoff will be directed to the water treatment plant or to the TMA. Non-contact runoff will be directed to existing natural drainage features after passing through runoff basins. Precipitation falling within the TMA will co-mingle with process water and become part of the water used in the mill circuit. Some of the surface water drainage

originating from outside the active mining area will be intercepted by a series of drainage swales and directed to existing natural drainage features.

2.4.10 Wetland Mitigation

Although mine facilities have been designed to minimize impacts on wetlands, as part of project construction activities, approximately 29.5 acres of wetlands will be either excavated or filled. To compensate, CMC will develop replacement wetlands on a site located in Shawano and Oconto Counties. The selected site is in an area that was originally wetlands, but was converted to cropland. The establishment of the compensation site involves reconverting it from cropland back to wetlands.

2.4.11 Mine Reclamation

Topsoil will be salvaged and stored from all disturbed areas for use in reclamation activities. Reclamation of the mining site will occur on an ongoing basis during construction and operation, and as the final phase of the project. After mining, the area will be used for forestry and as open green space. During construction, disturbed soil areas will be revegetated on a continual basis such that wind and water erosion potential is significantly reduced. These areas will either be temporarily reclaimed or finally reclaimed depending upon their location relative to future construction activities.

Final reclamation of the plant site will begin after completion of mining. All open boreholes will be sealed in compliance with applicable regulations. Salvageable equipment from the mine will be brought to surface. Any equipment left underground will have potentially harmful fluids removed. The shafts to the mine will be sealed with reinforced concrete plugs. Surface facilities may be converted to other uses if possible. If other uses are not feasible, those facilities will be removed. The site area will be regraded and revegetated. Settling basins and ponds will be drained and the area reclaimed. Containment structures will be removed. Disturbed areas will be regraded and revegetated. The TMA will be reclaimed in phases during its lifetime. Final closure of the last cell of the TMA will occur late in the sequence of project reclamation.

The water treatment plant and associated pipelines will be removed after they are no longer required. Salvageable equipment will be transported off-site. Scrap and treatment solids will be placed in the TMA prior to closure of the final cell. Buried segments of pipelines will be purged and left in place. Above-grade pipelines will be removed. The water treatment plant area and pipeline routes will be graded and revegetated.

On-site roads, the plant site access road and the railroad spur line will be among the last items to be reclaimed. Reclamation of these features would be dependent upon the final site use. If no future use is anticipated, the construction materials will be removed. Bituminous pavement will be salvaged for use elsewhere, if possible, or placed in the TMA. Rail will be salvaged. The areas will be regraded and revegetated.

Utilities that service other customers along the route to the plant site will be left in place. The portion of the utilities that extend onto the plant site will be removed if above ground, or remain in service depending upon the final use of the site. Below ground piping will be flushed as required, capped and left in place, if no longer in service.

FIGURES FOR SECTION 2.0

2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E

125,000 N

120,000 N

115,000 N

110,000 N

PROJECT AREA BOUNDARY

PROPOSED RAILROAD SPUR

PROPOSED ACCESS ROAD

TMA BORROW SITE

PLANT SITE

TMA

RECLAIM POND

TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE

SKUNK LAKE

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

DEEP HOLE LAKE

WISCONSIN CENTRAL LIMITED RAILROAD

OUTLET CREEK

SWAMP CREEK

HEMLOCK CREEK

SHERWIN LN

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- 1075 EXISTING CONTOUR
- 1692.6 EXISTING SPOT ELEVATION
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	PAE	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 2-2
PROJECT AREA

Scale: 0 1000' 2000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JRB

93C049

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CRANDON
LINCOLN
LAONA
PLANT SITE NASH-VILLE
TMA
FREEDOM
AINSWORTH
ONEIDA CO. FOREST CO.
LANGLADE CO.
FOREST CO. LANGLADE CO.
Crandon
Nashville
Mole Lake
Laona
Blackwell
Padus
Wabeno
POTAWATOMI INDIAN RESERVATION
MOLE LAKE INDIAN RESERVATION
Lit. Rice L.
Whiteye L.
Pesntigo L.
Clear L.
Bug L.
Otter Spgs.
Dawson L.
Bobs L.
Scattered Rice L.
Lit. Birch L.
Birch
Langer L.
Purdy L.
Wablkon L.
Lit. Pine L.
Silver L.
Rat R.
Otter Cr.
N.B.N.
Whiting
Gruman Cr.
Camp
Metonga L.
Devils L.
Lake Lucerne
Wyman L.
Indian L.
Indian R.
Lit. Riley L.
Honey Cr.
Swanson
Camp 20
Shabo Cr.
Stony
Wolf R.
Mud R.
Gliske Cr.
Logan
Swamp
Hemlock
Bradley L.
Horseshoe L.
Skunk
Ground Hemlock L.
Mole L.
Oak L.
Duck L.
Sand L.
Spring L.
Lost L.
Deep Hole L.
Kimberly
Walsh
Clark L.
Cook L.
Jungle L.
St. Johns L.
Crawford L.
Rolling Stone
Berendsen L.
Agnes
Crane L.
Spider
Lost L.
Pickerel
Pickerel Lake
Hollister L.
Deadman
Tekakwitha
Horseshoe L.
Crystal L.
Arbutus L.
Grass L.
Mud L.
Deer
Bogbrook
Bk.
Windmill L.
Br. Lily R.
Glade L.
Campbell Cr.
Spgs.
Wayflower L.
Hardwood L.
Midget L.
Lit. Popple L.
Popple L.
Lit. Star L.
Eds L.
Lundington L.
Himley
Roberts L.
Richardson
Spring L.
Bass L.
Lit. Long L.
Zarling L.
Shoe L.
Roxy L.
Spring Pd.
Kohlhoff L.
Range Line
Torpe
Finnerty L.
Round L.
Woods L.
Ham L.
Kazlmer L.
Spencer
Swan
Trump L.
Eugene L.
Oconto
Torpe
Lit. Birch L.
Lit. Pine L.
Lit. Riley L.
Lit. Popple L.
Lit. Star L.
Lit. Long L.
Deep Hole L.
Mud Cr.
Swamp Cr.
Wolf R.
Mud R.
Rat R.
Otter Cr.
Indian R.
Br. Lily R.
Campbell Cr.
Gliske Cr.
Stony Cr.
Shabo Cr.
Camp 20 Cr.
Honey Cr.
Swanson Cr.
Range Line Cr.
Wabeno Cr.
Torpe Cr.
Swamp Cr.
Mud Cr.
Pickerel Cr.
Swamp Cr.
Skunk Cr.
Hemlock Cr.
Swamp Cr.
Swan Cr.
Cr.
R.
36
31
6

LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- (8) U.S. HWY NO.
- (47) STATE HWY NO.
- [W] COUNTY HIGHWAY LETTER
- NATIONAL & STATE FOREST BOUNDARY
- CORPORATE LIMITS
- UNINCORPORATED VILLAGE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

N

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
3. ADDITIONAL POTAWATOMI LANDS LOCATED TO THE EAST OF MAP COVERAGE.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	PAE	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 2-1
SITE LOCATION

Scale: 0 5000' 10,000 Date: MAY, 1995

Prepared By: Foth & Van Dyke By: BSH

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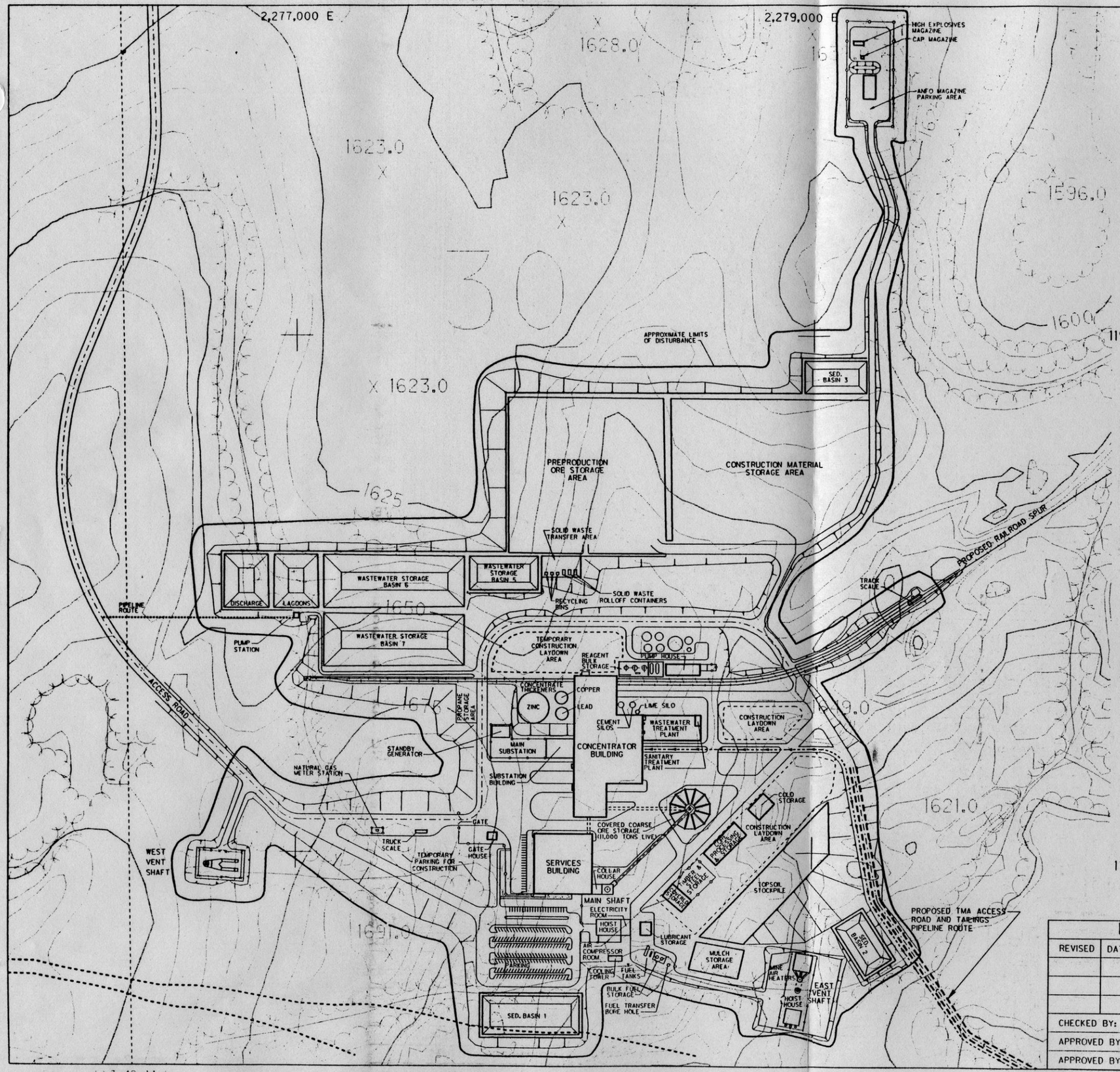
93C049



N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- —1675— EXISTING CONTOUR
- x 1692.0 SPOT ELEVATION
- ---------- SECTION LINE
- ORE BODY

SCALE
0 200' 400'

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1"=1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS FIVE FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.

TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE PRIOR TO CONSTRUCTION.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

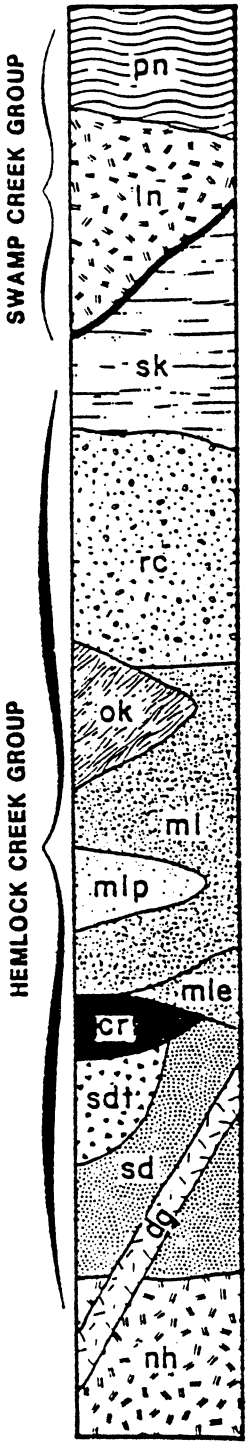
CHECKED BY:	JKSI	DATE: MAY.'95
APPROVED BY:	PAE	DATE: MAY.'95
APPROVED BY:	JWS	DATE: MAY.'95

Crandon Mining Company

FIGURE 2-3
PLANT SITE LAYOUT

Scale:	SEE BAR SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JRB2

93C049



PINE FORMATION (pn)
Cherty tuff and argillite.

LINCOLN FORMATION (ln)
Quartz porphyritic rhyolite flows with minor interflow tuff, chert and argillite.

SKUNK LAKE FORMATION (sk)
Predominantly fine to coarse ash chert tuff, some cherty and very minor argillite.

RICE LAKE FORMATION (rc)
Volcanic debris flows (blocky chloritic and minor siliceous lapilli and breccia size debris) and eutaxitic ash flows, some chert.

OAK LAKE FORMATION (ok)
Sequence of cherty tuff and sericitic tuff.

MOLE LAKE FORMATION (ml)
Predominantly mafic ash tuff.

PROSPECT MEMBER (mlp)
Volcanic debris flow consisting of siliceous, lapilli size debris.

EAGLE MEMBER (mle)
Volcanic greywacke.

CRANDON FORMATION (cr)
Laminated, bedded & replacement sulfides (zinc ore) interbedded with pyritic argillite, pyritic felsic tuff and chert.

SAND LAKE FORMATION (sd)
Sequence of fine felsic tuffs and minor felsic debris & lava flows.

TOWNSHIP MEMBER (sdt)
Volcanic vent breccia affected by multiple stage hydrothermal alteration and sulfide enrichment.

NASHVILLE FORMATION (nh)
Feldspar porphyritic mafic flows.

DUCK LAKE GABBRO (dg)
Fresh, 2 pyroxene gabbro.
Cross cuts nh and sd.

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	APR.'95
APPROVED BY:	PAE	DATE:	APR.'95
APPROVED BY:	GWS	DATE:	APR.'95

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FIGURE 2-4
STRATIGRAPHIC COLUMN

Scale:	NOT TO SCALE	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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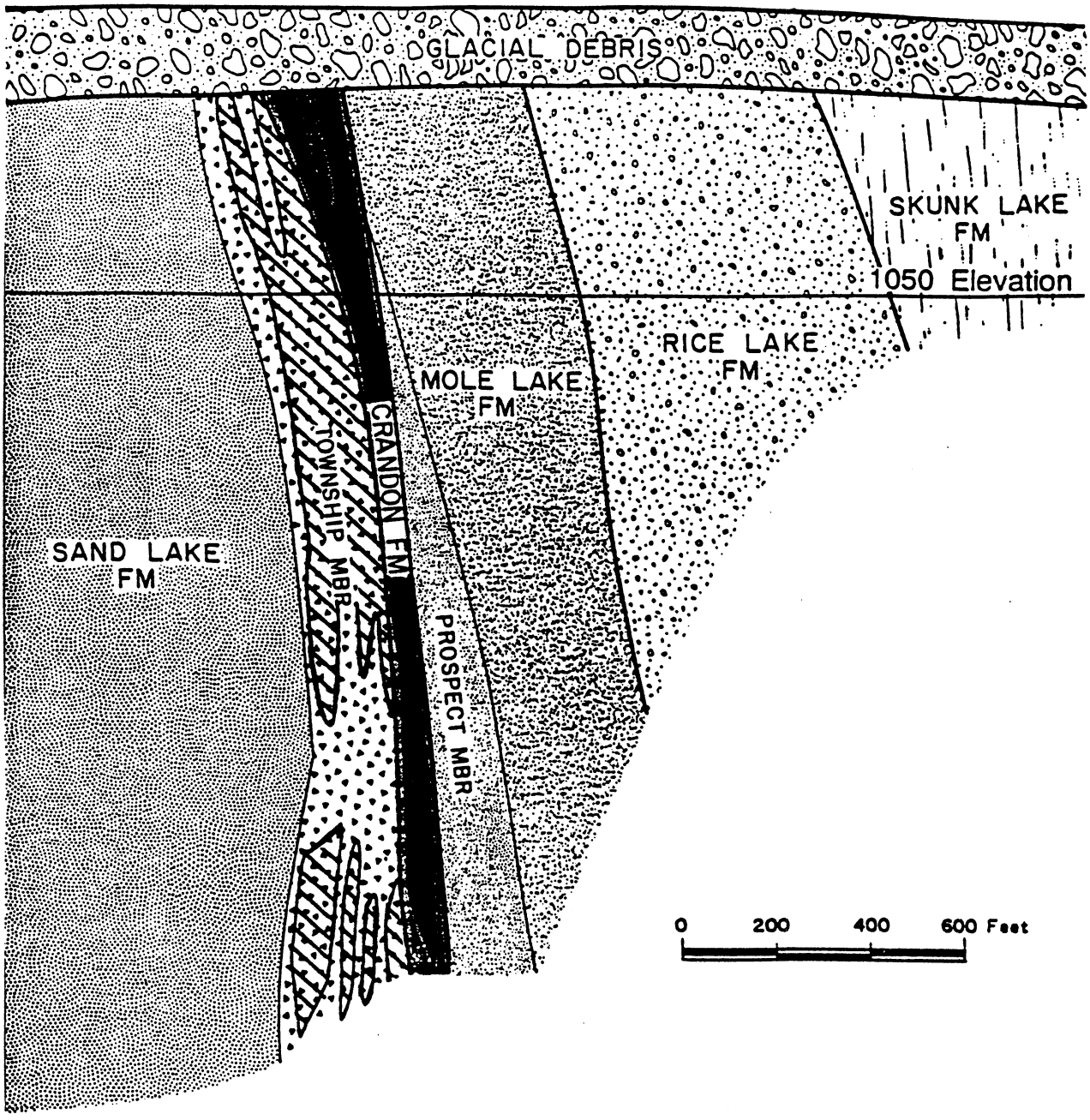
LOOKING WEST



ZINC ORE

COPPER ORE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	APR.'95
APPROVED BY:	PAE	DATE:	APR.'95
APPROVED BY:	GWS	DATE:	APR.'95

Crandon Mining Company

FIGURE 2-5

GENERALIZED GEOLOGIC CROSS SECTION C-C'

Scale:	AS SHOWN	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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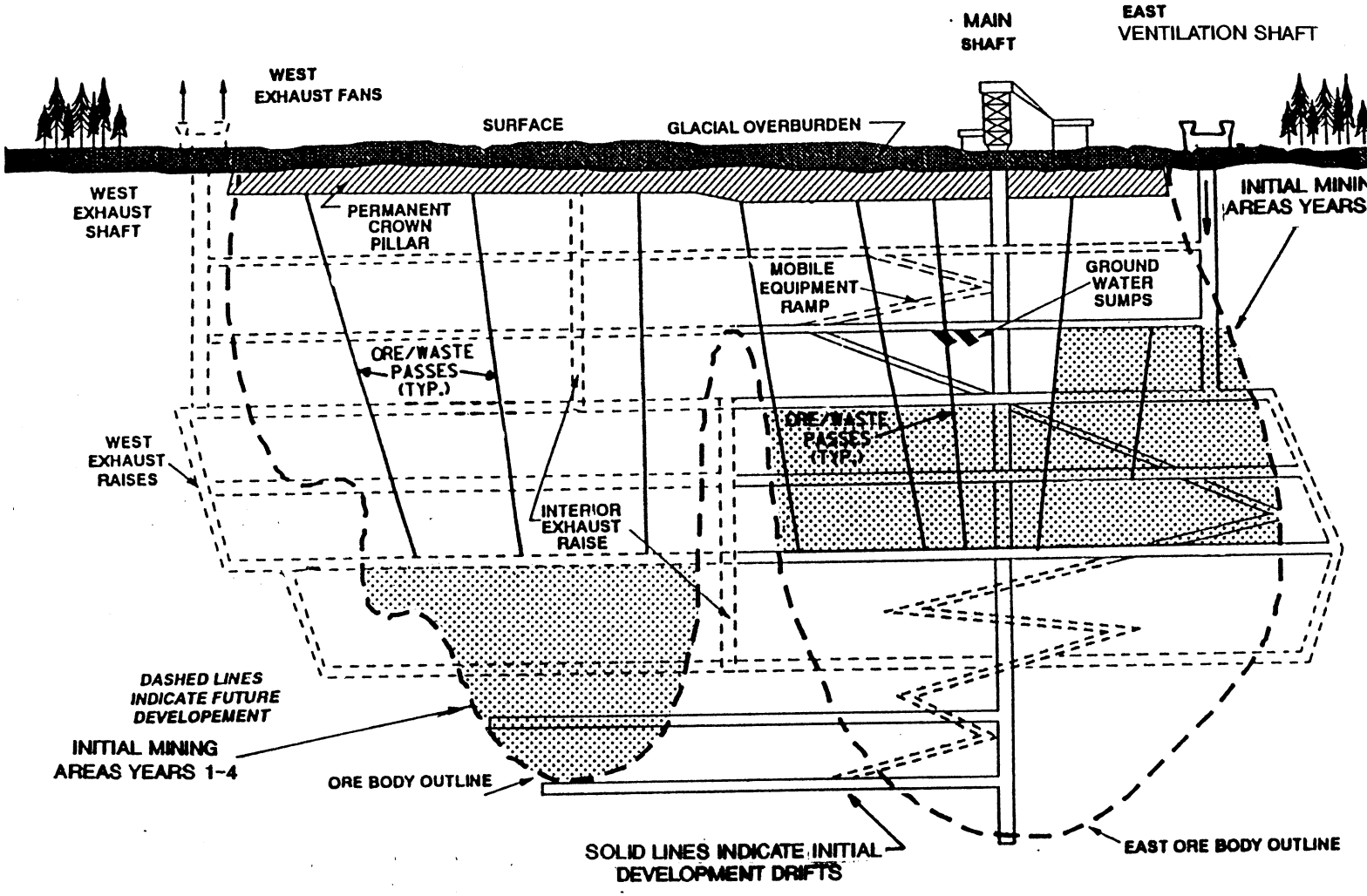

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	APR.'95
APPROVED BY:	PAE	DATE:	APR.'95
APPROVED BY:	GWS	DATE:	APR.'95

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FIGURE 2-6

SCHEMATIC LONGITUDINAL SECTON (LOOKING NORTH)

Scale:	NOT TO SCALE	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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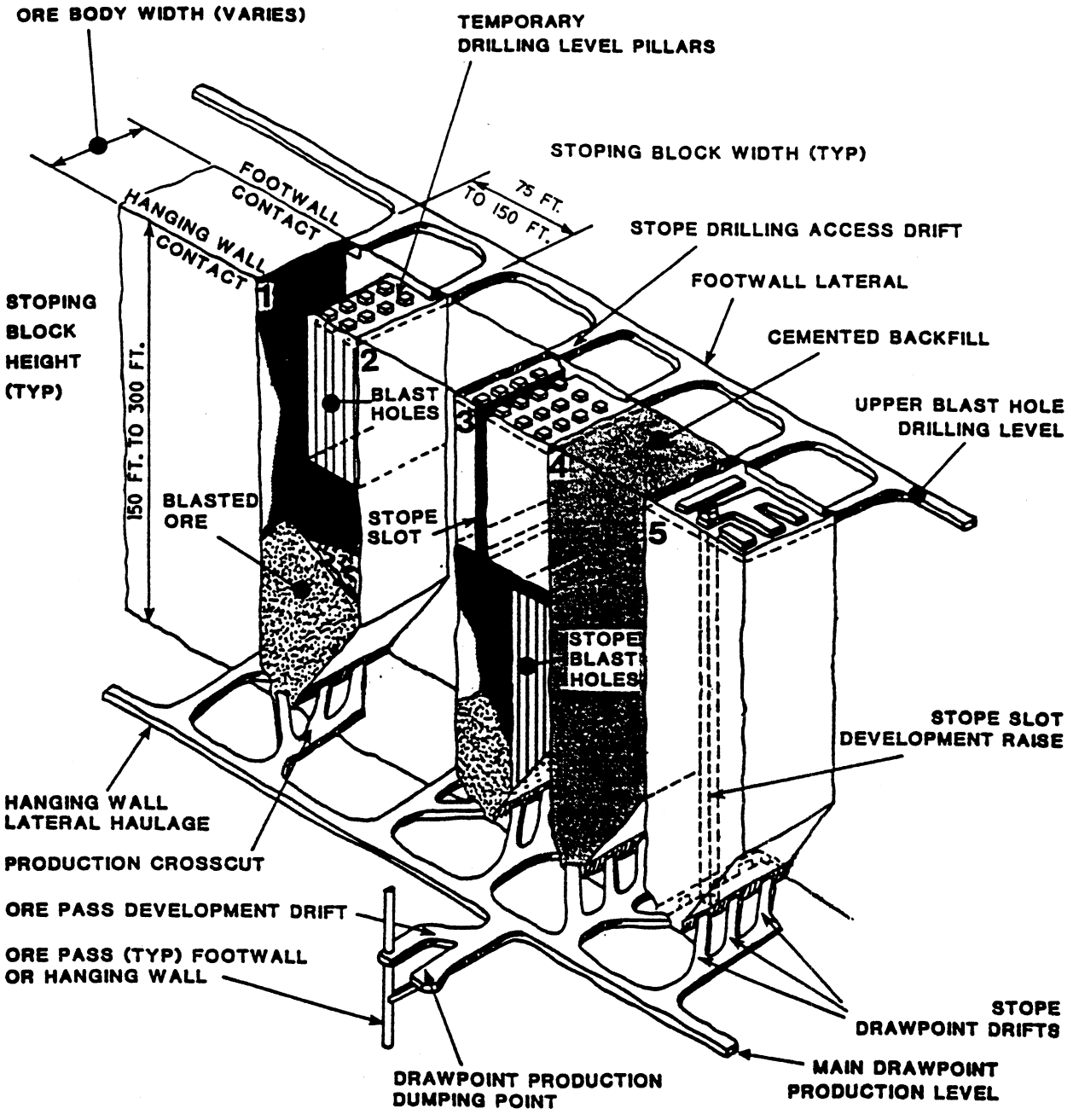

STOPING BLOCK NO. 1-ACTIVE PRODUCTION-STOPE BLASTING NEARING COMPLETION

STOPING BLOCK NO. 2-ALTERNATE STOPING BLOCK/PILLAR-TO BE MINED AFTER BACKFILLING ADJACENT STOPES

STOPING BLOCK NO. 3-ACTIVE PRODUCTION-INITIAL STAGES OF STOPE BLASTING

STOPING BLOCK NO. 4-DEPLETED STOPE BLOCK-CEMENTED BACKFILL IN PLACE

STOPING BLOCK NO. 5-STOPE BLOCK PARTIALLY DEVELOPED

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: APR.'95
APPROVED BY:	PAE	DATE: APR.'95
APPROVED BY:	GWS	DATE: APR.'95

Crandon Mining Company

FIGURE 2-7

CONCEPTUAL STOPING SEQUENCE

Scale:	NOT TO SCALE	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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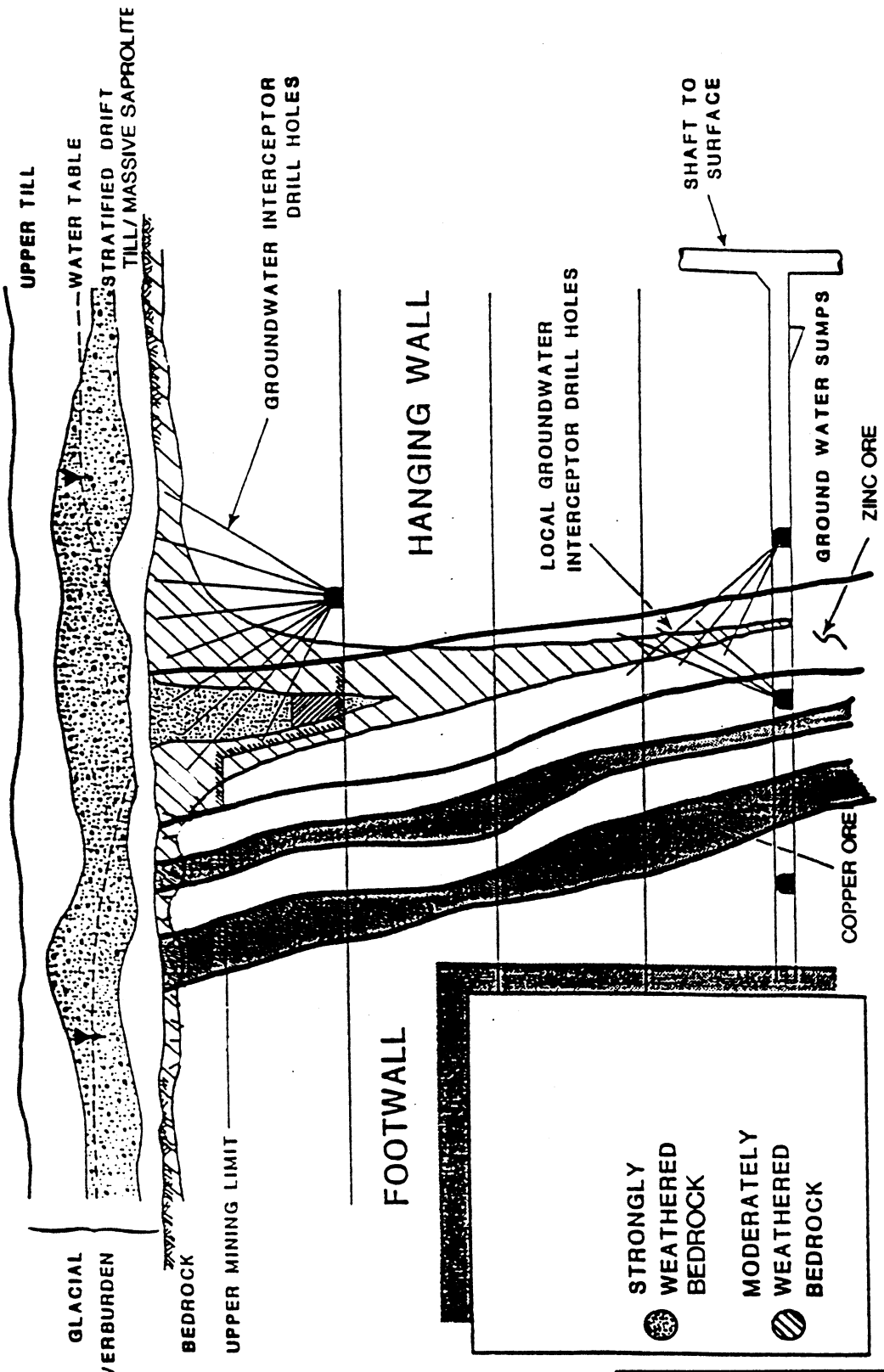

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: APRIL '95
APPROVED BY:	PAE	DATE: APRIL '95
APPROVED BY:	GWS	DATE: APRIL '95

Crandon Mining Company

FIGURE 2-8

GROUNDWATER INTERCEPTOR SYSTEM
(CONCEPTUAL CROSS SECTION)

Scale:	AS SHOWN	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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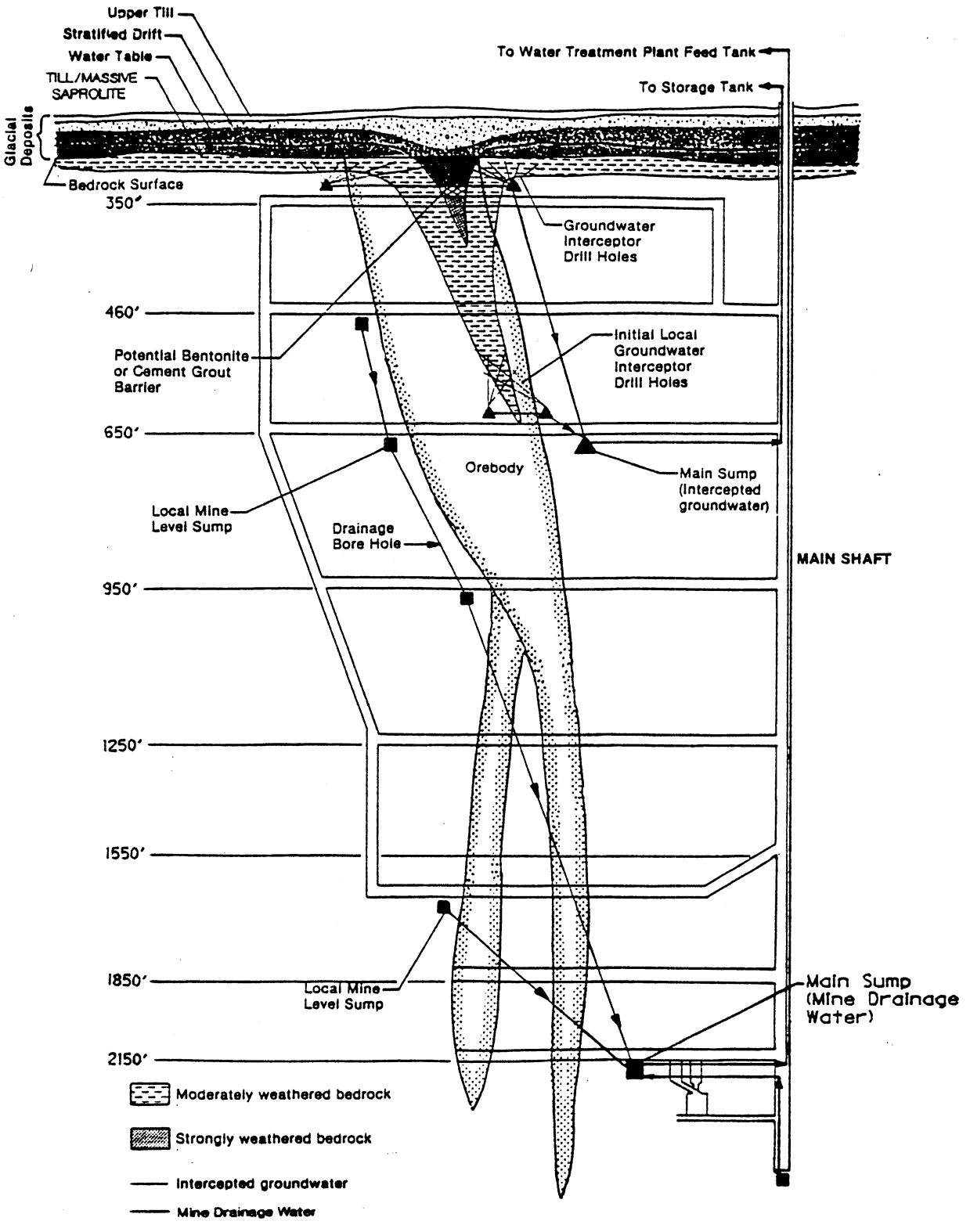

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: APR.'95
APPROVED BY:	PAE	DATE: APR.'95
APPROVED BY:	GWS	DATE: APR.'95

Crandon Mining Company

FIGURE 2-9

MINE DRAINAGE SCHEMATIC

Scale:	NOT TO SCALE	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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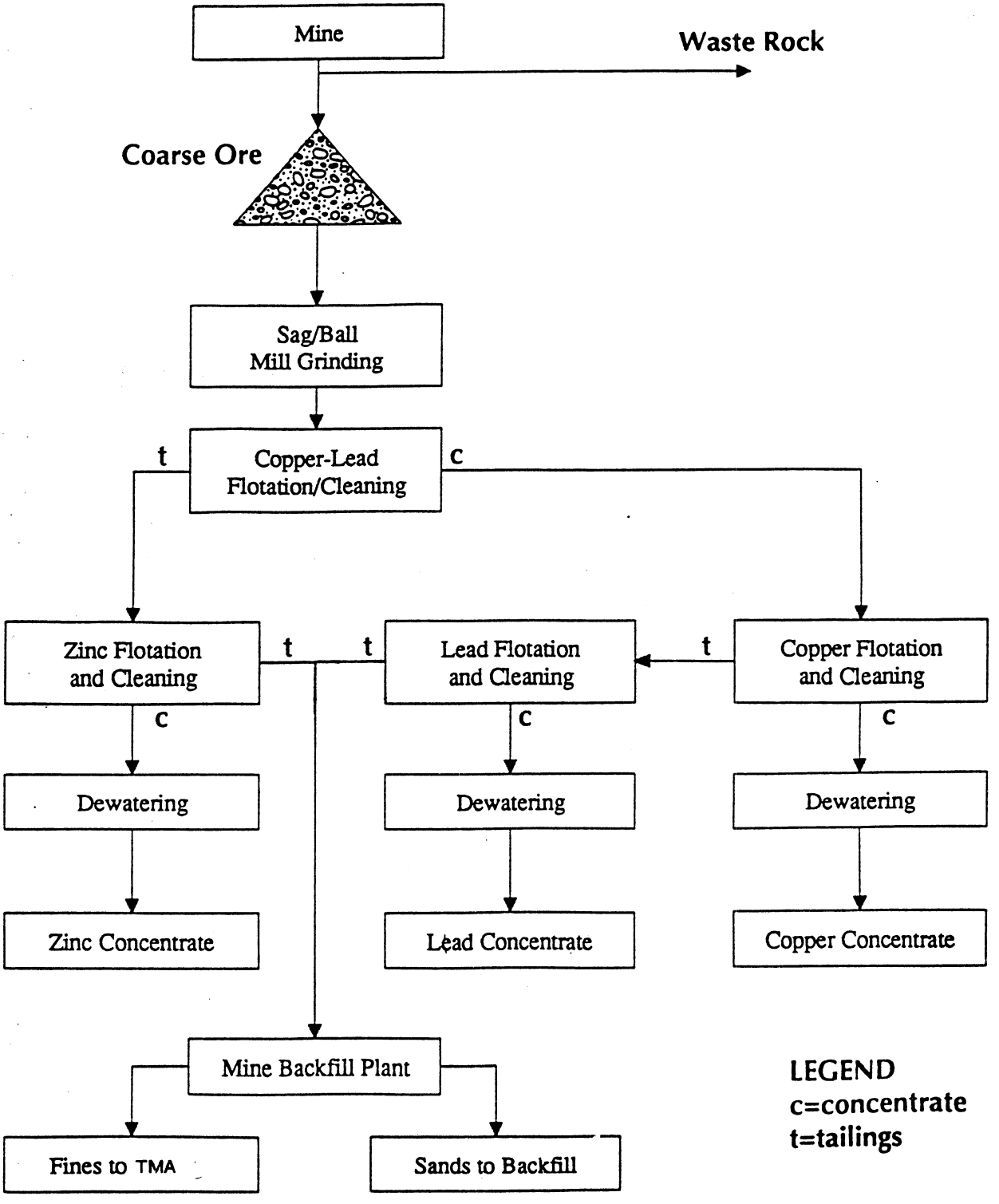

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	APR.'95
APPROVED BY:	PAE	DATE:	APR.'95
APPROVED BY:	GWS	DATE:	APR.'95

Crandon Mining Company

FIGURE 2-10
CONCENTRATOR PROCESS FLOWSHEET

Scale:	NOT TO SCALE	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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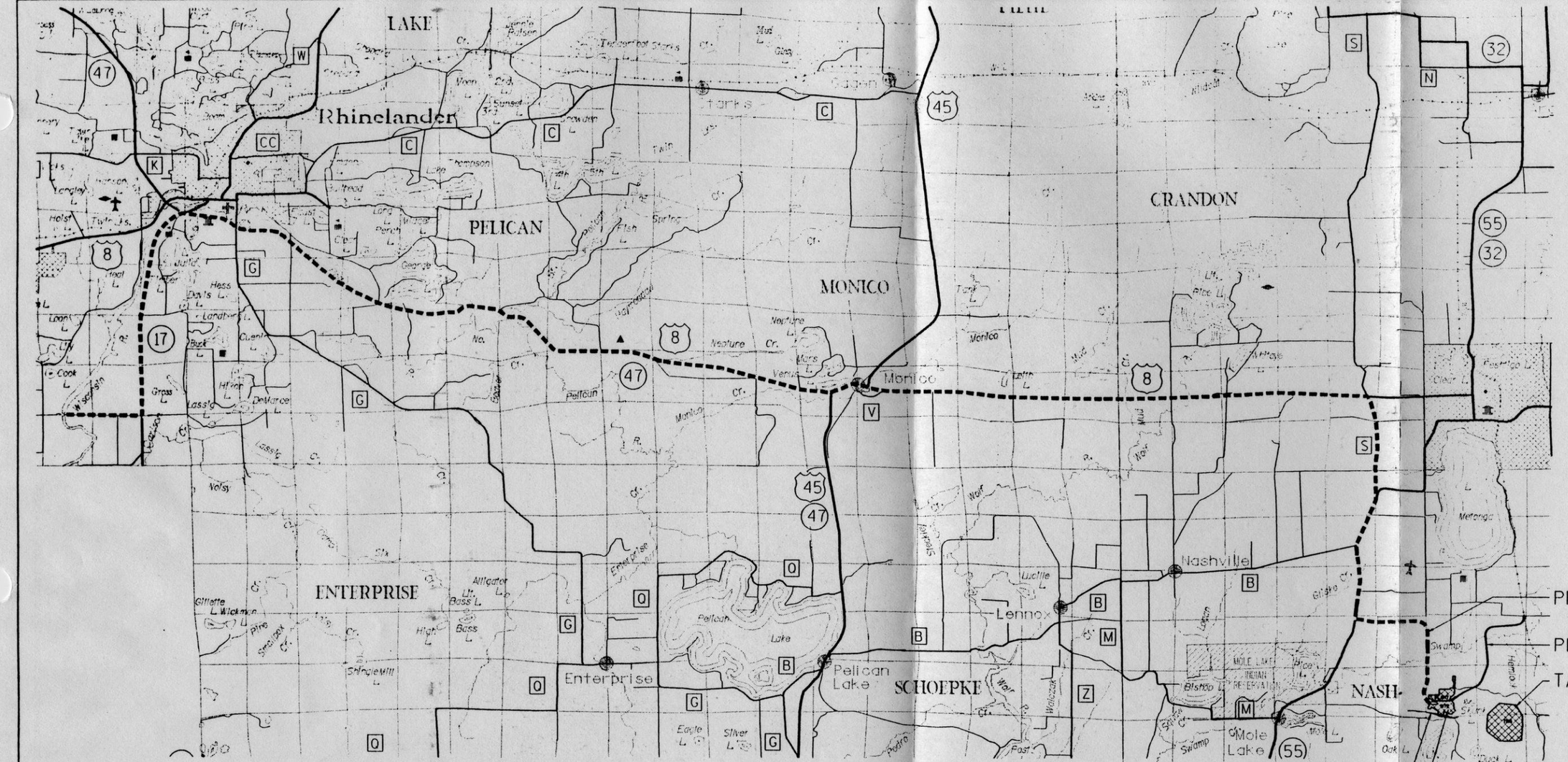


LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- SECTION LINE
- (8) U.S. HWY NO.
- (47) STATE HWY NO.
- [W] COUNTY HIGHWAY LETTER
- PROPOSED WASTEWATER PIPELINE

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE PRIOR TO CONSTRUCTION.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY,'95
APPROVED BY:	PAE	DATE: MAY,'95
APPROVED BY:	GWS	DATE: MAY,'95

Crandon Mining Company

FIGURE 2-11

PROPOSED PIPELINE ROUTE FOR WISCONSIN RIVER DISCHARGE

Scale: 0 6000 12,000 Date: MAY, 1995

Prepared By: Foth & Van Dyke By: GAM

c:\cadwork\4c65f7.dgn

93C049

2,283,000 E

2,285,000 E

2,287,000 E

117,000 N

115,000 N

113,000 N

A'

A

SEE FIGURE 2-12 FOR TYPICAL SECTION THRU TMA

APPROXIMATE LIMITS OF DISTURBANCE

PROPOSED LEACHATE FORCEMAIN

PROPOSED PERFORATED LEACHATE COLLECTION PIPE

PROPOSED CLEANOUT

PROPOSED RECLAIM PIPE

PROPOSED SUMP

PROPOSED SIDE SLOPE RISER

PROPOSED DECANT STRUCTURE

TMA 1

TMA 2

TMA 3

TMA 4

DUCK LAKE

1654.0 1631.0 1647.0 1643.0 1614.0 1673.0 1707.0 1689.0 1683.0 1685.5 1683.0 1718.0 1719.0 1726.5 1578.5 1692.0

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- 1675 — EXISTING CONTOUR
- 1692.0 SPOT ELEVATION
- SECTION LINE
- TMA APPROXIMATE LIMITS OF DISTURBANCE

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1"=1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS FIVE FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.

SCALE
0 300' 600'

TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE PRIOR TO CONSTRUCTION.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY.'95
APPROVED BY:	PAE	DATE: MAY.'95
APPROVED BY:	GWS	DATE: MAY.'95

Crandon Mining Company

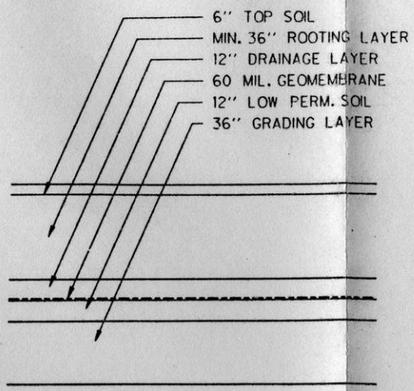
FIGURE 2-12

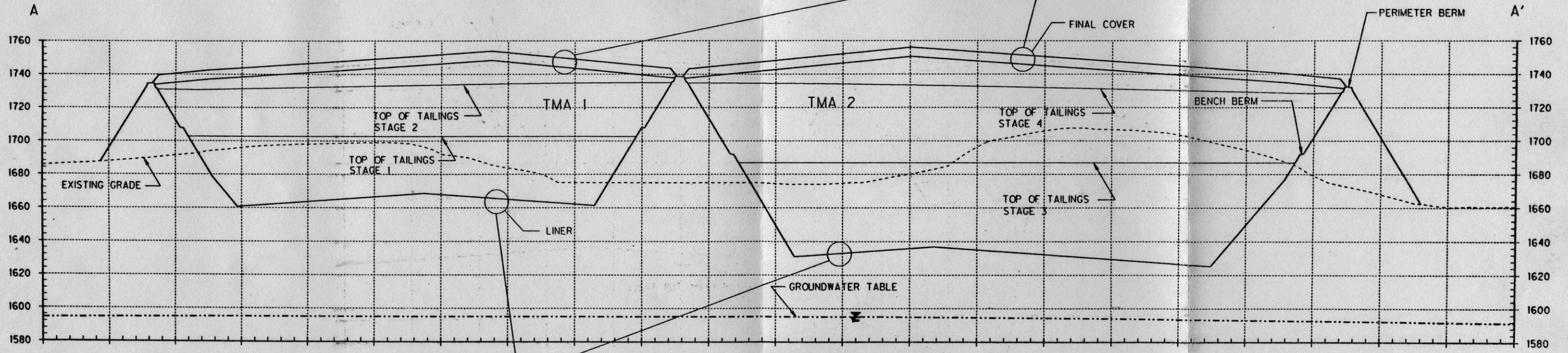
PROPOSED TMA LAYOUT

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	MRS

930049

a:\cadwork\3a48m6.dgn

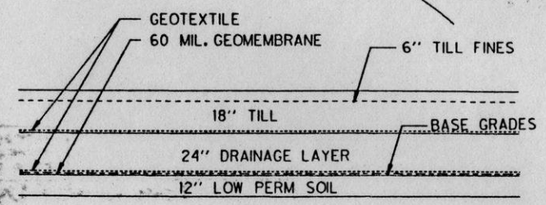


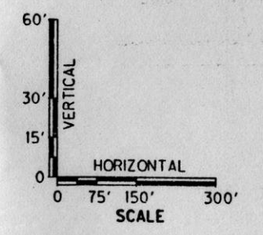


NOTE: VERTICAL SCALE IS EXAGGERATED

TYPICAL CROSS SECTION A-A' THROUGH TMA

NOT TO SCALE





TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE PRIOR TO CONSTRUCTION.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	PAE	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 2-13
TYPICAL CROSS SECTION THROUGH TMA

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	MRS

/d3/dl/users/jprl/3c49m7.dgn

93C049

Crandon Mining Company

Environmental Impact Report

Section 3

Description of Environmental Setting

Crandon Mining Company
Environmental Impact Report

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Appendices

Appendix 3-1 Project Quality Assurance Plan Updates
Appendix 3-2 Wisconsin River Discharge Environmental Evaluation

3 Description of the Environmental Setting

The purpose of this section of the EIR is to present a description of the physical, chemical, biological, cultural, and socioeconomic environment associated with the Crandon Project. The information contained in this section has been derived from existing sources and new studies performed to evaluate ambient conditions relating to air quality and meteorology, geology, surface water, groundwater, aquatic and terrestrial ecology, historical and archaeological features, noise, land use, aesthetics, transportation and utilities, wetlands and socioeconomics. This section also presents the rationale and methodology of the various past and current project related studies.

The Crandon Project is unique in that a very extensive data base from work completed for the project in the 1970s and 1980s exists. As described in the NOI/SOS this data base was extensively reviewed to determine what portions were applicable to the current project and what additional information would be needed to support 1995 permit applications. The results of this review formed the basis for the scope of study included in the NOI/SOS.

The environmental studies outlined in the NOI/SOS were designed and conducted by a multi-disciplinary team of professionals in close coordination with the WDNR, USCOE and other agencies. The technical content of the studies was determined based on the requirements of state and federal law, and discussions with the WDNR, the USCOE and other agencies. Since the publication of the NOI/SOS in February 1994, a number of additions and modifications to the scope of study were made in response to regulatory agency input, input received during and following public hearings on the scope of study, and in response to the results obtained from the completion of work originally outlined in the scope of study. These additions and modifications are outlined in this section.

Quality control programs were developed and applied to all phases of data gathering. These programs were originally documented in three separate plans. The first plan related to surface water sampling. The second, titled *Project Quality Assurance Plan*, addressed biology, geology and soils, groundwater, noise, sediments, waste characterization, etc. The third plan addressed ambient air quality monitoring. The first two plans were appended to the project's NOI/SOS. The third plan was submitted to the WDNR shortly after the NOI/SOS was prepared. Throughout the project, modifications to certain features of the plans were made to respond to requests from regulatory agencies, public comment, and project needs. To document these modifications, revisions or updates to the appropriate plans have been prepared and submitted to the appropriate review agencies. Each of the revisions or updates are included in the appendices to this EIR. The revision to the ambient air monitoring plan and the update to the surface water sampling quality assurance plan are included in the appendices to Sections 3.4 and 3.7, respectively. The updates to the Project Quality Assurance Plan are included in Appendix 3-1. Due to the wide distribution of the NOI/SOS, the original quality control plans appended to that document are not duplicated here.

In addition to describing the environment, the information provided in this section will facilitate the assessment of the potential project-related environmental impacts discussed in Section 4. Further, the data gathered were incorporated into decisions made during project design and site selection to minimize potential environmental effects and to provide a basis for reclamation planning.

Many projects involve the development of a single environmental study area within which data is collected. For the Crandon Project, an individual environmental study area was typically established for each of the environmental topics referred to above. For instance, the groundwater quality study area was roughly linked to the anticipated compliance boundaries for the plant site and TMA. Since groundwater standards cannot by law be exceeded at the compliance boundary, studying groundwater quality much beyond the compliance boundary is of little value. In the case of socioeconomics, the study area was much larger, encompassing almost all of Forest County and sizeable portions of both Oneida and Langlade Counties. The basis for the selection of this study area was the reasonable expectation that workers at the mine would be drawn from or would locate in that large of an area. The boundaries of the individual study areas and the rational for their selection are discussed for each topic addressed in this section.

The Wisconsin River discharge pipeline and outfall, and the wetland mitigation site, are located some distance from the plant site, and therefore are outside the study areas for most Section 3 topics. To address this issue, a separate environmental evaluation of the wastewater discharge pipeline, outfall and discharge into the Wisconsin River will be completed and included in Appendix 3-2 by addendum to this EIR. A description of the existing environment as relates to the wetland mitigation site will be included as part of the 404 permit application update to be submitted to the USCOE and others.

Crandon Mining Company

Environmental Impact Report

Section 3.1

Regional and Local Setting

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3.1 Regional and Local Setting

The Crandon Project site area is located in rural northeastern Wisconsin, about five miles south of the City of Crandon, which has a population of approximately 2,000; 28 miles east of the City of Rhinelander, with an approximate population of 7,600; and 29 miles northeast of the City of Antigo, with an approximate population 8,500. The region is known for its outdoor recreation activities, tourism, and commercial logging. Figure 2-1 in Section 2 of the EIR shows the relative location of the project in relation to surrounding features.

The underlying rock in the project area is composed of Precambrian bedrock. The region is in the seismically stable Southern Province of the Canadian Shield. The surficial deposits are glacial till in origin. These are divided into till, coarse and fine grained outwash and lacustrine (lake bottom) deposits. The surficial topography is primarily the result of the latest glacial ice age and is characterized by southwest trending ridges and valleys.

The site lies within the Wolf River-Lake Winnebago-Fox River-Green Bay drainage basin. The highest monthly stream discharge on the Wolf River typically occurs in April when snowmelt runoff is highest, and is lowest in January and February when precipitation is retained on the ground as snow. The area is characterized by northern hardwood forest interspersed with lakes and wetlands. The streams transport only a small amount of sediments due to the forested nature of the surrounding area, the granular nature of the soils, moderate slopes, low stream velocities, and many lakes and wetlands which serve as sediment catchment basins.

Groundwater occurs primarily in the glacial materials and to a lesser extent in the upper zones of weathered bedrock. Regional groundwater flow is generally from east to west. A stratified layer of glacial outwash consisting of sand and gravel is the primary aquifer. This layer is located below a surficial till layer, and is separated from the bedrock by a layer of less permeable material which is glacial till and massive saprolite, the latter of which is a highly weathered bedrock which has been altered to form clays or iron oxides.

Land use and land cover within a 100 square mile area of the plant site consists of 76.5 percent in forests; 11.8 percent devoted to recreation; 6.4 percent in residential use; five percent used for agricultural; and less than one percent devoted to transportation uses. Approximately 18 percent of the land in the 100 square mile area is publicly owned, most of which is county forest land. There are three town parks and one county park, thirty-one lakes, and approximately 27 miles of trout stream in the area. The abundant public land provides ample opportunity for land-based recreational uses.

The majority of the residences in the area reside in the City and Town of Crandon, or in areas located along lake shores. There is also a relatively high density of residences in the Village of Mole Lake on the Mole Lake Indian Reservation. There are no commercial or retail facilities in or immediately adjacent to the site area. There is one airport approximately four miles northwest of the plant site. The Wisconsin Central Limited Railroad passes east of the site in an approximate north-south direction approximately four miles from the plant site. The area contains the visual amenities common to northern Wisconsin. Lakes and streams, forestlands, and gently rolling terrain contribute to the scenic diversity of the area. Seasonal attractions include the autumn leaf colors, winter snow scenes, and spring flora. The Nicolet National Forest is located approximately six miles to the east of the plant site. There are no state parks, Wisconsin Scientific or Natural Areas, or National Natural Landmarks in or near the area.

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Environmental Impact Report

Section 3.2

Cultural Resources

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3.2 Cultural Resources

The purpose of the Cultural Resources studies is to identify features near the mine site that may have historical, cultural or archaeological importance to the state or to local residents, including Native Americans. Section 106 of the National Historic Preservation Act of 1966, as amended, requires that appropriate steps be taken to identify, evaluate, and determine and mitigate the effects of the proposed project on cultural properties (see 36 CFR Part 800, Regulations of the Advisory Council on Historic Preservation Governing the Section 106 Review Process). All of the investigations reviewed below were designed to meet or exceed the requirements of the Section 106 review process as specified in 36 CFR 800.

Cultural resource management (CRM) investigations relative to the proposed Crandon Project were initiated in 1977 when the first archaeological survey in the vicinity of the plant site was completed. Through the late 1970s and into the early 1980s, six additional CRM surveys were completed. In 1994 and 1995, further additional studies related to the project were performed. In addition, in 1994 CMC began the process of establishing the presence or absence of Traditional Cultural Properties (TCPs) within the area of potential effect (APE) of the proposed project. The nature and the results of this work are the subject of this section of the EIR.

3.2.1 Historical and Archaeological Studies

The following discussion summarizes the results of the various historical and archaeological related investigations conducted to date for the Crandon Project. These studies include archaeological investigations and an architecture-history review. Investigations can be grouped into three sets of related studies. First, historical and archaeological studies were initiated by EMC in 1977 and were conducted as needed until permitting activities were temporarily suspended in 1986. The permitting effort was reinitiated in 1993 by CMC. A variety of additional historical and archaeological investigations have been conducted since that time. The second set of investigations includes work undertaken to meet the requests detailed in the Wisconsin State Historical Preservation Officer's (SHPO) review letters of January 19, 1994 and August 18, 1994 (Appendix 3.2-1). Finally, a variety of studies have been conducted to meet evolving project needs subsequent to the SHPO review. Work completed to date is summarized below. Figure 3.2-1 illustrating the areas surveyed and the results of those surveys in the vicinity of the general project area is contained in confidential Appendix 3.2-17 to be provided to relevant regulatory agencies upon request.

3.2.1.1 Overview of Previous Work

Cultural resources investigations relative to the proposed Crandon Project were initiated in 1977 when Beloit College conducted an archaeological survey of approximately 3,820 acres of Crandon Project land holdings (Salzer and Birmingham, 1978). These holdings included areas planned at that time to contain the plant (formerly mine/mill site) and TMA sites. Eleven archaeological site locations were identified as a result of the work and subjected to additional investigations in order to assess each sites eligibility for listing on the National Register of Historic Places. Results suggest that no significant archaeological resources are present within the surveyed area. The Beloit College findings included a recommendation that additional architecture/history studies be conducted within the Crandon Project area.

Investigations relating to potentially significant historic sites and properties were conducted by the MacDonald and Mack Partnership (1982). This study resulted in the evaluation of three separate building clusters consisting of five individual structures, none of which were deemed historically or architecturally significant.

Archaeological survey work continued in 1981 when Great Lakes Archaeological Research Center, Inc. (GLARC) conducted both survey and preliminary evaluations at two archaeological sites. A total of 990 acres were investigated (Overstreet and Brazeau, 1982). The survey resulted in the identification of a single previously unrecorded prehistoric site. Nine previously unrecorded historic sites were also identified. Preliminary evaluations of each site were conducted to determine if any of the identified locations represented significant cultural resources eligible for listing on the National Register of Historic Places. In addition, preliminary evaluations were conducted at one previously reported site, Oak Lake No. 1 (47 FR 121). Results suggest that both Oak Lake No. 1 (47 FR 121) and Oak Lake No. 2 (47 FR 143) may be eligible for listing on the National Register of Historic Places. However, neither site is included in areas of planned project development.

Ancillary facility locations subjected to archaeological review include the corridor for a planned railroad spur, an access road, a natural gas transmission line, and an earlier proposed wastewater discharge pipeline route to Swamp Creek. The railroad spur corridor study was investigated pursuant to completion of the original GLARC study (Overstreet and Brazeau, 1982). A single historic period Euro-American site (47 F 147) was identified within its proposed alignment. Investigations for the planned access road indicate that no archaeological resources are located coincident with the planned alignment (Overstreet, 1982). The route of a planned natural gas transmission line was subjected to archaeological reconnaissance at the request of Wisconsin Public Service Corporation. Two prehistoric sites and two historic period sites were identified during that survey. Preliminary evaluation of these properties suggests that none are potentially eligible for listing on the National Register of Historic Places (Overstreet, 1983a). The proposed right of way for the previously planned wastewater discharge pipeline route was archaeologically surveyed in 1983. Results indicated that no historic resources are present within the study corridor (Overstreet, 1983b).

The various cultural resources investigations were reviewed and commented upon by the Historic Preservation Division, State Historical Society of Wisconsin during the years 1977-1986. Subsequent to reactivation of the Crandon Project in 1993, SHPO requested a comprehensive summary of Crandon Project cultural resource management studies conducted to date. A copy of this request is included in Appendix 3.2-1. GLARC was asked to compile this summary by Foth and Van Dyke, Inc. *Overview: Cultural Resource Investigations for the Crandon Mining Company Crandon Project, Crandon, Wisconsin* (Richards, 1994) provided the requested summary of previous cultural resources investigations at the Crandon Project site. A copy of this report is included in Appendix 3.2-2.

The office of the SHPO reviewed the overview study and provided recommendations for additional archaeological studies associated with development of the Crandon Project. A copy of this second review letter is included in Appendix 3.2-1. Recommendations of the overview study included: (1) collection of a 10 percent shovel probe sample from within the plant (formerly mine/mill) site and the tailings management area in order to verify the sufficiency of previous survey work in these areas; (2) additional archival research designed to establish a historic context for 47 FR 147, and if the archival documentation was found to exist, the site should be

formally evaluated to determine if it is potentially eligible for listing on the National Register of Historic Places; (3) 47 FR 121 (Oak Lake site) and 47 FR 143 (Oak Lake II site) should be nominated to the National Register of Historic Places; and (4) a cultural resource management plan should be developed for the Crandon Project. In response to SHPO's letter, three studies as discussed in Section 3.2.1.2 were completed. As per agreement with SHPO work associated with 47 FR 121 (Oak Lake Site) and 47 FR 143 (Oak Lake II Site) will commence once the project is permitted.

3.2.1.2 1994 and 1995 Archaeological Studies

The recent 1994 and 1995 archaeological studies included a field verification of prior work, an evaluation of the Keith's Siding site (47 FR 147), and the development of a cultural resources management plan. Results of the verification survey confirmed prior studies. The evaluation of 47 FR 147 confirmed the existence of intact subsurface archaeological material associated with an early 20th Century logging era occupation at Keith's Siding. The management plan addresses the identification, evaluation, protection/preservation, and conservation principals that will be followed by CMC to manage the archaeological resources associated with the project. Additional details on the 1994 and 1995 studies are provided in the following sections.

3.2.1.2.1 Verification Survey

GLARC's overview of pre-1994 Crandon Project historical and archaeological studies raised an issue regarding the initial archaeological reconnaissance of the project area carried out by Beloit College (Salzer and Birmingham, 1978). The issue stemmed from differences between survey methodology used in the earlier Beloit College survey and that typical of current archaeological surveys. The 1994 overview noted that there is a ". . . possibility that an unknown number of archaeological sites may have been missed by the Beloit crew as a consequence of not screening shovel test spoil" (Richards, 1994). However, the report stressed that "It is unlikely that any of these site locations represent significant cultural resources eligible for listing on the National Register of Historic Places" (Richards, 1994). Following recognition of this issue, CMC initiated the design and implementation of an additional archaeological survey to verify the sufficiency of the previous archaeological survey work.

The strategy chosen entailed the collection of a 10 percent sample from within both the plant site (PS) and the tailings management area (TMA) in order to verify the sufficiency of previous survey work in these areas. The PS and TMA sites were selected for additional survey since these areas represent locales where extensive ground disturbance will occur if the project proceeds. Results of the verification survey were to be compared with Beloit College findings from the same areas. If no significant variation in site frequency was observed, results would reinforce the sufficiency of the earlier survey work. This strategy was approved by the office of the SHPO (Appendix 3.2-1).

Results of the verification survey showed no significant variation in site frequency. No archaeological materials were recovered from either the PS or TMA. Consequently, no additional investigations are recommended within the PS and the TMA. Moreover, the results of the verification survey reinforce the findings of the original Beloit survey and suggests that the frequency of sites recorded would not be significantly increased by re-survey using currently conventional techniques. A copy of this report (Richards, 1995a) is included in Appendix 3.2-3. At the subsequent request of the Wisconsin SHPO, results of the verification survey were

compiled in a report format consistent with Wisconsin Archaeological Survey (WAS) guidelines (Richards, 1996a). This report, which does not change the results of the investigations, was forwarded to the Wisconsin SHPO and the U.S. Army Corps of Engineers (USCOE) in November of 1996.

3.2.1.2.2 Archaeological Evaluation of 47 FR 147

The Keith's Siding site (47 FR 147) was initially identified during GLARC's 1981 reconnaissance of the alignment of a proposed railroad spur (Overstreet and Brazeau, 1982). In response to SHPO's recommendations, CMC initiated the design and implementation of a Phase II archaeological investigation for the Keith's Siding site. The goals of the Phase II investigation were to determine: (1) if an interpretable historic context existed with which to evaluate site-related archaeological deposits; and (2) whether intact archaeological deposits and artifacts were present below the plow zone (Ap horizon). This information was needed to evaluate 47 FR 147's potential eligibility for listing on the National Register of Historic Places. Results reported in Mier, et al. (1995) suggest that the Keith's Siding site (47 FR 147) is characterized by extensive subsurface integrity and is potentially significant from a historical and archaeological perspective. Consequently, GLARC prepared a formal determination of eligibility (NPS Form 10-900) for the Keith's Siding site, which was forwarded to the USCOE, Wisconsin SHPO, and others in September 1996 (Moe, 1996). Results suggest that the site is eligible for listing on the National Register of Historic Places.

Two options exist with regard to cultural resource management at the Keith's Siding site. The first option would involve reconfiguring the project to avoid disturbing the site. The second option would involve archaeological data recovery in those portions of the site affected by project development. Either approach could be considered an appropriate methodology in this instance. A copy of the summary report of the Phase II investigations (Richards, 1995b) is included in Appendix 3.2-4.

3.2.1.2.3 Cultural Resource Management Plan

A Crandon Project Cultural Resource Management Plan (CRMP) was developed by GLARC and incorporates four major components: (1) Identification; (2) Evaluation; (3) Protection/ Preservation; and (4) Conservation. A copy of the CRMP (Overstreet and Richards, 1995) is included in Appendix 3.2-5. A summary of the main points of the CRMP are listed below.

- The majority of identification level studies have already been completed (Richards, 1994), particularly in those areas where project impacts are known, or are suspected to occur in the future.

- Approximately 5,300 acres have been subjected to archaeological reconnaissance. An additional 1,700 acres have not been surveyed. Should any ground disturbing activities be planned within the 1,700 acres, affected locations will be archaeologically surveyed employing contemporary methods and techniques in order to identify any historic properties which may be present.

- Those archaeological sites that have not been evaluated will be addressed if project impacts are predicted to occur from future project developments. In the

interim, these sites will be preserved in place and no project activities will be allowed in the immediate environs of known potentially eligible sites.

- During construction, those archaeological sites known to be significant and those which may be significant will be clearly delineated in the field in order to prevent incidental disturbance from construction related activity.

- Whenever feasible, those sites determined eligible for the National Register of Historic Places will be preserved in place. Should this not be feasible, recovery operations consistent with policies of the Advisory Council on Historic Preservation will be implemented through consultation with SHPO. Any such activities will be guided by a detailed research design or data recovery plan.

- A program designed to provide interpretation of project area cultural resources will be implemented.

In addition to the above, the CRMP contains an appendix (Appendix II) that outlines a protocol for any accidental discovery of archaeological material that may occur during project construction.

3.2.1.3 Additional Studies

During 1994 and 1995 additional archaeological studies were conducted in conjunction with facility design and facility alternative evaluations. The archaeological reviews included investigations associated with the TMA borrow area, wetland compensation site, Wisconsin River water discharge pipeline, and soil absorption ponds. The findings of these investigations are summarized in the following sections.

3.2.1.3.1 TMA Borrow Area Survey

Subsequent to a recent reconfiguration of the TMA site, an archaeological survey of a proposed borrow area situated adjacent to the northern boundary of the TMA was initiated by CMC. The survey was considered necessary since the proposed borrow site was not within the limits of previously surveyed Crandon Project lands. Accordingly, GLARC designed and implemented a standard Phase I archaeological reconnaissance of the proposed borrow site. A copy of this report (Richards, 1995c) is included in Appendix 3.2-6. At the subsequent request of the Wisconsin SHPO, results of the TMA borrow area survey were compiled in a report format consistent with Wisconsin Archaeological Survey (WAS) guidelines (Richards, 1996a). This report, which does not change the results of the investigations, was forwarded to the Wisconsin SHPO and the USCOE in November of 1996.

Results of the archaeological investigations indicate that no prehistoric or historic archaeological sites are present within the limits of the archaeologically surveyed area. Further, no standing structures or other above ground historic resources are present. Consequently, use of the TMA borrow site should have no effect on area cultural resources.

3.2.1.3.2 Wetland Compensation Site Survey

The project's proposed wetland compensation site is located in an area which has not been previously subjected to archaeological survey. Typically, SHPO requires that potential wetland compensation sites be subjected to an archaeological reconnaissance prior to development. Consequently, GLARC designed and implemented an archaeological survey to accomplish this work. A copy of this report (Richards, 1995d) is included in Appendix 3.2-7. At the subsequent request of the Wisconsin SHPO, results of the wetland compensation site survey were compiled in a report format consistent with Wisconsin Archaeological Survey (WAS) guidelines (Richards, 1996b). This report, which does not change the results of the investigations, was forwarded to the Wisconsin SHPO and the USCOE in November of 1996.

The wetland compensation site straddles the Oconto-Shawano County Line north of Shawano Lake. The southern portion of the parcel is located in T27N, R17E, Section 5, N 1/2, NE 1/4, Washington Township, Shawano County and the northern part is located in T28N, R17E, Section 32, S 1/2, SE 1/4, Underhill Township, Oconto County. The project area is situated within an agricultural field comprising approximately 150 acres. Prior to being farmed, the project area was likely part of an extensive wetland currently occupying portions of Sections 31 and 32 immediately northeast of the project area. At the time of the survey, the property had been partially drained by construction of several interconnected drainage ditches which channel water southwestward into Duchess Creek. An east-west ditch paralleling the northern border of the project area appears to represent a post-1974 addition to this drainage system since the feature does not appear on the 1974 Cecil, Wisconsin USGS quad map. The property reportedly supports a perennial mint crop which is turned under in the fall and allowed to regenerate each spring. Topography is virtually flat with no significant local relief present. However, the northern portion of the property is marked by the scattered presence of barely discernible, eroded rises which appear to be sandier than the surrounding soils.

Results of the archaeological investigation indicate that a prehistoric archaeological site is located within the project area, near the northern limits of project development. The site location was identified by the presence of two chipped stone projectile point fragments. Both artifacts are suggestive of contracting stemmed forms commonly associated with Early and Middle Woodland occupations of the area. The absence of associated artifactual debris such as lithic debitage, pottery, or fire-cracked rock, suggests that the site is neither extensive nor representative of an intensive occupation. The site location near what would have been the northern margin of the former wetland, adjacent to a low rise, suggests an occupation directed toward exploitation of wetland resources. Agricultural activity has disturbed the upper 30-40 cm of soil. However, the presence of peat-bearing soils suggest the possibility that the recovered tools may be associated with buried archaeological and/or paleontological deposits incorporated in near shore peats formed during the time that the project area was an active wetland. Alternatively, the site location may have been associated with an occupation of the low rise noted earlier. In this case, it is unlikely that substantial archaeological deposits remain below the present, plow-truncated surface.

Currently, no ground disturbing activities are planned in the immediate vicinity of the newly discovered archaeological site. Consequently, project development should have no affect on any archaeological deposits present. If future project development involves ground disturbance coincident with the location of the archaeological site, additional archaeological investigations are

warranted in order to determine the potential significance of any remaining archaeological deposits.

If the archaeological site is to be disturbed by project development, a coordinated program of geoarchaeological studies supplemented by limited archaeological testing should be implemented. The focus of these investigations should be: (1) An accurate reconstruction of the project area environment prior to European settlement; (2) the potential of the project area land forms to harbor archaeological deposits; and (3) archaeological testing centered on the locations from which the recovered artifacts were collected.

3.2.1.3.3 Wisconsin River WWDC Reconnaissance

As part of its review of a Wisconsin River treated wastewater discharge option, CMC initiated a comprehensive historical and archaeological investigation related to the route of the proposed Wisconsin River Wastewater Discharge Corridor (WWDC) in Forest and Oneida Counties, Wisconsin. The Crandon Project's proposed WWDC extends from the wastewater treatment facility at the Crandon Project site west to the Wisconsin River. The proposed construction easement is currently designed to coincide with: (1) the previously surveyed right-of-way of the Crandon Project's plant site access road; (2) various existing state, county, and township highway rights-of-way; (3) existing right-of-way coincident with the snowmobile trail in the northern half of the existing USR 8 right-of-way from CTH S to CTH V; and (4) a portion of Wisconsin Public Service Corporation land along the Wisconsin River just below the Hat Rapids Dam.

The route originates at the Crandon Project site in Forest County and follows the previously surveyed (Overstreet, 1982) right-of-way of the plant site access road to the intersection of the access road and STH 55. At this point, the proposed route extends north along the west side of STH 55 to the intersection of STH 55 and CTH S. The proposed easement is situated 25 feet from the edge of the STH 55 pavement. The route continues north along the top of the roadside ditch on the west side of CTH S to the intersection of CTH S and USR 8. From this point, the pipeline route is situated within the northern right-of-way of USR 8 coincident with the old USR 8 road bed (now used as a snowmobile trail) to the intersection of USR 8 and CTH V in Oneida County. At this intersection, the route crosses to the south side of USR 8 and continues, 25 feet from the pavement edge, west to the Rhinelander Beltline. It then follows the Rhinelander Beltline (USR 8) west, 25 feet from the north pavement edge, to the intersection of the Beltline and STH 17. From this intersection the proposed route is 25 feet west of the pavement edge of STH 17 south to the intersection of Hat Rapids Road with STH 17. At this point the proposed route parallels the south (eastbound) lane of Hat Rapids Road west to the Wisconsin River. At the east bank of the Wisconsin River the proposed route turns north along the river bank to a discharge point at the Hat Rapids Dam.

Three separate but related studies designed to inventory cultural resources within the WWDC right-of-way were conducted by GLARC. Initial efforts were designed as an archaeological/historical literature search and visual reconnaissance of the project route. A second study provided a more detailed review of pertinent geomorphological and engineering design data. The final effort was directed to subsurface sampling of areas targeted as a result of both earlier studies. The results of these studies are documented in the report *Archaeological and Geoarchaeological Investigations of the Proposed Route of a Waste Water Discharge Corridor, Forest and Oneida County, Wisconsin* (Richards and Kolb, 1996) contained in Appendix 3.2-15 (Volume IIIb). It should also be noted that the route of the WWDC was included in the study

area for an ethnographic literature and archival investigation conducted pursuant to compilation of a Traditional Cultural Properties inventory of the Crandon Project Area as discussed in Section 3.2.2 and 3.2.3 of this EIR.

Results of the GLARC study indicate that: (1) approximately 30 percent of the route has been subjected to previous archaeological survey and determined to be devoid of archaeological sites; (2) 19 percent of the route is coincident with massively cut highway right-of-way in which no archaeological deposits are preserved; (3) 34 percent of the route traverses areas of hydric soil or locales characterized as unlikely to harbor archaeological deposits; (4) approximately 17 percent of the route is coincident with areas potentially capable of harboring archaeological deposits. However, archaeological and geoarchaeological testing within these latter areas indicates that no subsurface archaeological deposits are present within the proposed pipeline right-of-way. A single early 20th Century Euro-American habitation site was identified near Hat Rapids Dam at the western terminus of the route. Shovel test data indicates that site deposits are disturbed and thinly scattered. Consequently, the site is unlikely to be eligible for listing on the National Register of Historic Places. However, planned construction has been designed to avoid any archaeological deposits associated with this site. Thus, project development should have no affect on the Hat Rapids Dam site.

3.2.1.3.4 Soil Absorption Pond Surveys

Three discrete locations selected as possible sites for soil absorption ponds were investigated during two separate archeological studies at the Crandon Project. The first study was initiated by CMC to provide recommendations relating to the sufficiency of previous archaeological surveys within two locales proposed as sites for potential soil absorption ponds. These two locales are designated Areas C and D on Foth & Van Dyke planning documents. An archaeological investigation was designed for each of the locales. A copy of the subsequent report (Richards, 1995e) is included in Appendix 3.2-8. At the subsequent request of the Wisconsin SHPO, results of the Area C and D soil absorption pond surveys were compiled in a report format consistent with Wisconsin Archaeological Survey (WAS) guidelines (Richards, 1996a). This report, which does not change the results of the investigations, was forwarded to the Wisconsin SHPO and the USCOE in November of 1996.

Although both areas C and D had been subjected to shovel test survey by Beloit college field crews, Area C is located in close proximity to Oak Lake, an archaeologically sensitive area known to harbor potentially significant prehistoric sites. In addition, Area C is marked by the presence of a land form feature typically associated with preferred locations for aboriginal habitation. - Consequently, Area C was subjected to additional pedestrian reconnaissance using current Wisconsin Archaeology Survey guidelines.

Conversely, Area D is not located adjacent to any known prehistoric archaeological sites. Moreover, Area D is characterized by a lack of terrain normally associated with a high probability of archaeological site location. As a result, Area D investigations were restricted to archival research. However, a previously reported Euro-American logging camp (47 FR 148) is located approximately 300 meters west of the project area limits.

Background information pertinent to Areas C & D indicate that no reported archaeological sites are located in either area. Moreover, both areas have been subjected to pedestrian archaeological survey by Beloit College field crews (Salzer and Birmingham, 1978). No

archaeological materials were recovered within or directly adjacent to Area C or Area D during the 1994 GLARC survey. Consequently, development of either Area C or Area D should have no effect on project area archaeological resources.

The second soil absorption pond study was conducted during February 1995. The study's goal was identification of any archaeological resources located at nine specific backhoe trench locations within a locality identified as Area E. The study was required since the proposed site is situated in an area not previously subjected to archaeological survey. The methodology employed to successfully complete a late winter archaeological investigation was jointly developed by GLARC and the SHPO's office. A copy of the subsequent report (Richards, 1995f) is included in Appendix 3.2-9. At the subsequent request of the Wisconsin SHPO, results of the Area E soil absorption pond survey were compiled in a report format consistent with Wisconsin Archaeological Survey (WAS) guidelines (Richards, 1996a). This report, which does not change the results of the investigations, was forwarded to the Wisconsin SHPO and the USCOE in November of 1996.

Background information pertinent to Area E indicated that no reported archaeological sites are located within the area. Backhoe trench locations were selected to maximize recovery of soil/sediment data while limiting potential adverse effects to unreported cultural resources. Trench size was restricted to approximately four feet (≈ 1 m) X 15 feet (≈ 5 m).

Following selection of back hoe trench location, two archaeological soil test pits were excavated within the limits of each backhoe trench. Frozen sediments extending from ground surface to approximately 8 inches below surface were removed as a unit and saved for later processing. Hand excavation supplemented by a gasoline powered flight auger equipped with 16" diameter flights was attempted, however it was not possible to adequately penetrate the frozen soil with the auger. Consequently, sediments had to be removed manually with the use of picks and shovels. Following removal of the overlying frozen sediments, the pits were excavated into the B horizon or sterile sediments. Soil profiles were recorded and test pit walls were examined by an archaeologist and a geomorphologist for evidence of subsurface archaeological deposits. Frozen surficial sediments were transported to a nearby laboratory facility and allowed to thaw. Once thawed, sediments were subjected to water separation. Each sample matrix was inspected for the presence of artifactual debris or other indicators of the presence of archaeological deposits.

Archaeological investigations did not show the presence of archaeological deposits within any of the selected trench locations. Consequently, backhoe excavations began immediately. Trench excavations were monitored by an archaeologist. Results of the archaeological study support the contention that excavation of the project related backhoe trenches had no effect on project area archaeological resources. Since the investigations were not designed to constitute a survey of the entire Area E project site, a conventional archaeological survey would be designed and implemented in the event that additional development is planned in the area.

3.2.2 Native American Cultural Resources

3.2.2.1 Preface

The following narrative replaces Section 3.2.2 of this EIR previously prepared by the Commonwealth Cultural Resources Group (CCRG) and submitted in May 1995. James Robertson was CCRG's Principal Investigator with Wesley Andrews as the Project Ethnologist.

For the most part, prior work has been retained as presented in the original document, although it has been reorganized with some editing and minor revision undertaken. The Project Ethnologist's Interim Report (Andrews, 1995) from this period is included in the EIR as Appendix 4.2-9. Wesley Andrews left CCRG and the project in August of 1995, and in December of 1995, Clyde M. Woods of Woods Cultural Research, Inc. (WCRI) was retained by CMC to complete the Traditional Cultural Properties Investigations (TCPI). Based upon a review of the research included in the May 1995 EIR and comments from cultural resources staff of the Wisconsin SHPO and the USCOE, the scope of work was expanded to include additional information. Included were ethnographic overviews for the study area tribes, expanded research on the potential for cultural sites in the study area and vicinity, an inventory of cultural sites in the study area and vicinity, and additional attention to potential Traditional Cultural Properties (TCPs) in the study area and vicinity. In discussing "cultural sites," the reference is to historic and ethnographic, rather than prehistoric, sites. The term "cultural site" is used rather than "ethnographic site" since a considerable amount of prehistoric and historic research has been included in the various analyses. Still, in the common use of the terms, either ethnographic site or cultural site could be used. The term Native American cultural resources is also found in the literature in reference to ethnographic, ethnohistoric, and cultural sites. This term is used in the present report as well.

The ethnographic overviews (Section 3.2.2.3) were undertaken to provide historical and cultural context for the aboriginal occupants of the study area, the Ojibwa (Sokaogon Chippewa), Potawatomi (Forest County Potawatomi), and the Menominee (Menominee Tribe of Wisconsin). The research on potential cultural sites (Section 3.2.2.4) was put together to indicate the range and types of sites which might be expected in the study area and vicinity. The inventory of cultural sites (Section 3.2.2.5) was conducted to develop an actual inventory of Native American occupation and activity in the study area and vicinity from existing published and unpublished literature sources. The overviews, potential cultural sites, and inventory of cultural sites sections were prepared by GLARC and submitted to WCRI for review, revision, additions, and final incorporation into the report. John Richards served as Principal Investigator for the GLARC studies. GLARC was selected for this work because they prepared the archaeological studies for the Crandon Project, have extensive experience in the study area, and have conducted a range of related historical and cultural research in the Great Lakes Region.

At the inception of the TCPI study, CCRG and Wesley Andrews invited the Mole Lake Sokaogon Chippewa Community, the Forest County Potawatomi, and the Menominee Tribe of Wisconsin to participate in the identification, documentation, and evaluation of potential TCPs in the Crandon Project area. Only the Menominee elected to participate. Similarly, WCRI and Clyde Woods invited the three tribes to participate in the TCP studies beginning in December of 1995 and continuing well into 1996. Again, only the Menominee agreed to participate.

3.2.2.2 Introduction

Native American cultural resources are sites or places of heritage and/or contemporary concern to Native Americans along with the associated values and concerns for these places. Native American cultural resources can be identified in literature sources and in the oral history traditions of contemporary Indian groups. Native American cultural resources are commonly referred to as ethnographic or ethnohistoric sites. As used in this section, "ethnographic site" refers to a post-contact Native American site identified from published or unpublished literature sources, and "ethnohistoric or oral history site" refers to a post-contact Native American site

identified through oral history interviews. The ethnographic and ethnohistoric records may also include events and places from the pre-contact period insofar as they are reported from the memory of Native Americans who provided this information after Euro-American contact. Within this context, ethnographic and ethnohistoric refer to the same general period but are identified from different sources. Along with prehistoric and historic cultural properties, they may also be referred to as "cultural sites."

Traditional Cultural Properties, or TCPs, are Native American cultural resources which are eligible for inclusion in the National Register of Historic Places (NRHP) because of their special characteristics and cultural significance. The identification, documentation, and evaluation of TCPs is discussed in some detail below.

3.2.2.2.1 Regulatory Context

The major federal legislation which incorporates language and measures for the protection and preservation of Native American cultural resources includes the American Indian Religious Freedom Act (AIRFA), the Native American Graves Protection and Repatriation Act (NAGPRA), the Religious Freedom Restoration Act (RFRA), and the National Historic Preservation Act (NHPA), as revised. AIRFA requires federal agencies to evaluate policies and procedures with the aim of protecting religious freedoms of Native Americans including "access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites." NAGPRA sets forth the rights of Indian Tribes (and Native Hawaiians) with respect to human remains, funerary objects, sacred objects, and objects of cultural patrimony (collectively NAGPRA items) with which they can demonstrate lineal descent or cultural affiliation, and conveys to such groups the right to decide disposition or take possession of such items. The act protects Native American burial sites and controls the removal of NAGPRA items on federal, Indian, and Native Hawaiian lands. RFRA provides that governmental activity may substantially burden a person's free exercise of religion only if the activity is in furtherance of a compelling government interest and is the least restrictive means of furthering that interest.

Two Executive Orders are also relevant to the preservation of Native American cultural sites. Executive Order 11593 [36 CFR 8921, 16 U.S.C. 470], *Protection and Enhancement of the Cultural Environment* (1971), requires all federal agencies to inventory cultural resources on their lands, nominate significant properties to the National Register of Historic Places, and ensure that such properties are not inadvertently destroyed, damaged, or disposed of. More recently, Executive Order 13007 (1996), the *Indian Sacred Sites Executive Order* (61 FR 26771) (1996), directs federal land managers, to the extent practicable, permitted by law, and not clearly inconsistent with essential agency functions, (1) to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners, (2) avoid adversely affecting the physical integrity of such sacred sites, and (3) maintain the confidentiality of such sacred sites where appropriate.

The key federal guidelines for the protection and preservation of Native American cultural resources, and for Native American consultation on federal projects are embedded in the NHPA. Section 106 of the NHPA is applied in assessing the effects of a project on cultural resources (historic properties), and includes the stipulation that the federal agency seek information regarding the identification and evaluation of historic properties from Indian Tribes likely to have knowledge of or concerns for such properties in the area [36 CFR §800.4(a)(1) (iii)]. The

regulations also provide that when an undertaking may effect properties of historic value to an Indian Tribe on non-Indian lands, the Indian Tribe should be consulted [36 CFR §800.1(c)(2)(iii)], and that additionally, the government should seek similar information from "other Native Americans" with respect to undertakings that may effect historic properties of significance to such persons [36 CFR §800.1(c)(2)(iii)].

National Register Bulletin 38, *Guidelines for Evaluating and Documenting Traditional Cultural Properties* (Parker and King, 1990), reflects the government's partnership with Native Americans in the protection and preservation of cultural sites. Bulletin 38 is significant because it provides procedures to identify, document, and evaluate Traditional Cultural Properties (TCPs) and other cultural sites of importance to living Native Americans. Many of these sites were previously excluded for National Register eligibility due to their religious and often intangible nature. Similar to other potential National Register eligible sites, project effect for TCPs is determined through application of the NHPA regulations at 36 CFR §800.9(a-b). Also important, Bulletin 38 draws the attention of federal land managers and others to the range of cultural sites considered significant by Native Americans which have commonly been ignored in project planning. These kinds of sites are important, and should be considered in project planning and execution, even though they may not meet the requirements set forth in Bulletin 38 for TCPs. It is important to note that Bulletin 38 provides guidelines for federal agencies to follow according to their own particular policies, and that the conduct of TCP studies is similarly based upon individual agency policies and procedures.

3.2.2.2.2 Resource Identification

Native American cultural resources are commonly identified, documented, and evaluated through the application of three complementary and interdependent research efforts. These include (1) preparation of the ethnographic setting (overviews) which provides the historical and cultural context for the study area tribes, (2) preparation of an ethnographic inventory of Native American cultural resources in the study area and vicinity identified from literature sources, and (3) preparation of an inventory of Native American cultural resources in the study area and vicinity identified from oral history interviews and other sources. Some of these oral history sites may be potential Traditional Cultural Properties (TCPs) eligible for listing in the NRHP. For purposes of the present study, the overviews (Ethnographic Setting) are followed by a section which discusses potential cultural resource types which might be found in the study area and vicinity (Potential Cultural Site Types in the Study Area and Vicinity), and an inventory of cultural resources identified in the study area and vicinity (Inventory of Cultural Sites in the Study Area and Vicinity). The ethnohistoric research is encompassed within the TCPI work, with sections on potential TCPs which might be found in the study area and vicinity (Potential TCPs in the Study Area and Vicinity) and an inventory of potential TCPs in the study area and vicinity (Traditional Cultural Properties Inventory). The methodology employed to conduct the research is described preceding each of the sections. Since the Wisconsin SHPO made a specific request for an investigation of TCPs in the project area, a more detailed research design was prepared for this research component.

3.2.2.2.3 Study Area

The project site, or area of disturbance for the Crandon Project, is described and defined in Section 2 of the EIR. It includes the plant site (PS), tailings management area (TMA), a wastewater discharge corridor (WWDC), and a wetland compensation site (WCS). The access

road, tailings pipeline corridor, and railroad spur are also included. The inventory study area for the present investigation of Native American cultural resources for the PS/TMA encompasses a circular area delimited by an eight mile diameter centered over the Crandon ore body; the study area for the WWDC is defined as a two mile wide corridor centered over the approximate 38.3 mile length of the pipeline alignment; the study area for the WCS includes a one mile buffer zone on each side of the wetlands compensation location; the study area for the access road (ACR) is a one-half mile corridor centered over the road; the study area for the tailings pipeline corridor (TPL) is a one-half mile corridor centered over the pipeline; and the study area for the railroad spur (RRS) is a one-half mile corridor centered over the railroad spur. In order to provide a better understanding of Native American occupation and utilization of places in the vicinity of the project, many sites situated well beyond the study area defined for the PS/TMA are included in the inventory. This approach is further described in Section 3.2.2.5.2.2 and Section 3.2.2.6.3.

The USCOE has described the methods to be used in defining the preliminary Area of Potential Effect (APE) for the cultural resources studies in several letters to the tribes. They note that "Until watershed and groundwater modeling efforts are concluded, the area of potential effect will include an area extending roughly two and one-half miles in circumference [radius] from the ore body", bounded by Swamp and Hemlock creeks to the north, Rice and Mole lakes to the west, Rolling Stone and St. John's lakes to the south, and Ground Hemlock Lake to the east. Other areas of potential disturbance include all ground disturbance, the corridor along the entire WWDC route, and a corridor along STH 55, between the towns of Crandon and Mole Lake, subject to potential secondary development. The USCOE will also evaluate any physical, visual, or auditory effects on any historic or traditional cultural property that has been determined eligible for listing on the National Register of Historic Places that the tribe believes will be affected by the project, as long as the tribe can clearly demonstrate the extent and nature of the effect (Wopat, 1996, letter). In a subsequent letter to the tribes, the USCOE states that ". . . we have determined that the best strategy is to not specifically define the Area of Potential Effects. Rather, we will review all properties the [tribes] submit for consideration as TCPs (Wonsik, 1996, letter)." Accordingly, the tribe/s will need to show that the property is a TCP (eligible for listing on the National Register), and that the project would have a physical, visual, or auditory effect on the property.

The Study Area, and area of potential effect, defined for the Native American cultural resources studies in this report is consistent with the approach suggested by the USCOE, although it covers a more extensive area for purposes of the preliminary inventory of cultural sites, including potential TCPs, in the study area and vicinity of the project.

3.2.2.3 Ethnographic Setting

3.2.2.3.1 Methods

The major historical, ethnographic, ethnohistoric, archaeological, and other literature sources were reviewed to identify the principal Native American tribes who occupied the study area from the contact period to the present. The Ojibwa (Chippewa) and Potawatomi were identified as the historic occupants of the study area. Contemporary descendants of the Ojibwa and Potawatomi are the Mole Lake Sokaogon Chippewa and the Forest County Potawatomi. Both groups have reservation lands in the vicinity of the proposed project and within the limits of the study area defined for the Native American studies.

The Menominee are included because of their prehistoric and historic occupation and utilization of parts of the study area and vicinity, because their historic lands included the wetlands compensation site, and because of their concerns for the waters of the Wolf River. The Menominee were included at the outset of the project because of their strong concerns and beliefs regarding the potential for impacts to the Wolf River, which runs through their reservation. A tributary of the Wolf River was originally proposed for the waste water discharge. Even though the project has been redesigned so that the proposed wastewater discharge would be to the Wisconsin River, the Menominee retain their concerns for potential impacts to the waters of the Wolf River.

The key literature sources which deal with the historic and contemporary lifeways and culture of the Sokaogon Chippewa, Forest County Potawatomi, and the Menominee Tribe of Wisconsin and their predecessors were reviewed to prepare summary overviews for each group. Each of the overviews includes a brief account of bibliographic sources, prehistory, history, tribal territory, settlement patterns, subsistence and technology, social and political organization, religion and ritual, and life cycle and mortuary practices. This information also provides the historical and cultural context for the identification of Native American cultural resources, including potential TCPs, in the study area and vicinity. The Chippewa overview, which is presented first, includes a more extensive review of prehistory and history since much of this information applies to all three groups.

Additional information on Sokaogon Chippewa, Forest County Potawatomi, and Menominee culture, history, and cultural sites is provided in Section 3.2.2.4, Potential Cultural Site Types in the Study Area and Vicinity, Section 3.2.2.5, Inventory of Cultural Sites in the Study Area and Vicinity, and Section 3.2.2.6.4, Potential TCPs in the Study Area and Vicinity.

3.2.2.3.2 Results

3.2.2.3.2.1 Sokaogon Chippewa (Ojibwa)

Introduction

The Chippewa (or Ojibwa) are part of a larger body of Algonquian speaking people who once occupied much of the heavily forested regions of the Upper Great Lakes and south-central Canada (Tanner, 1987:map 13). The Mole Lake Sokaogon Chippewa Community belongs to the Lake Superior bands of the Chippewa who share cultural characteristics with many of their neighbors such as the Lac Vieux Desert, Lac du Flambeau, and Lac Courte Orielles communities of Chippewa. The Ojibwa called themselves the Anishinabe, meaning "original people," while neighboring groups referred to them as the Ogibwa, meaning "people who make pictographs" (Danziger, 1979:7). The name Ojibwa was corrupted into Chippewa by the British, a name by which the tribe is still known.

The Ojibwa speak a language which is part of the Central Algonquian group of the larger Algonquian linguistic family (Goddard, 1978:583). The Central Algonquian group consists of seven languages that were spoken aboriginally in the Upper Great Lakes region and areas of northern Canada east of the Great Plains (Goddard, 1978:583). These languages include Potawatomi, Menominee, Fox, Miami-Illinois, Shawnee, Cree, and Ojibwa.

The Algonquian linguistic family, consisting of some ten languages, is believed to have developed from a Proto-Algonquian parent language that was spoken an estimated 2,500 - 3,000 years ago (Goddard, 1978:586). Linguistic evidence suggests that the most likely homeland of the Proto-Algonquian language is the area between Georgian Bay and Lake Huron (Siebert, 1967). The linguistic evidence also suggests that as the original Proto-Algonquian core area began to expand, the language fragmented into ten or more distinct languages, which became the progenitors of the historically known Algonquian language groups.

Ojibwa is recognized as a single language made up of numerous dialects (Goddard, 1978:583). In addition to the many dialects, regional linguistic subtypes have been identified within the Ojibwa language. The most distinct of these subtypes, described by Bloomfield (1957), is that known as Southern Ojibwa. Dialects of Southern Ojibwa are spoken by the Ojibwa and Ottawa of Michigan's Lower Peninsula, the Ottawa of Manitoulin Island, and the Ojibwa and Mississauga occupying southern Ontario (Goddard, 1978:583).

Other Ojibwa subtypes are less well defined than Southern Ojibwa. In the area to the north of the Southern Ojibwa area, distinct dialects are reflected in the speech of Ojibwa speakers living near the mouth of the Ottawa River in southern Quebec, and those along the St. Lawrence River. The Ottawa River dialect is believed to reflect the speech of missionized Indians originally from the Lake Nipissing region, while the dialect of Ojibwa speakers along the St. Lawrence is believed to closely resemble the Algonquian originally spoken along the St. Lawrence (Goddard, 1978:583). Together with other dialects spoken north of the Southern Ojibwa area, the Ottawa and St. Lawrence river dialects are believed to comprise a second subtype of the Ojibwa language.

The third major Ojibwa linguistic subtype is represented by the dialects spoken in the Upper Peninsula of Michigan, northern Wisconsin, and northern Minnesota. Within this subgroup, there is an additional dialectical break between the speech of the southern shore of Lake Superior and that of central and northern Minnesota (Goddard, 1978:583). Additionally, Minnesota Ojibwa is comprised of a Mississippi dialect spoken in the Mille Lacs Lake region and a northern dialect spoken on the larger northern reservations such as Red Lake (Goddard, 1978:583).

Bibliographic Sources

An extensive series of published and unpublished sources are available with regard to the ethnohistory of the Ojibwa. The major source referencing the 17th and 18th Century Ojibwa is the multi-volume transcription of the Jesuit Relations (Thwaites, 1869-1901) which details early European interaction with Ojibwa and other Native American groups. A variety of sources are available for 18th and early 19th Century accounts. Among the more comprehensive of these works is William Warren's 1885 history based largely on oral traditions of Minnesota and Wisconsin Ojibwa groups. The recollections of Alexander Henry (1809) provide an important source for descriptions of Upper Great Lakes Ojibwa lifeways. Another fairly comprehensive treatment is found in Copway's 1860 memoir of life among the Ojibwa. Benjamin Armstrong's (1892) reports of early 19th Century Ojibwa-Sioux-U.S. Government relations provide first-hand accounts of many treaty era events. Finally, a detailed description of Great Lakes Ojibwa life in the early and mid-19th century is available in the account of the German traveler Johann Kohl (1860).

Major ethnographic studies relative to Ojibwa groups in the Great Lakes area include Densmore's 1929 general ethnography, and Ruth Landes' (1937, 1968) studies of Ojibwa sociology and religion. Also invaluable is the Ojibwa life cycle ethnographic study reported by Inez Hilger (1950). The Garland series of ethnohistorical studies edited by David Horr (1974) includes seven volumes dealing with Ojibwa lifeways and tribal movements. Hickerson's (1970) ethnohistorical study also provides detailed syntheses of Ojibwa culture and external relations. Northern Ojibwa groups are well documented in Rogers' (1962) account of fieldwork among the Round Lake band. A more recent scholarly portrayal of Ojibwa ethnography is Danziger's (1979) study. Ancillary studies of note include Quimby's (1960, 1966) overviews of Great Lakes Indian culture history and Vernon Kinietz's (1940) *The Indians of the Western Great Lakes.*

Useful introductions to Ojibwa culture and history can be found in summaries provided by Ritzenthaler (1978) and Rogers (1978). Modern comparative historical treatments relative to Great Lakes Indian life are contained in White's (1991) study of unfolding Indian-White relations in the Great Lakes region and Cleland's (1992) account of the history and culture of Indian groups resident in Michigan. Finally, a uniquely comprehensive cartographic compilation of Great Lakes Indian groups is available in the *Atlas of Great Lakes Indian History*, edited by Helen Tanner (1987).

The Sokaogon Ojibwa remain one of the more poorly documented Ojibwa groups. Scattered references to Ojibwa bands living in the general vicinity of the existing Mole Lake Reservation can be found in a number of the sources listed above. However, the group has never been the subject of a formal ethnography. A history of the Ojibwa published in 1956 (Levi, 1956) does include a brief summary of the Sokaogon band drawn from oral accounts and archival documents. Charles Wisdom's (1936) investigations into the problems of landless Indians of the Great Lakes also includes some information specific to the Mole Lake Sokaogon Chippewa.

Primary source materials including documents, oral accounts, and maps relating to the history of the Sokaogon are on file with the Archives Division of the Wisconsin State Historical Society. The Sokaogon also maintain a variety of records in their Tribal Archives on the Mole Lake Reservation. Additional material is curated at the National Archives in Washington, D.C. An exhaustive compilation of much of the archival materials noted above, along with secondary and tertiary sources, has been prepared by the law firm of Foley & Lardner in conjunction with *Sokaogon Ojibwa Community vs. Exxon Corporation et al.* (Case No. 86-C-0599). These 1991 documents represent an invaluable research tool and guide to the materials available.

There is very little published or unpublished material relating to the contemporary society and culture of the Mole Lake Sokaogon Chippewa. Statistical data is available from BIA sources (1976). A number of Section 106 compliance driven studies focusing on the Sokaogon are available. Among these is an economic study conducted by the Bureau of Indian Affairs (Anonymous, 1977), and socioeconomic assessments related to the potential effects of the Crandon Project (Cleland, et al., 1995; WDNR, 1986; Geisler, et al., 1982; Geisler, et al., 1980).

Prehistory

Ojibwa tradition holds that in prehistoric times, the tribe occupied a homeland located near an ocean. Ethnographic evidence suggests that this homeland was located on the Atlantic seaboard, probably near the mouth of the St. Lawrence River (Warren, 1885:76-81). From this eastern base, the Ojibwa and the Algonquian speaking Ottawa and Potawatomi gradually migrated west

along the St. Lawrence, and arrived in the western Great Lakes region during the late 16th and early 17th centuries. Arriving at Sault Ste. Marie, Michigan, the three groups split from one another. The Potawatomi migrated south along Lake Michigan, while the Ottawa occupied the region around Lake Nipissing and the northern shore of Lake Huron (Danziger, 1979:7). By the late 1600s, the Ojibwa were firmly established along the southern shores of Lake Superior, where their villages were encountered by the earliest French missionaries and voyagers who entered the Great Lakes region (Wheeler-Voegelin and Hickerson, 1974).

History (1610 - 1820)

The Historic Period in the Great Lakes began in 1615 when Samuel de Champlain sailed into Lake Huron and established trade relations with the Hurons (Stone and Chaput, 1978). Responding to Huron stories of a great sea to the west, Champlain initiated a policy of sending young Frenchmen west to live among the various Indian tribes, learn their lifestyles, and seek out the western sea. Thus, Etienne Brule traveled to the northern reaches of Wisconsin territory in 1622, and Jean Nicolet landed at Green Bay in 1634.

The French voyagers Radisson and Groseilliers were among the first Europeans to enter the western Lake Superior region. Warren (1885) describes an oral account told among the Lake Superior Ojibwa of two white traders wintering on Madeline Island sometime in the 1650s. It is tempting to suggest that the Ojibwa account refers to the 1654-1656 journey of Radisson and Groseilliers recounted in the *Jesuit Relations* (Thwaites, 1869-1901:28:319; 42:219-221). Whether Radisson and Groseilliers are the white men of the Ojibwa account, by the end of the 1660s, the Lake Superior Ojibwa were fully aware of the European presence in the Great Lakes region, and were active participants in the European fur trade.

The advent of the fur trade in the Lake Superior region had a number of lasting ramifications for the Ojibwa people. First, the unprecedented quantity and quality of the furs from the region quickened the pace of European advances into the region. The second, and more far reaching effect the fur trade had on the Ojibwa, was that it created a situation where hunting was no longer purely a subsistence activity. Rather, the pursuit of game and the type of game hunted "was made systematic and stimulated by the European demand for furs" (Turner, 1977:36). As the trade in furs increased, so too, did the amount of manufactured European goods acquired by Indian groups. In the early stages of the fur trade, Indians were highly selective in their demand for European goods, trading only for articles that were improvements on ones they already had, or that offered more efficient ways of doing things they had already done.

With their presence firmly established in the Western Great Lakes, symbolized by permanent settlements at Sault Ste. Marie, Michilimackinac, Chequamegon, Green Bay, and La Pointe, French influence was at its apex by the end of the 1660s. Much of this would change, however, as a series of European wars decided the spheres of influence in the New World. Beginning with the War of Spanish Succession in 1701, France and England were involved in a series of conflicts on the European mainland. These wars had a disastrous effect on the French position in the New World. Under the terms of the Treaty of Utrecht, which ended the War of Spanish Succession in 1713, the British gained control of the French settlements at Hudson Bay, Newfoundland, and Acadia. Most importantly, the treaty allowed the British to establish trade relations with the Indian tribes of the Western Great Lakes. The influx of British trade goods, which were higher quality and less costly than comparable French items, seriously undermined the French monopoly on the fur trade in the region.

Tensions between the British and French continued to escalate throughout the 1700s, as each sought to incorporate North America into their empire building plans. The rivalry between the European powers for control of the North American fur trade culminated with the opening of hostilities of the French and Indian War in 1754. Central in the dispute between the two countries was the encroachment of British traders into lands in the Ohio Valley, Upper Mississippi, and Great Lakes region, which the French "considered theirs by inviolable right" (Kellogg, 1925:406). The war lasted seven years, ending with the surrender of Montreal and Canada to the British in 1761 (Stone and Chaput, 1978).

The end of the war in North America, and the subsequent terms of the Treaty of Paris in 1763, resulted in profound changes for the Indian people of the Western Great Lakes. According to the peace terms, Britain gained control of all of the French holdings in North America. French citizens were allowed to retain their property holdings and remain in the former French areas, but were subjected to British rule and laws.

For Wisconsin's Indian population, the British era in the state posed different challenges. The first French traders among the Indians were not agriculturalists. As such, their interests were in harvesting the furs of the forest, not in acquiring vast tracts of land. Where the French did establish permanent settlements, they were most often adjacent to existing Indian villages. The British, however, "were interested not only in pursuing the fur trade, but also in expanding the colonization and settlement of new areas of North America and in acquiring and developing other types of resources and products, such as mining interests and forest and agricultural products" (Stone and Chaput, 1978:606). A policy of the British that was particularly insulting to Indian groups was that the British did not freely exchange trade goods with native groups in order to secure friendship and cooperation as did the French. Instead, British trade goods were used only as part of an economic exchange.

British trade policies toward the Indians, as well the growing suspicion among native groups that the British were bent on seizing their lands, led to Pontiac's Rebellion in 1763, during which Michilimackinac was captured. The uprising of 1763 prompted the British to instigate a number of policies favoring Indian concerns, including the reservation of all lands west of the Allegheny Mountains for Indian use. However, before the effects of these policies could be felt in the Western Great Lakes, the Revolutionary War had begun in the American colonies.

The onset of the American Revolution forced Indian people to once again choose sides between different foreign powers. Most of the Indian tribes of the Western Great Lakes aligned themselves with the British, perceiving them as less of a threat to their homelands than the land-hungry colonials (Stone and Chaput, 1978:607). During the course of the Revolution, the fur trade in the Great Lakes region was severely curtailed, putting an additional economic hardship on Indians, who by this point had become almost wholly dependent on the trade for their survival.

The end of the Revolutionary War in 1783, signaled the end of the era of British control within the territory of the United States. The beginning of the subsequent American period of control brought with it additional challenges for Indian people, particularly in relation to the acquisition and control of land. For the most part, the American public viewed the western lands gained from the British as conquered territories which were open for settlement. Much of the lands held by Indians in the Western Great Lakes were eventually ceded to the United States Government in partial atonement for their support of the British during the Revolutionary War.

Indians were forced to relocate on reservation lands which were often encroached upon or usurped by American settlers.

During the American period, the fur trade in the Upper Great Lakes was nearing its peak. Under the administration of the American Fur Company, the trade operated out of Michilimackinac with a number of sub-agencies placed throughout the northern Great Lakes. Indian trappers were able to trade their furs at the sub-agencies in exchange for goods and supplies. Typically, the seasonal round followed by Indians involved in the fur trade consisted of trapping during the winter and delivery of furs during the spring. Pelts brought in during the spring delivery were traded for supplies necessary to continue trapping during the coming winter.

History (1820 - Present)

Throughout the late 1700s and the early 1800s, the United States government entered into a series of treaties with the various Indian tribes of the Upper Great Lakes. During this period, numerous tribes sold their lands to the United States in exchange for the continued use of the land, and annual payments in cash and goods. These treaties were typically negotiated separately with each tribe, and often differed substantially in the terms they granted to the tribes. Treaties were negotiated at the various agencies established throughout the Western Great Lakes, including the La Pointe agency, established in 1831, and the Green Bay agency, established in 1824 (Stone and Chaput, 1978:608).

In an effort to "Americanize" the Indian people, the treaties usually included provisions to supply each tribe with a carpenter, blacksmith and farmer. While many Indians learned these or other trades such as lumbering, the efforts of the government to end traditional Indian values and attitudes often ended in failure. The traditional culture of the Indians of the Western Great Lakes was altered by nearly 300 years of contact with Europeans, but the "old ways" were not forgotten. Traditional beliefs and values often survived intact and unchanged. For example, various efforts of the United States governments could do little to ease the traditional, nearly continual, state of warfare that existed between the Ojibwa and the Dakota Sioux. Throughout the early part of the 1800s, battles between the tribes continued to be fought in northern Wisconsin and Minnesota, despite the efforts of the United States Government to secure peace between the two groups.

The origins of the Sokaogon Chippewa can be traced to the westward expansion of the Ojibwa (Chippewa) during the late 17th century from Sault Ste. Marie at the eastern end of Lake Superior. The Ojibwa established major settlements along the northern and southern shores, and then pushed further south where they encountered the Menominee and other tribes who hunted and gathered on the highlands of northern Wisconsin (Mason, 1988). The Chippewa had permanent possession of northern Wisconsin by the middle of the 18th century with major settlements at Lac Vieux Desert, Lac du Flambeau, and Lac Courte Orielles (Cleland, et al., 1995:40). The Sokaogon Chippewa have a history of intermarriage with other Chippewa bands at Lac Vieux Desert and Lac du Flambeau, and it is probable that families of Sokaogon left that area and arrived at the headwaters of the Wolf River around the middle of the 18th century (Cleland, et al., 1995:41). Warren (1885:192) reports groups of Lac du Flambeau Chippewa leaving the village in the mid-1700s "to occupy the Pelican Lakes in the direction of Lake Michigan."

According to tribal testimony given in the 1920s, other groups had left the Upper Peninsula of Michigan and emigrated to the area during the 1840s (SCC vs. Exxon, 1991:11-12, 116, 120-121). In a 1966 written statement, tribal member Alice Randall states that the tribe migrated from Madeline Island in the early 1700s. Interviews with band members in Crandon, Wisconsin in 1919 revealed that the band came from the Lake Butizar region (Coleman, 1919). Whatever their derivation, ancestors of the Sokaogon Chippewa were in the vicinity in 1843 when a BIA census recorded 134 full-blood Chippewas living at Pelican Lake (Danziger, 1979:79). There is little mention of the Sokaogon in historical records until the treaty and reservation period.

Sokaogon chiefs were signatories to the 1854 La Pointe Treaty, which granted several Chippewa bands reservations of their own and created larger residual reservations for the remaining bands. Following the Treaty, the United States insisted that the Sokaogon move north to the reservation at Lac du Flambeau. The Sokaogon refused to leave the area, however, insisting that they were entitled to a reservation of their own. According to Sokaogon tribal oral traditions, they were promised a 12 square mile reservation in the area around Pelican, Mole, and Post lakes at La Pointe in 1854, a promise which was never acknowledged by the federal government. Danziger (1979:153) notes that this promise to the Sokaogon was made by BIA negotiators when they signed a treaty in 1855, and that the United States Senate's refusal to ratify it left this Lost Band landless. In any case, the federal government rejected the Sokaogon claim to their own reservation, but did allow the Sokaogon to remain in their homeland rather than remove them involuntarily to one of the other Chippewa reservations.

The Sokaogon were to remain in this area as squatters on lands they had occupied since the middle 1800s, "eking out a living as best they could in what had been their tribal homelands (Lurie, 1980:1)," until they were given reservation lands in 1939, a period of over 80 years. Some of the more descriptive accounts regarding the Sokaogon Chippewa quest for a reservation and assistance from the federal government documented in the archival records are summarized below.

In March of 1868 Chief *Me-gee-see* (through an interpreter) wrote to the Detroit Office of Indian Affairs from Rice Lake, noting that his band could receive their annuities at Shawano or Keshena, but that they would prefer to receive them at Post or Rice lakes (Me-gee-see, 1868a), and in June wrote again explaining that the two bands congregated at Post Lake and Swamp Lake (Rice Lake) in the latter part of August and stay until the end of October (Me-gee-see, 1868b). In 1869 he petitioned the Commissioner of Indian Affairs in Washington for a reservation explaining that they signed the Treaty of 1854 with the understanding that the two bands "were not signing away our homeland altogether, but that we would have a reservation in the vicinity of Post Lake, where we could fish, gather rice and make sugar (Me-gee-see, 1869)." The petition was signed by 74 members of the two bands. In a letter dated July 18, 1872 then Chief *Wambisk-ki-ba-nince* (1872) wrote to the Commissioner of Indian Affairs in Washington again requesting that their annuities be paid at "Post Lake, Rice Lake, or vicinity."

In one of many investigations ordered by the federal government to report on the condition and status of the bands at Post Lake and Rice Lake, Indian Agent E. Stephens met with Chief *Guing Guish* and second Chief *Kosh Kish* at Keshena in 1879 to discuss their land claim and past distribution of annuities. Wm. W. Johnston [aka Johnson] served as interpreter. The chiefs testified that 200 members of the Post Lake band lived at Post Lake and Pelican Lake and that they were the *Megesee* (eagle) and *Neegisk* (otter) bands named in the treaty of 1854 (Stephens, 1879).

In July of 1897, District Attorney Samuel Shaw of Crandon wrote to the Secretary of the Interior in Washington regarding the plight of the 170 Rice Lake Indians, noting that ". . . their chief is *Yabiskeebeneesa*, (White Eagle), whose father was *Meekeesi*, now dead for about 25 years. The last government aid these people got was about 29 years ago . . .(Shaw, 1897)."

In August of 1897, in compliance with orders from the Commissioner of Indian Affairs, an Indian Agent G.L. Scott (1897a) met with the band at Rice Lake, noting that they numbered between 150-200 and that their condition warranted improvement. Scott commented in a letter dated November 1897 that "they have never lived on a reservation; but the majority of them have always lived in Forest County, Wisconsin near Rice Lake . . . [they] . . . eke out a miserable existence by hunting, fishing, gathering berries and wild rice and a few persons do a little work for white people among whom they live . . . [and] . . . it would be impossible to remove them to any of the other reservations without resorting to force; as they seem very much attached to the country in which they have lived so long (Scott, 1897b)."

In March of 1899, again with the aid of District Attorney Samuel Shaw, members of the band petitioned the Secretary of the Interior for a reservation, noting that "we greatly prefer that it be at or near Rice Lake, the home of our band for many generations (Shaw, 1899)."

Annual Reports to the Commissioner of Indian Affairs in the early 1900s reference the conditions of the Rice Lake Band of Chippewa Indians living near Crandon Wisconsin. Indian Agent Campbell at the La Pointe Agency refers to them as the "Lost Tribe" or "Rice Lake Band of Chippewas" in 1910 (Campbell, 1910); Indian Agent Bennett at Laona in his 1916 annual report references the "approximately 100 Chippewa Indians, known as the Rice Lake Band, located near Crandon, Wisconsin" (Bennett, 1916); Bennett then notes in his report of 1917 that the Rice Lake Band are living or camping on lands belonging to lumber companies and roaming from place to place as they have no settled home or lands on which to live (Bennett, 1917); and in 1918, Agent Bennett states that he has been giving assistance to " the approximately 100 Chippewas located in the vicinity of Crandon, Wisconsin, known as the Rice Lake Band (Bennett, 1918)."

Acting under instructions from the Commissioner on Indian Affairs, in November of 1919 Inspector W.S. Coleman investigated the conditions of the Rice Lake, Post Lake, and Mole Lake Indians and their status under the treaty of 1854. Coleman talked with *Me-sa-bay, Ma-gwa-ya-chi, Ashe-we-be-ne-si, O-ne-ta-mekesick*, and others in Crandon, Wisconsin. He was told that the people descended directly from the Lake Superior Chippewa, that they came from the Lake Butizar region directly to the Mole Lake region they now occupy, that they have no land or home of their own, and that the basics of their treaty allowing for hunting, fishing, fuel, berry picking, and wild rice gathering have been denied to them (Coleman, 1919). Coleman's recommendations for land and assistance were not acted upon.

Again, in 1920, under instruction from the Commissioner on Indian Affairs, Superintendent W.W. Bennett was dispatched to the Rice Lake area to investigate the rights as far as possible of the Rice or Post Lake Band of Chippewa Indians. Bennett held council with members of the band and concluded that "These people seemed to have settled at Rice or Post Lake long prior to making of the treaty with the various Chippewa bands in 1854 . . . [and that] . . . these Indians were settled in the vicinity of Rice Lake or Post Lake . . . seventy-five years or more ago and have always remained in the vicinity (Bennett, 1920)."

The Post Lake Chippewa Band again petitioned the government for land and relief in 1922, providing a history of their chiefs and the place of their burial, and in that same year, another investigation was ordered by the Commissioner of Indian Affairs. The investigation was undertaken by Inspector Heber M. Creel, who compiled tribal rolls and interviewed many of the tribal members (Creel, 1922). Places of birth and habitation within the general area included Post, Rice, Mole, Sand (Pelican) lakes, Pelican Creek, and Crandon. Creel concludes that "in general these Indians testify that their parents lived in the vicinity of Rice, Mole, and Post lakes, were born there, that their grandparents were here alive in some cases, that they were told by their parents that they too always lived in this vicinity." He goes on to state that "if I spent days in further investigations, their testimony would not vary as to the fact that they were and have been over 100 years a distinct-independent band of Chippewa Indians . . . (Creel, 1922)."

In a Memorandum to the Commissioner of Indian Affairs in 1930, a Dr. Wooster stated that there were about 141 of these Indians (nearly all full-bloods) residing in Forest, Langlade and Oneida counties with 87 at Mole Lake, "where, as shown by the record, they were living as early as 1800 (Wooster, 1930a)." In a subsequent report to the Commissioner, Wooster (1930b) after conducting interviews and reviewing previous reports states that, "The evidence obtained is compelling that these chiefs of the Lost Band of Chippewas about 1841 left L'Anse Reservation to seek better hunting grounds, and removed to Pelican, Post, and Mole lakes, Wisconsin, where they remained."

The Sokaogon were not recognized by the United States as a distinct Chippewa band, and were largely ignored by the government, until passage of the Indian Reorganization Act of 1934 (Geisler, et al., 1980:412). Under the terms of this act, in 1939 the United States government purchased 1,680 acres centered on Rice Lake in Forest County, Wisconsin and provided these to the Sokaogon as a permanent reservation (Danziger, 1979:154). Tribal membership is determined by direct blood relationship to anyone on the tribal rolls established in 1937. In 1982 the reservation was increased to 1,800 acres.

Ethnographic accounts of the Sokaogon Chippewa are lacking. Ross (1937) offers some insights on the Indians in the Crandon area for the late 1880s. Sketchy accounts for the 1930s and 1940s are available in Wisdom (1936) and Levi (1956). Wisdom reported that since Post Lake had become a resort, the Mole Lake community, situated between Rice and Mole lakes, had become the principal community. It was reportedly closer to Rice Lake because of the abundance of rice there. Mole Lake had no rice, but was used for fishing and trapping of muskrats (Wisdom, 1936:407). For the early 1940s, Levi reported that:

> The principal means of gaining a livelihood for this group are boat building, gathering wild rice and wreath greens, and selling souvenir bows and arrows, and other novelties. The soil, a sandy loam with gravel outcroppings, yields fair crops of potatoes and vegetables, oats, clover, and timothy hay. Game on the reservation includes deer, muskrats, and wild fowl . . . since they have become an organized band of Indians, the stigma "Lost Tribe" has been removed (1956:98-9).

The dominant physical feature of the Mole Lake Indian Reservation is Rice Lake, considered one of the best wild rice producing lakes in Wisconsin, and a vital part of the economic and social life of the Sokaogon Chippewa (WDNR, 1986:113). In 1986, the WDNR reported total membership of the Mole Lake Sokaogon Chippewa at 1,093; with 271 living on the reservation, 72 living within a fifty mile radius of the reservation, and about 750 living elsewhere. According

to statistics reported by the tribe to the BIA in 1993, there were 512 Indian residents at Mole Lake, with 464 living on the reservation. The majority of the work force is employed in tribal programs, and some work for the gambling casino at Mole Lake. Settlement is clustered along the roadways and concentrated along STH 55 with some residences south and west of Rice Lake. The Mole Lake reservation is the smallest and poorest in Wisconsin (Cleland, et al., 1995:48-9).

In the mid-1980s, a household survey reported that over 86 percent of Sokaogon Chippewa families relied, in a range from somewhat to a great deal, on hunting and fishing for food, and over 90 percent used gardening, ricing, and picking wild plants somewhat to a great deal (WDNR, 1986:108). Cleland, et al., reported that the Sokaogon Chippewa are a traditional band which follows many of the cultural traditions of their ancestors, such as the observance of harvest rituals under the leadership of Rice Chiefs, preservation of the "big drum", and participation by some tribal members in the *Mide-wi-win* Society (1995:47). Hunting, fishing, gathering, and wild rice harvesting are important traditional activities which remain highly significant for tribal economics and family subsistence.

The Sokaogon Chippewa opened a bingo hall on the Mole Lake Reservation in 1975, and in 1991, casino style gaming facility was added at a separate location on the reservation. These developments, along with tax-free tobacco sales and other tribally owned and operated activities has increased employment opportunities and tribal revenues.

Tribal Territory

By the middle part of the 17th century, the Ojibwa had established themselves as permanent residents of the region around northern Lake Huron and eastern Lake Superior, with their primary village located at Sault Ste. Marie (Hickerson, 1970:13). From this settlement, bands of Ojibwa steadily pressed further west along the southern shore of Lake Superior and into the lake country of Wisconsin and Minnesota.

Hickerson (1970:13) has pointed out that while many Indian groups experienced significant territorial restrictions as a result of European encroachment, Ojibwa territories actually expanded. This result reflects the ardent Ojibwa participation in the Great Lakes fur trade which led them to occupy new trapping grounds (Hickerson, 1970:13). Because of their friendly relations with the French and increasing role in the fur trade, the western expansion of the Ojibwa was largely coincidental with French expansion of the fur trade into western Wisconsin and northern Minnesota (Ritzenthaler, 1978:744). As the Ojibwa expanded their range in Wisconsin and Minnesota, there was a tendency for population centers and settlements to be established near trading post locations. In 1692, when the French reopened their trading post at Chequamegon Bay, on the south shore of Lake Superior, there was an estimated population of 1,000 Ojibwa at the settlement (Ritzenthaler, 1978:744).

According to various authors (Danziger, 1979; Hickerson, 1962, 1970, 1974; Neill, 1885; Ritzenthaler, 1978; Warren, 1885), prior to 1679, the southwestern Ojibwa were concentrated in a main settlement at Sault Ste. Marie. Between 1679 and 1736, a commercial alliance with their former adversaries, the Dakota Sioux, allowed groups of Ojibwa an opportunity to leave the Sault and enter into formerly contested lands, establishing settlements along Lake Superior (Wright, 1951:65). The majority of these transplants from the Sault were concentrated in two villages located on the Chequamegon and Keweenaw peninsulas (Wright, 1951:65). During this

same period, a group of Chequamegon Ojibwa occupied a settlement on the Vermilion River, in northeastern Minnesota (Wright, 1951:71).

Ojibwa expansion into northwestern Wisconsin and adjacent parts of Minnesota brought them into direct competition with the Dakota Sioux for the use of the territory and its abundant resources, particularly the numerous wild rice lakes. Throughout the 18th and 19th centuries, the Ojibwa and Dakota fought a series of battles as each group attempted to expel the other from the rice lakes region. Early Ojibwa successes in these skirmishes strengthened their foothold in the Lake Superior region, and allowed them to advance into the interior of Wisconsin and Minnesota. By the end of the century, the Dakota were effectively driven from portions of the lake country, and the Ojibwa began to establish village sites in the contested territory.

By the beginning of the 19th century, the Ojibwa in Minnesota and Wisconsin formed two principal groupings. These were the Ojibwa of the Mississippi who occupied the former Sioux lands in the upper Mississippi River valley from St. Anthony Falls to the Canadian border, and the Ojibwa of Lake Superior who lived in areas of Michigan, Wisconsin and Minnesota adjacent to Lake Superior.

Beginning in the early 1800s, white settlement throughout the upper Great Lakes steadily increased, prompting the United States government to enter into land cession negotiations with the various Indian tribes in the region. The first of these treaties, the Prairie du Chien Treaty of 1825, attempted to end hostilities between the Indian groups of the upper Great Lakes by establishing territorial boundaries for each group (Danziger, 1979:75-76). The Treaty of Prairie du Chien defined a boundary between the Ojibwa and Sioux that ran southeast through Minnesota into Wisconsin. The Sioux were to remain south of the line and the Ojibwa to the north. The treaty officially conferred to the Ojibwa nearly the entire northern half of Minnesota, an area they had recently driven the Sioux from (Danziger, 1979:75).

Subsequent treaties between the United States and the Ojibwa resulted in the transfer of immense tracts of Indian land to the United States government. The first of these treaties, concluded in July of 1837, transferred the region between the Mississippi and St. Croix rivers, along with a large portion of northern Wisconsin from the Ojibwa to the United States (Royce, 1899:766; A. Smith, 1985:147). Five years later, the Chippewa were persuaded to sell their remaining territory in Wisconsin and Michigan (A. Smith, 1985:149). In both treaties, the Ojibwa specifically retained the right to hunt, fish and gather wild rice from the ceded territories (A. Smith, 1985:147). Eventually, however, these rights were restricted, as the Lake Superior Ojibwa were assigned to reservation lands set aside for their use by the 1854 Treaty of La Pointe.

Although the Lake Superior Ojibwa had been assigned reservation lands by the 1854 La Pointe treaty, the majority of the Mississippi River Ojibwa did not enter into treaty negotiations with the United States government until 1855. In a treaty signed that year in Washington D.C., the Mississippi River bands of Ojibwa ceded to the United States the heartland of the Mississippi River headwaters in exchange for ten tracts of reservation land in the ceded territory (Royce, 1899:802). Many of these reservation lands were later ceded to the United States by a treaty signed in 1864 at Washington D.C. (Royce, 1899:832). The treaties with the Ojibwa opened vast areas of Minnesota and Wisconsin to settlers, miners and loggers. Additionally, the establishment of individual, geographically discrete reservations contributed to the isolation of the Ojibwa as each group became identified with its particular reservation location.

Settlement Patterns

The settlement system of the Ojibwa can be viewed as a regional adaptation to the Great Lakes forest. Additionally, the settlement system was largely shaped by seasonal food procurement activities and the seasons of the year. During the summer, the main subsistence activities of the Ojibwa focused on fishing, wild food gathering, and small scale horticulture (Ritzenthaler, 1978:746). And it was during the summer months that the Ojibwa formed extensive semi-permanent villages comprised of a number of families (Fitting and Cleland, 1969:294). The summer village comprised the largest settlement unit in the Ojibwa settlement system (Fitting and Cleland, 1969:294).

In the late summer and early fall, the Ojibwa left the summer village in small groups and established temporary camps where wild rice was harvested and processed. Ricing camps consisted of several families who worked together harvesting the rice for several weeks. The work was labor intensive, but resulted in the collection of a valuable resource that could be stored indefinitely and provided a reliable source of food for the winter.

Following the wild rice harvest, the Ojibwa again dispersed into small winter encampments. Winter camps tended to consist of a single family comprised of two or three generations (Densmore, 1929:28). Although hunting was an activity that was carried out throughout the entire year, hunting activity intensified during the winter months. In addition to big game hunting, Ojibwa men also tended trap lines and fished through the ice of frozen lakes (Ritzenthaler, 1978:747). The winter was a stressful time for the Ojibwa since weather conditions and hunting success could mean the difference between conditions of relative comfort or near starvation. During the winter, individual families relied on the stores of food they had collected in the summer and fall, which were often the only available food resources.

In the early spring, the drudgery of the winter camp was lifted by the beginning of the maple tapping season. As with wild rice camps, maple sugaring camps were made up of several families who gathered together to work the same maple grove (Ritzenthaler, 1978:747). After it was collected, maple sap was boiled and granulated into sugar. Since the Ojibwa did not use salt, maple sugar was used as a seasoning for a variety of foods (Danziger, 1979:12; Ritzenthaler, 1978:747). The maple sugar season signaled the beginning of the seasonal round of the Ojibwa. Shortly after the end of maple sugaring activities, the summer villages would again begin to be filled by families returning from their winter dispersal.

Fitting and Cleland (1969) have identified three settlement pattern types among late prehistoric archaeological manifestations in the Upper Great Lakes region, each of which correlates with one of three distinct and readily recognizable biotic zones. Criteria utilized in the definition of these settlement patterns are site size, season of occupation, and site specialization, particularly as related to the sexual division of labor.

Included in the Fitting and Cleland framework is what they refer to as the "Chippewa Pattern" of late prehistoric settlement in the Upper Great Lakes region. The Chippewa Pattern is adapted to the Canadian biotic province which is found in those parts of northern Wisconsin and the Upper Peninsula of Michigan influenced by Lake Superior (Fitting and Cleland, 1969:289-291). The Canadian biotic province is characterized by a mixture of the plant and animal species found in the biotic provinces to its north and south. The mixture of these species is unique to the Canadian biotic province (Fitting and Cleland, 1969:291).

The Chippewa Pattern is marked by large summer settlements, generally located on or near lakes, which were focused on the exploitation of fish. The summer settlements show evidence of balanced male-female group composition (Fitting and Cleland, 1969:298). The primary subsistence activity of Chippewa Pattern summer sites was hunting and fishing. Winter sites of the Chippewa Pattern also have a balanced male-female ratio, but are generally smaller and more numerous over the landscape. Hunting was the primary subsistence activity at these sites.

Subsistence and Technology

The contact period Ojibwa possessed a cultural system that was optimally adapted to their forest homeland. Subsistence was based on a seasonal round of hunting game and gathering wild plant foods. Deer and a variety of smaller mammals were primary game animals, and the abundant fish of the region's many lakes provided another important source of animal protein. Edible woodland plants were additional important elements of the diet, wild rice being by far the most important. The shallow inland lakes of the Great Lakes forests supported dense strands of wild rice which was harvested in the late summer and early fall. In addition to collecting wild rice and edible plants, the Ojibwa also raised small patches of corn, beans and squash (Ritzenthaler, 1978:746).

Before the arrival of Europeans in the Upper Great Lakes region, the Ojibwa possessed a technological system typical of a generalized Woodland pattern. Raw materials utilized in the construction of day to day items were those available in the forest environment that was the homeland of the Ojibwa (Ritzenthaler, 1978:749). Wood was the most common element used to construct utilitarian objects such as bowls, ladles, bows and arrows, canoe frames, snowshoes, cradle boards, drums, and fish lures (Ritzenthaler, 1978:749). Tree bark was an additionally important raw material. Birch bark was used extensively in the construction of containers and canoes, while cedar bark was woven into mats and baskets. Other plant materials, such as cattails and nettle stems were spun into twine and thread used in the manufacture of clothing, mats and baskets (Ritzenthaler, 1978:749).

Material derived from animals was also important in the Ojibwa technological system. Tanned animal skins and warm pelts were the primary material used for clothing and blankets. Bones of various animals were fashioned into knives and other utensils, while deer and elk antlers provided material for knife handles and projectile points. Decorative beads were made from porcupine quills and mussel shells, and feathers were utilized in the construction of headdresses.

Stone was used in a number of ways by the Ojibwa. Water smoothed and rounded igneous and metamorphic rocks derived from glacial till were used as hammers and grinding stones. A variety of chipped stone items were manufactured from a wide range of lithic material, including cherts, quartzites, and silicified sandstones.

Social and Political Organization

The pre-contact Ojibwa had a classless, egalitarian society that was not highly stratified with regard to status/role relationships (Ritzenthaler, 1978:753). Within each Ojibwa group, however, there were people of prestige and influence who achieved important positions through their abilities as orators, warriors, civil or religious leaders, or shamans (Ritzenthaler, 1978:753). In particular, shamans were greatly respected and feared.

The smallest social unit among the Ojibwa was that of the family. A number of related families formed a band, which was comprised of between 20 to 50 individuals and a leader whose religious, economic, and social roles were based on kinship obligations (Ritzenthaler, 1978:753). Bands were organized into clans named after an animal. Descent in clans was traced through the male line, and members of a certain clan were forbidden from marrying within the clan. Clans, in turn, were organized into a phratry system, which consisted of groupings of related clans.

The chief organizing principle of Ojibwa society was kinship. Nearly every member of a particular band was related in some way to one another through some kinship bond (Ritzenthaler, 1978:754). An authoritative study of Ojibwa kinship is included in Landes (1937).

Religion and Ritual

Ojibwa religious belief is permeated by a number of benevolent and malevolent spirits which inhabit trees, rocks, animals and birds, and elements such as the earth, the sky and water. The spirits were honored or placated by individuals through prayers and offerings of food or tobacco (Ritzenthaler, 1978:754). Pre-contact Ojibwa religion was highly personal and individual, but following the arrival of Europeans into the Great Lakes region, the personal focus of religious activity among the Ojibwa began a slow transformation. Increased contact with whites and other Indian peoples increased exposure to a variety of religious, nativistic, and revitalization movements, including the Midewiwin, or Medicine Dance, the Drum Dance, and the Chief Dance.

The Midewiwin, or Medicine Dance, is the most important ceremony of the Midewiwin society, also known as the Medicine Lodge Society (Ritzenthaler, 1978:754). Membership was obtained in the Midewiwin after a candidate passed through a series of instructional and initiative rites administered by recognized Mide priests. The Midewiwin ceremony was held once or twice a year, lasting from two to five days. The final Midewiwin rite was held at a specially selected site in a lodge constructed specifically for the ceremony (Ritzenthaler, 1978:754).

There is some debate over the origins of the Midewiwin ceremony. Hickerson (1962, 1970) believes that the Midewiwin originated as a nativistic movement in reaction to contact with Europeans, while earlier writers such as Warren (1885) and Hoffman (1891) maintain the Midewiwin to be a pre-contact ritual. Whatever the origins of the Midewiwin, by early historic times, it was not only practiced among the Ojibwa, but among the Menominee, Winnebago, Ottawa, Potawatomi, Sauk, Fox and Kickapoo as well (Ritzenthaler, 1978:755).

The Drum Dance was introduced to the Minnesota Ojibwa by their Dakota neighbors during the late 1800s (Ritzenthaler, 1978:756). Once accepted among the Minnesota bands, the ceremony was passed on to the Wisconsin Ojibwa. Drum Dance ritual centered on several elaborately decorated sacred drums. During the Drum dance ceremony, groups of followers would position themselves around their specific drum, where they would assume carefully proscribed duties such as that of the drum beater, singer, pipe tender, or speaker (Ritzenthaler, 1978:756). Women were not allowed to become members of the drum society, but participated in the ritual by dancing and humming along with the songs.

The Drum Dance ceremony was a four day event which was held in a special lodge or open area marked by benches or fencing (Ritzenthaler, 1978:756). Members seated around the drum sang and drummed, while the other members danced outside the drum circle. Gift giving was an

important element of the drum ceremony. After a member had finished his song, he distributed a gift to another member of the ritual. Guests from outside settlements were also presented a gift to acknowledge their presence at the ceremony.

As originally practiced, the Drum Dance ceremony was often used as the occasion for weddings, divorce, removal of mourning, or other social functions (Ritzenthaler, 1978:756). Today, the ceremony is primarily used as an opportunity for social gathering and interaction.

The Chief Dance, also called the War Dance, is a ceremony that has undergone a complete shift in meaning from aboriginal times to the present (Ritzenthaler, 1978:756). Originally held prior to a war expedition, the Chief Dance was conducted to ensure the support and guidance of the spirits in the upcoming battle. Today the Chief Dance primarily consists of a large feast which is held to gain the favor of guardian spirits. Prior to the feast, the host sends runners to neighboring communities who invite individuals to the ceremony with an offering of tobacco. At the feast, food and tobacco are dedicated to the spirits, whose aid is then requested in ensuring general good health and well being for the assembled participants (Ritzenthaler, 1978:756).

Life Cycle and Mortuary Practices

The life cycle of the contact period Ojibwa was marked by a number of ceremonies which marked important stages in an individual's life. Ojibwa children spent most of their infancy in a cradle board which was carried on the back of the child's mother. Infants were tightly strapped into the cradle board, a practice that was believed to ensure that the child would grow straight and vigorous (Densmore, 1929:48). Shortly after birth, infants were named in a special naming ceremony. A small number of friends and relatives were invited to the naming ceremony, as well as the namer. The namer was a person selected by the parents, who bestowed a name onto the child that he or she had received during a period of fasting (Densmore, 1929:52-53, Ritzenthaler, 1978:750). More importantly, the namer was also expected to confer the help and protection of their guardian spirit onto the child (Ritzenthaler, 1978:756).

Ojibwa children were raised in a manner that instilled the basic fundamental skills they would need later in life. Boys were taught by their fathers the roles and skills expected of Ojibwa men, especially those related to hunting. They were introduced at an early age to bow and arrow use, and a special Feast of the First Kill was held upon their first successful hunting expedition (Ritzenthaler, 1978:756). Young girls accompanied their mothers throughout the day, learning from them the various tasks they would perform upon reaching adulthood. They were taught to chop and carry bundles of wood, gather wild rice, make maple sugar, and other tasks assumed by women. Girls were also taught by their mothers the arts of beadwork and weaving.

Puberty marked additional important rites of passage for Ojibwa boys and girls. At the time of her first menstruation, a girl was isolated from the rest of the village for a period of four days and nights (Densmore, 1929:70). During this time of separation, she was required to stay in a specially built wigwam and abstain from food until the end of the four days. After the four day separation period was complete, the fast was broken by a special feast held in honor of the young woman (Densmore, 1929:70). At about the same age, young men were required to undertake a vision quest for a guardian spirit (Ritzenthaler, 1978:751). During the course of the vision quest, a young man prepared himself to receive the spirit by blackening his face with charcoal and isolating himself in the forest some distance from the village. Once the spirit guardian of the

young man was revealed to him in a dream, a good relationship with the guardian was maintained through frequent offerings of food and tobacco (Ritzenthaler, 1978:751).

Courtship and marriage among the Ojibwa was carefully regulated by the adults of the tribe, especially mothers and grandmothers who kept diligent watch over the young women. If a young man wished to gain the favor of a particular young woman, he first had to secure the blessing of the girl's parents and grandparents (Densmore, 1929:72). When the young man called on the young woman at her parents' wigwam, he was permitted to enter and talk to her, but she could not leave with him.

When the courtship became serious, the young man killed a deer and offered it to the girl's parents as a sign of his ability to provide for her in the future. If the parents approved of the suitor, he was invited to share in the feast, and allowed greater freedom in visiting their daughter. There was no formal marriage ceremony among the Ojibwa (Ritzenthaler, 1978:752). A couple was considered married when they established their own household, or the husband moved into the household of his chosen wife.

A death among the Ojibwa triggered a set of socially prescribed responses to that death. In preparation for the funeral ceremony, the body of the individual was washed and dressed in fine clothing, and the hair combed and braided (Ritzenthaler, 1978:752). Often, an individual's face, moccasins and blanket were painted. If the deceased was a member of the Midewiwin Society, their Mide bundle was placed alongside their body. Sometimes, items that were particularly valued by the deceased were placed next to the body. Utilitarian items were not normally included with a burial, since the Ojibwa believed that everything a person could want or need was provided for in the afterlife (Densmore, 1929:74).

Cremation appears not to have been a common Ojibwa practice but according to Kinietz (1940:325), the French explorer Radisson reported that it was customary among the Ojibwa to burn to ashes the bodies of warriors slain in battle. The occasional use of cremation is also supported by the archaeological evidence from the Marina Site (Salzer and Birmingham, 1981).

The Ojibwa, like many of their Algonquian neighbors, appear also to have participated to some extent in the pan-Algonquian mortuary ritual commonly referred to as the Feast of the Dead (Bruhy, et al., 1986:81). Feast of the Dead ceremonies involved the communal reburial of deceased members of participating groups. These reburial rites were held episodically and individuals to be buried were interred in large ossuaries often accompanied by a variety of grave goods (Heidenreich, 1978:376).

Archaeologists, ethnographers, and others have reported a considerable amount of variability in Ojibwa burial practices (Bruhy, et al., 1986; Bushnell, 1927; Densmore, 1929; Hilger, 1950; Salzer and Birmingham, 1981). Such variability is typical of many ethnographically reported burial programs. While in-ground inhumation or "primary burial" may be the most common form of Ojibwa interment, secondary reburial, scaffold burial, cremation, and interment in communal grave facilities are all reported to have been practiced by Ojibwa groups at one time or another. Reservation era and later Ojibwa burials commonly include above ground shelters placed over the grave site.

3.2.2.3.2.2 Forest County Potawatomi

Introduction

The Potawatomi are an Algonquian group distinguished from the closely related Ojibwa and Ottawa by linguistic differences (Clifton, 1978:725). The Potawatomi were known to neighboring Indian tribes as the "fire people". The Ojibwa term *Potawatamink*, from which the name Potawatomi is derived, literally means "people of the place of fire". One of the earliest references to the Potawatomi is provided by Champlain, who in 1615, found the Ottawa and Neutrals at war with the "fire people" who lived to the west of Lake Huron (Clifton, 1978:308). These "fire people" were most certainly the Potawatomi of the lower peninsula of Michigan.

The language of the Potawatomi is considered separate from the seven other Central Algonquian languages spoken throughout the upper Great Lakes region and Canada (Clifton, 1978:725). The languages comprising the Algonquian family are believed to derive from a Proto-Algonquian parent language spoken 2,500-3,000 years ago. Siebert suggests that the origins of Proto-Algonquian may be associated with locales in the vicinity of Georgian Bay and Lake Huron (Siebert, 1967). In any case, relatively early in the language's development, Proto-Algonquian split into a variety of distinct languages (Goddard, 1978:586).

Spoken Potawatomi is characterized by a number of dialectical variations. However, the best documented are dialects associated with members of the Forest Potawatomi located in Wisconsin and the dialects spoken by the Potawatomi residing in Oklahoma. Potawatomi groups in Kansas, Michigan, and Ontario presumably possess discrete dialects, but less information is presently available concerning linguistic variety among these groups (Hockett, 1948:216).

Bibliographic Sources

The Potawatomi people have been the subject of a number of documented accounts and ethnographic studies since they were first encountered by Europeans in the mid-1600s. Some of the first recorded contacts between the Potawatomi and other American Indian groups are documented in the *Jesuit Relations* (Thwaites, 1869-1901). In addition, Pierre Esprit Radisson (1967) provides an early account of Potawatomi and European interactions during the mid to latter half of the 17th century.

A number of ethnographic studies focusing on the Potawatomi were conducted in the middle to late 19th century and the early part of the 20th century. One of the better documented early accounts is contained in Henry R. Schoolcraft's comprehensive treatise on American Indian groups (1851-1857). Publius V. Lawson provides a summary description of the Wisconsin Potawatomi based on historical research. Lawson's study (1920) documents the contact period through the period of land cessions and treaties with the U.S. Government. Anthropological studies, such as those by Alanson B. Skinner (1924-1927) and Charles Callender (1962) provide detailed descriptions of Potawatomi social and political organization. A major linguistic study focusing on Potawatomi language and its place in the Central Algonquian language family was published by Charles F. Hockett (1948). Overviews providing information on Potawatomi ethnology and history have been compiled by Vernon L. Kinietz (1940) and James Clifton (1978). Additional works by Clifton (1977, 1984) and others (Edmunds, 1974, 1978; Ritzenthaler, 1953) provide supplementary ethnohistorical information on Potawatomi lifeways in the Great Lakes area. Archaeological investigations reported at the Dumaw Creek site in

Michigan (Quimby, 1966b) and more recent efforts by Mason (1974, 1986) also provide information pertinent to the prehistory and history of the Potawatomi. More recent works include Lantz's (1992) study focusing on 19th Century Potawatomi history, White's treatise on Indian-White relations in the Great lakes region (1991), and Cleland's (1992) account of the history of various Michigan Indian groups.

A series of manuscripts have documented land cessions and treaties between the U.S. government and the Potawatomi (Fay, 1978; Jablow, 1974; Royce, 1899; Svanda, 1965). Helen Tanner Hornbeck's (Tanner, 1987) *Atlas of Great Lakes Indian History*, provides a valuable cartographic resource documenting the American Indian groups of the Great Lakes region. Additional sources relating to Potawatomi history may be found in an annotated bibliography compiled by David R. Edmunds (Edmunds, 1987).

There is very little published or unpublished material relating specifically to the Forest County Potawatomi, particularly for the contemporary period. Charles Wisdom's (1936) investigations into the problems of landless Indians of the Great Lakes includes some information about the Forest County Potawatomi. Statistical data is available from BIA sources (1976). More recently, some material can be found in socioeconomic assessments related to the potential effects of the Crandon Project (Cleland, et al., 1995; WDNR, 1986).

Prehistory

The Potawatomi, Ottawa, and the Ojibwa share an oral tradition that all three groups descended from a single common ancestor originating on the east coast of North America. Additionally, these histories suggest that the three groups split from the main group to form separate Potawatomi, Ottawa, and Ojibwa tribes (Mooney and Hewitt, 1910:289-290). The date of this division is unknown; however, all three groups were present at the Straits of Mackinac prior to the 1600s. In any event, the Potawatomi had moved into the southern territories of Michigan's lower peninsula by the 1640s (Schoolcraft, 1851-1857:308).

Many Algonquian groups fled west following devastating attacks by the Five Nations Iroquois (Clifton, 1977:37-38). Groups such as the Potawatomi and the Sauk, skilled in the art of birch bark canoe construction and travel, followed fluvial routes north until they reached Green Bay on the western shores of Lake Michigan. Here, along with groups of Ottawa and Petun, the Potawatomi re-established a territorial foothold. Other Potawatomi groups traveled south around the southern shore of Lake Michigan moving west into prairie country (Clifton, 1977:38). Once established in the Upper Peninsula of Michigan, these groups developed ties with the French and became deeply involved in the French fur trade.

History (1610 - 1820)

Following their initial settlement of the area in the 1640s, the Potawatomi, Ottawa, and Petun established a number of villages located on Rock and Washington Islands in Green Bay. Archaeological and ethnohistorical evidence (Mason, 1974) indicates that Rock Island harbored the main settlement and trading center relating to trade between the Ottawa, Petun, Potawatomi, and French. The Rock Island settlement remained in use from the late 1640s through the reservation period of the 1800s (Mason, 1974).

Ethnohistorical documentation describes a conflict in 1653 between the Iroquois and several Indian groups that inhabited the area near Green Bay, in which the Potawatomi made up roughly 40 percent of the defending group (Thwaites, 1869-1901:38:181). The Indian groups defending the Green Bay area were successful in repelling the Iroquois and driving the invaders back to New York state (Clifton, 1977:39).

Following the defeat of the Iroquois, the Ottawa regained their former position acting as middlemen between the French traders and other western Indian groups. However, the Potawatomi, having proven themselves in the conflict with the Iroquois, developed aspirations to usurp the Ottawa role (Clifton, 1977:39). By the late 1650s, the Potawatomi controlled extensive areas along the Fox River and the shores of Green Bay. Control of this territory allowed the Potawatomi to restrict access to the entrance to the riverine trading systems of central and western Wisconsin. As a result, the Potawatomi were successful in vying for the position traditionally held by the Ottawa as middlemen in the French fur trade (Clifton, 1977:40-41).

History (1820 - Present)

Potawatomi arrival into the northern Wisconsin has its origins in the 1833 Treaty of Chicago. Under the terms of the treaty, the Potawatomi renounced their claim to their remaining Wisconsin holdings. Included in the cession were the lands bordering the western shore of Lake Michigan between the Rock and Milwaukee Rivers, including the Milwaukee region which was becoming a leading population center in Wisconsin. The provisions of the Wisconsin treaties included an option for removal to western Iowa, which many of the united Potawatomi, Ojibwa, and Ottawa elected to exercise (Bloomfield, 1928:737). Other members of the three tribes attempted to remain in ceded territories, but were gradually pressured into less heavily populated areas in northern Wisconsin, including what was to become Forest County.

Clifton argues that the Forest County Potawatomi (and the Potawatomi at Hannahville in the upper peninsula of Michigan) are remnant groups who fled into the area after 1850 to avoid removal to Iowa Territory, and "include descendants of villagers from the prairie lands of the Milwaukee-Waukesha area and Lake Geneva, others from the Prairie Band in Kansas who later returned to Wisconsin, and some migrants to Canada who returned after several decades of residence there (1978:727)." A Potawatomi informant reported to Ritzenthaler (1953:107) that the major portion of the Forest County Potawatomi migrated from "the Horicon Marsh to Black Wolf and Waukau in 1863; then to Little Wolf in Waupaca County, where they stayed for ten years; to Wittenberg in Shawano County for a fifteen year stay; to Oconto County northeast of Gillett, where they lived until final settlement in their present home in Forest County in 1914 (cited in Cleland, et al., 1995:31-2)." Some Potawatomi may have come from the Chicago, Illinois area.

Regardless of their specific origins, the Potawatomi began moving into Forest County in the 1890s to work in the logging industry, and individual Potawatomi began acquiring small tracts of land. In response to legislation introduced by Wisconsin Senator Robert M. LaFollette, Congress in 1913 provided for the purchase of additional lands in Forest County for the Potawatomi, which were acquired in so-called "checkerboard" fashion (that is, in non-contiguous parcels) in order to promote "assimilation" with whites.

Regarding the Potawatomi, in his 1914 annual report, Superintendent Bennett of the Carter, Wisconsin Agency stated that "The Wisconsin Potawatomi are located in several different

counties in northern Wisconsin and the upper peninsula of Michigan and in nearly every instant far removed from settlements (Bennett, 1914)." He noted that some were in homesteads acquired under the 1884 Homestead Act, that others were living in shacks or camps abandoned by the lumber companies, and that their condition was improving. In his 1919 annual report, Bennett noted that most of the Potawatomi were living on land purchased for them, that houses had been built or would be built for them, and that their situation was greatly improved (Bennett, 1919). Subsequent Annual Reports to the Commissioner of Indian Affairs describe similar settlement patterns and conditions for the Wisconsin Potawatomi. In his report on the problems of landless Indians of the Great Lakes, Wisdom (1936) notes that the Wisconsin Potawatomi are squatting on land owned either by the counties or private individuals, or government tracts near Soperton. He recommended the purchase of lands near Wabeno and Blackwell with the idea to establish "the entire group in a single locale, with a contiguous territory of their own (1936:23-4)."

Eventually, the Potawatomi formed two communities in Forest County, one at Stone Lake and the other at Wabeno, and some individual Potawatomi began acquiring small tracts of land. Congress gave them scattered lands (non-contiguous parcels) in 1913. Both groups adopted tribal constitutions under the Indian Reorganization Act of 1934. In the 1950s, they lived on scattered households on 40 acre allotments around Wabeno and Stone Lake. During this period, tribal members worked in the logging industry, as fishing guides, and in seasonal jobs such as picking cherries, cutting hay, and digging potatoes. Some sold Indian handicrafts (Ritzenthaler, 1953:113). Forest County Potawatomi lands were not placed in federal trust until 1988, at which time they were given reservation status.

Ritzenthaler (1953), in the early 1950s suggested that the Potawatomi's marginalization and isolation resulted in the retention of many of their historic cultural practices. This assessment was supported with examples of traditional cultural practices such as indulgent child rearing, naming and first kill feasts, and menstrual seclusion, all for purposes of guardian spirit acquisition. Ritzenthaler also notes the presence of the Medicine, War, and Dream dances at that time, along with sacred bundle ceremonies and Peyote meetings, to organize the spiritual and social life of the people (cited in Cleland, et al., 1995:33). In the mid-1980s, a household survey reported that over 30 percent of Potawatomi families relied somewhat to a great deal on hunting and fishing for food, and 26 percent used gardening, ricing, and picking wild plants somewhat to a great deal (WDNR, 1986:108). Cleland and Nesper conducted interviews with some Forest County Potawatomi in 1994, and indicate that their research supports the traditionalism and distinctiveness of the present day Forest County Potawatomi (Cleland, et al., 1995:35-7).

Potawatomi tribal lands consist of scattered holdings totalling 11,786 acres in Forest County. Once a mature hardwood forest, these lands were logged and now consist of second-growth forest vegetation. The population is concentrated in the Stone Lake and Wabeno areas, which are about 20 miles apart. In 1984, there were 683 enrolled members, with 333 resident on tribal lands and 133 living adjacent to tribal lands (WDNR, 1986:108-9). Cleland, et al. (1995:35) report 847 enrolled members in 1994, with 462 residing on the reservation. In 1991 the Forest County Potawatomi opened a bingo hall on the reservation, and in 1992, added a gambling casino in the unincorporated Village of Carter. Combined with the Potawatomi casino in Milwaukee, these endeavors have increased employment opportunities and the generation of tribal revenues. Tribal members are employed at the gambling casinos in Carter (250) and Milwaukee (15). The tribe manages a timber operation, and is planning a campground and RV

park; and an aquaculture program to produce bait fish. A game farm to raise red deer was started in 1996.

Tribal Territory

Following the initial separation from the Ottawa and the Ojibwa, the Potawatomi occupied areas throughout the Upper and Lower Peninsulas of Michigan and Eastern Wisconsin. The historical trajectory of Potawatomi movements throughout the Michigan/Wisconsin area has been referred to by Clifton as comprising three successive Potawatomi territories (1978:725). These were an initial "protohistoric estate," a successive move west to the "refuge area" followed by a final occupation of the "tribal estate." Each occupation was territorially more extensive than its predecessor but each generally overlapped the area comprising the previous territory (Clifton, 1978:725).

The first territory, "the protohistoric estate," is marked by Potawatomi occupation of areas on the eastern shore of Lake Michigan on the Lower Peninsula of Michigan and corresponds to the years prior to about 1641 (Clifton, 1978:725). During this time, groups such as the Sauk, Fox, Mascouten, and Kickapoo were located south and east of the Potawatomi territories (Clifton, 1978:725).

The second Potawatomi territory, "the refuge area," marked a Potawatomi retreat in the face of Iroquois hostilities. The Potawatomi, Ottawa, and Petun fled north and south around Lake Michigan to a "refuge area" in Upper Michigan and Wisconsin. Initially, the Potawatomi, along with the Ottawa and Petun, established villages along the western shores of Lake Michigan and Green Bay. The Upper Michigan and Wisconsin groups were successful in defending their new territory from the advancing Iroquois groups that had previously forced them out of Lower Michigan. Following the battle with the Iroquois the Potawatomi began establishing themselves as one of the more dominant groups in the area. The Potawatomi occupied the territories of the "refuge area" from roughly 1641 until the 1670s when they began to exert control over a wider portion of eastern Wisconsin and the Upper Peninsula of Michigan.

By the early 1670s, the Potawatomi had obtained control over an area that encompassed not only the "refuge area," but also the area surrounding the southern tip of Lake Michigan. This third territory, or "tribal estate," subsumed the former "refuge area" and extended south to about the present day Illinois-Wisconsin border. Additional Wisconsin territory was claimed in areas located east of the Wisconsin River. In addition, the tribal estate included the northern portions of Indiana and Illinois and the western portion of the Lower Peninsula of Michigan, extending as far east and north as the St. Joseph and Grand Rivers (Clifton, 1978:726).

Beginning in 1789, the Potawatomi tribal estate began to decrease in size as the tribe entered into a series of land cession treaties with the United States (Royce, 1899:959). The Potawatomi of northern Indiana and southern Michigan were affected by the treaties the earliest, since they occupied areas that were intensively settled earlier than territories inhabited by the western Potawatomi (Clifton, 1978:737). This portion of the tribe was subjected to increased external pressure as settlers and missionaries migrated into recently ceded lands in Indiana and Michigan. Nonetheless, the Indiana and Michigan Potawatomi resisted acculturation and expulsion from their lands until 1841, after which they were forcibly removed to a reserve in Kansas (Clifton, 1978:737).

Land cessions and removal occurred somewhat later in Wisconsin and Illinois, and were of a slightly different nature. In Wisconsin, the Potawatomi were the dominant tribe in the areas adjacent to the southern one-third of Lake Michigan and held claim to lands extending to the Mississippi River in the southern part of the state (A. Smith, 1985:131-141). Forming a loose confederation with the Wisconsin Potawatomi in these areas were small numbers of Ojibwa and Ottawa. In 1829, the united Potawatomi, Ojibwa, and Ottawa were persuaded to sell the lands which they had claim to lying south of the Wisconsin River between the Mississippi and the headwaters of streams flowing into the Mississippi (A. Smith, 1985:131). By making this and other land purchases, the United States had effectively ended Indian claim to lands within Wisconsin's economically important lead-bearing region in the southwest part of the state. The remaining Wisconsin holdings of the united Potawatomi, Ojibwa, and Ottawa were ceded by an 1833 treaty signed in Chicago (Royce, 1899:750-751). Included in this cession were the lands bordering the western shore of Lake Michigan between the Rock and Milwaukee rivers, including the Milwaukee region which was becoming a leading population center in Wisconsin. The provisions of the Wisconsin treaties included an option for removal to western Iowa, which many of the united Potawatomi, Ojibwa, and Ottawa elected to exercise (Clifton, 1978:737). Other members of the three tribes attempted to remain in ceded territories, but were gradually pressured into less heavily populated areas in northern Wisconsin.

Settlement Patterns

The Potawatomi inhabited areas within the Carolinian biotic province when they first reached the Lower Peninsula of Michigan. Following attacks from the Iroquois and their subsequent migration to the "refuge area" located in the Upper Peninsula of Michigan, the Potawatomi were situated in areas coincident with the Canadian biotic province and portions of the Carolinian-Canadian transition zone (Fitting and Cleland, 1969).

Potawatomi settlement patterns reflect two seasonally specific practices typical of the mixed farming and hunting economy characteristic of many historic Indian economies. During the summer months, the Potawatomi resided in large villages which were reused from year to year. Villages were often palisaded and harbored a series of dome-shaped domestic structures generally typified by a circular floor plan and pole and bark construction (Clifton, 1978:729). Villages were generally located within a forest setting near the transitional forest/prairie locales and with relatively easy access to riverine routes (Clifton, 1978:729). Most subsistence activities were considered gender specific tasks. For example, Potawatomi women were primarily responsible for agricultural related tasks, while men hunted areas near the summer villages. During the winter months, groups from the large, summer villages dispersed into smaller, temporary hunting camps where both men and women actively engaged in winter hunting activities (Fitting and Cleland, 1969:297). Dispersed winter groups were reunited in the spring and engaged in communal bison hunting or fishing (Clifton, 1978:729).

Subsistence and Technology

The archaeological evidence recovered from excavations of Potawatomi sites is limited. According to Quimby, the historic component at the Dumaw Creek site in lower Michigan can be assigned to a Potawatomi occupation. Evidence from Dumaw Creek suggests that the site's inhabitants grew corn and pumpkins and hunted and fished for a wide variety of small and large game (Quimby, 1966b). Mason's more recent work on Rock Island suggests an equally extensive utilization of game animals but provides little evidence for agriculture (Mason, 1986).

Ethnographic studies conducted by Skinner during the 1920s provide additional insights into the subsistence practices of the Potawatomi (Skinner, 1924-1927). Skinner's information indicates that the Potawatomi acknowledged four distinct seasons, and identified a series of seasonally specific activities linked to the yearly cycle.

Summer subsistence activities included the gathering of edible wild plants, such as choke cherries, black berries, and cranberries. Elk, deer, and beaver were hunted. Autumn tasks centered around harvesting of squash, beans, maize, and tobacco crops planted during summer months. Surplus food was stored for use during the leaner winter months (Clifton, 1978:729). Fishing provided food sources for the Potawatomi year round. During winter months, Potawatomi men would construct shelters over holes chopped through the ice, and spear fish lured towards the hole by carved wooden jigs (Skinner, 1924-1927:280). Fish caught during other times of the year would be driven into fish weirs, speared during spawning, or caught by net at night (Skinner, 1924-1927:280-281).

The Potawatomi were very skilled in the manufacture of clay pottery and stone tools. Canoes, a singularly necessary transportation device within the context of a riverine adapted society, were initially constructed from dug out tree trunks. Later forms were constructed utilizing cedar frames and birch bark hull coverings (Skinner, 1924-1927:295). The Potawatomi were also adept at the tanning of animal hides and the manufacture of a variety of leather goods. Rawhide trunks made of buffalo skin could only be fashioned by Potawatomi women, a right that was probably obtained through a dream (Skinner, 1924-1927:297). Similarly, woven mats were also produced by the women, although only upon consent of the chief's wife (Skinner, 1924-1927:291).

Social and Political Organization

Clifton suggests that the Potawatomi had "likely developed an Omaha-type kinship system, which strongly emphasizes patrilineal descent and a corporate clan system, with the clan being the basis of village organization" by late in the 17th Century (Clifton, 1978:729). Potawatomi political organization, prior to the tribe's first encounters with the French, was based on an egalitarian structure. Although some degree of charismatic leadership may have been recognized, most villages lacked true chiefs or headmen. Important village-level decisions were reached through community consensus (Clifton, 1978:730).

During the late 1700s, new villages were formed as a result of population growth, shifting economic strategies reflecting increased participation in the fur trade, and Iroquois aggression. Newly formed villages maintained clan ties to a parent village and all villages were part of a single Potawatomi tribal entity (Clifton, 1978:731).

By 1800, Potawatomi social organization was still highly egalitarian in nature. However, village political structure had begun to incorporate the office of a civil chief whose role was nonetheless largely ceremonial in nature (Clifton, 1978:732). These chiefs were invariably male, and were chosen by the village from a group of individuals of equally senior status. Decisions involving the village were arrived at by consensus among the chief and a council of adult males (Clifton, 1978:732). Police functions were the responsibility of a pan-tribal male sodality comprised of successful warriors (Skinner, 1924-1927:1:227). This organization crossed Potawatomi tribal lines and favored the development and maintenance of strong ties between individual villages.

Inter-village ties were further strengthened by the Potawatomi clan system which recognized six phratries corresponding to Bear, Bird, Buffalo, Man, Water, and Wolf divisions (Clifton, 1978:732). Villages typically included members of a number of different clans. Thus, lineage based links were established throughout the extensively dispersed settlement characteristic of the "tribal estate" and served to bind villages into a strong social and political system (Skinner, 1924-1927; Callender, 1962; Ritzenthaler, 1953).

Religion And Ritual

Clans were also important in structuring the ritual activities associated with Potawatomi religious beliefs. According to Clifton, each clan was linked with a sacred bundle, an origin myth describing the genesis of the bundle, and a proscribed set of songs, dances, and chants (Clifton, 1978:733).

Shamans and sorcerers were consulted for general advice, divination, and prophesizing. In addition, the pan-tribal Midewiwin or Medicine Society (found in a number of Algonquian groups) consisted of sorcerers who could choose to do good or evil (Clifton, 1978:734).

The *Midewin* (Medicine Lodge or Medicine Dance) is the oldest of the traditional religions associated with the Potawatomi. It is a society of persons who are concerned with the health and well-being of the community and its members. There is a good deal of knowledge within this religious group surrounding plants and their use for medicinal and ceremonial purposes. The *Midewin* also has strong influences that can be found among the Dream Drum religion (Ritzenthaler, 1953:152-3).

In the late 19th century, many Wisconsin Potawatomi had adopted the religion begun by the Santee Sioux prophetess named Wanaikwe. This religion was also known as the Dream Drum which was still found among the Wisconsin Potawatomi in the early 1950s, including those in Forest County. The Dream Drum symbolizes the end of hostilities between the Sioux and their traditional Woodland Tribal enemies. The Potawatomi cultural expression of this religious ceremony is quite similar to that which has historically been practiced among their neighbors, the Chippewa and the Menominee (Ritzenthaler, 1953:159-61).

About 1900, the Peyote Religion was introduced among the Potawatomi of Forest County and was, in part, responsible for the division of the two communities by religious affiliation. There are other traditional ceremonies among the Forest County Potawatomi such as the War Dance, known as the Chief's Dance among the Chippewa, and Sacred Bundle Ceremonies. These activities are less visible and are only partially understood by outside observers. The prevalence of these ceremonies is not well known. As of the 1950s, the closest cultural ties which the Forest County Potawatomi had were with their neighbors, the Ojibwa and the Menominee (Ritzenthaler, 1953:106, 153-59).

Life Cycle and Mortuary Practices

A number of taboos and restrictions were strictly adhered to by the Potawatomi from birth to death. During early childhood years, boys and girls were instructed to develop appropriate skills by simulating the roles portrayed by adult males and females of the community (Clifton, 1978:735).

Adulthood among the Potawatomi was marked by the onset of puberty, but full adult status was attained only through marriage. During adolescence, boys were sent off by themselves on vision quests, while girls were isolated from the rest of the group during periods of menstruation (Clifton, 1978:735). Birth occurred in designated bark covered houses where the mother and child were cared for exclusively by other women. After returning to the group, the child was given a name linking him/her to the clan (Clifton, 1978:735).

Potawatomi elders were responsible for performing several tasks associated with their age and wisdom. In particular, elders were responsible for the instruction of children and maintaining village functions until death (Clifton, 1978:736).

Mortuary practices are primarily documented in studies by Keating (1824), Landes (1970), and Turner (1892). Reportedly, the deceased was dressed in his or her finest clothing and laid near the door of the deceased's dwelling. Burial type and positioning was according to individual preference. Interment was in trees or in graves dug in the ground. Grave goods were commonly placed with the deceased in both instances. Grave markers were used to indicate grave sites and usually consisted of posts marked with pictographs denoting clan affiliation and describing the deceased and his or her accomplishments. Cemeteries appear to have been relatively common.

3.2.2.3.2.3 Menominee Tribe of Wisconsin

Introduction

The Menominee are widely accepted as having been one of two peoples inhabiting an indefinitely bounded region of what was to become the State of Wisconsin and the Upper Peninsula of Michigan prior to European intrusion into the region. Algonquian speakers, the Menominee were easily distinguished from the other indigenous group in Wisconsin, the Winnebago, who were Siouan speakers. Although the Menominee language has been classified as part of the Central Algonquian subgroup, it is not closely related to any other language of that subgroup (L. Spindler, 1978:708).

The Menominee language is part of the central Algonquian language stock. Central Algonquian is a convenient geographical grouping as is Plains Algonquian, according to Goddard, and as such the grouping does not imply that Central Algonquian languages share distinctions that set them apart from the rest of the Algonquian language groupings (Goddard, 1978:583). Only Eastern Algonquian can be considered a genetic unit with a period of separate development after splitting off from the Proto-Algonquian parent language. Central Algonquian speakers lived in the regions of the Upper Great Lakes and the Canadian North, east of the Great Plains.

Bloomfield notes that while there are some minor geographical variation among Menominee speakers (1962:34), the Menominee language has been spoken by a single homogeneous group occupying the same area since the earliest records of the tribe in the 17th century. It is the case, however, that many Menominee also spoke Ojibwa, particularly in their dealings with outsiders, and many Ojibwa cognates can be found in the Menominee language. Spoken Menominee began to go out of use in the 1920s and by 1970 the language was spoken by only a minority of tribal members (Goddard, 1978:584).

Bibliographic Sources

Important early accounts of Menominee history are included in the Jesuit Relations published from 1632 to 1673. While these accounts focus on topics of interest to the Jesuit community in the New World and in France, some information on material culture, settlement, territory and subsistence can be found in the documents. In particular, the memoirs of Nicolas Perrot, an insightful early French explorer of the Upper Great Lakes region, provide useful accounts of early Menominee history. The collections of the State Historical Society of Wisconsin house written documentation concerning early Menominee history as well as photographs, legal documents, maps and recordings. In addition, collections housed at the Neville Museum in Green Bay contain information on the Menominee.

A variety of works document various facets of traditional Menominee culture. W.J. Hoffman's (1896) account of the Menominee is a detailed description of the major components of Menominee life. Alanson Skinner collected information regarding Menominee social life (1913), association and ceremonies (1920), the Medicine ceremony (1920), material culture (1921) and folklore (Skinner and Saterlee, 1915). Jenks (1900) accounts of Menominee methods of gathering, preserving and using wild rice are central to reconstruction of Menominee subsistence practices. Bloomfield's (1928, 1962) linguistic studies provide an extensive investigation of Menominee texts and the Menominee language. Felix Keesing's (1939) work is considered to be the most complete ethnography of the Menominee. The work is an accurate and detailed recounting of historical documents and reports by traders and missionaries from first contact through 1930. George and Louise Spindler have published accounts of Menominee social roles (1958), acculturation (1970), and fieldwork experiences (1971). Louise Spindler (1978) combines her own Menominee experience with a review and summary of ethnographic and historical information. A more recent study by Patricia Ourada (1979) focuses on Menominee history. David Beck's dissertation (1994) documents Menominee adaptation to the modern world with an emphasis on the importance of traditional Menominee subsistence practices in maintaining tribal identity. A collection of articles edited by Susan Slader (Cleland, 1983; Harkin, 1983; Deer, 1983) focused on the environmental and social history of the Great Lakes forest includes chapters by Cleland, Harkin, and Deer, which provide insight into Menominee adaptive strategies.

Prehistory

The link between prehistoric archaeological cultures and the present-day Menominee tribe is yet to be documented by archaeological research. The antiquity of the Menominee in Wisconsin is assumed, however, based on three related lines of evidence. First, the uniqueness of the Menominee language when compared to other Central Algonquian languages and the relatively limited geographical extent of the speakers of the language argues for a long term in situ development of the tribe. Second, the three separate but similar recorded versions of the Menominee creation story (Hoffman, 1896; Skinner, 1913; Bloomfield, 1928) all place the Menominee at the mouth of the Menominee River from the time of the organization of the Bear Clan, the oldest and most prominent of the Menominee clans. And finally, the area claimed as ancestral by the Menominee is the same area in which they were initially contacted by the French in the early part of the 17th century. Nicolet locates the Menominee as follows:

> We enter the second fresh-water sea, upon the shores of which are the Maroumine [Menominee] and still further, upon the same banks, dwell the

> Ouinipigou [Winnebago] a sedentary people, who are very numerous (Thwaites, 1869-1901:XVII:231).

The Menominee and close neighbors, the Winnebago, apparently dominated the region of eastern Wisconsin prior to French presence.

History (1610 - 1820)

During the period between 1635 and 1667 when the Iroquois were actively attacking other central Algonquians, the Menominee escaped attack. This was due, no doubt, to the sheltered position of their village and hunting areas near the shores of Lake Michigan.

The earliest recorded European contact with the Menominee occurred in 1667 and was a result of the visit of French fur trader Nicolas Perrot (Blair, 1912:35-36). Additional early European contacts include Jesuit missionaries and French fur traders. The Jesuits were present and active among the Menominee from 1669 through 1684. Among the more notable of these Jesuits were Father Allouez and his successor among the Menominee, Father Andre. Andre lived with the Menominee for fourteen years.

In 1696, a slump in the fur market in Europe prompted a change in official French policy. As a result, French garrisons were unmanned, posts were evacuated, missionaries were recalled and the flow of French goods westward was restricted. This policy changed once again when the demand for furs increased in Europe and the Iroquois began to assume a dominant role as middlemen in the trade of furs to the east and trade goods to the west. The French government realized that the abandonment of the Great Lakes region was impractical and began to concentrate French power at a few strategic points. The first few decades of the 18th century saw French forces clashing with various Great Lakes Indian tribes, most notably the Fox, in an attempt to consolidate and control the trade in furs. The Menominee, while showing no inclination to move to one of the centers of French power, such as Detroit, New Orleans, or Chicago, became close allies of the French and consequently prospered. By 1736 the Menominee became one of the dominant tribes in the Upper Great Lakes region (L. Spindler, 1978:719).

By the time the English assumed control of the region in 1761, the Menominee were fully adapted to a fur trading economy and firmly linked to the French government. The English were eventually accepted by the Menominee, due, in part, to the English policy of lavish gift giving. The Menominee continued to prosper as traders under the English government (Keesing, 1939:84).

In 1815, the United States government established a trading post and Indian agency at Green Bay, Wisconsin. Once again Menominee tribal leaders were in the position of having to change their political allegiance and this was done despite opposition of many of the French-Menominee members of the tribe. This United States government venture into the fur trade was for the most part a failure. The French and British traders who preceded them had recognized the importance of establishing family and political ties with the groups with whom they traded. Many French traders had married Menominee women, and the English government had a policy of establishing carefully crafted relationships with the Menominee as partners. The American government was attempting to compete with these well established foreign trading networks and was unable to successfully do so. As a result, the American Congress passed several laws

forbidding entrance to all foreign traders and capital (Keesing, 1939:94). By 1821 the Congress ended the American fur trade by legislative action.

By the third decade of the 19th century the entire economy of the Menominee had become dependent on a system of extended credit based on participation in the fur trade. With the decline of the fur trade, the Menominee economy was on the verge of collapse. As Keesing states:

> . . . with the coming of the Americans . . . a system of institutionalized control was established, which later developed into the Office of Indian Affairs. Though the Great White Father in Washington was to emerge importantly, it will be seen that he has in general handed out rules and regulations rather than gifts. Even today the older Menomini recall stories they heard in youth about the "good old times" when the sovereigns of England cared for their Indian children and sent them presents (1939:100).

This change in the attitudes and related policies toward the Menominee was accompanied by an even greater threat to the tribe during the period from 1830 to 1850. Growing population pressure from white settlers increased dramatically with the influx of more than 300,000 white settlers during the years 1836 to 1850. Between 1831 and 1848, Menominee lands passed into white ownership as a result of a series of treaties between the American government and the Menominee tribe.

History (1820 - Present)

In 1852, members of the tribe were removed from their homes around Lake Poygan and along the Fox and Wolf Rivers to north central Wisconsin which was to officially become the tribe's reservation in 1854. The Menominee had been scheduled for removal to a reservation located in present-day Minnesota, granted them in the Treaty of 1848. Subsequently, the Menominee protested their removal and asked to remain in a more familiar setting. This was granted in the Treaty of 1854 whereby the lands in Minnesota were exchanged for the present reservation, a region of heavily timbered land on the Wolf River in northeast Wisconsin. Subsequently, in an 1856 treaty, the Menominee ceded two townships from their reservation for use by the Stockbridge-Munsee.

The reservation granted is within the heartland of the area the Menominee had inhabited when first encountered by Europeans (Keesing, 1939:148). These Lake Poygan Menominee were soon joined on the reservation site by coastal Lake Michigan bands of Menominee who had been residing at the mouths of the Menominee, Peshtigo, and Oconto Rivers. Soon after their arrival on the site of the reservation, both groups dispersed across the entire reservation area. After 1900, the tendency to disperse into small band-like settlements across the reservation was reversed and much of the population concentrated in the village centers of Neopit and Keshena (L. Spindler, 1978:720).

Although the new reservation was rich in natural resources, the fish, game, and wild rice beds, were not sufficient to sustain the population. As a result, many Menominee families turned to farming, an endeavor that was never successful (Keesing, 1939:155-6). The economic situation on the reservation worsened with the damming of the Wolf River below the reservation around the turn of the century (the first dam was built at Shawano in 1892) whereby the sturgeon could

no longer reach reservation waters to spawn. A tribally owned lumber mill was established in 1908 and logging and milling operations eventually became the economic mainstay of the tribe. The Menominee, with help from Senator LaFollette, established a selective cutting process whereby the forest maintained itself over the years, continuing to the present day. The Menominee successfully sued the federal government for mismanagement of their forest resources, but government manipulation tied release of their award ($7,600,00) to termination of the reservation (L. Spindler, 1978:722).

In 1961, as part of its experiment in "terminating the trust relationship," Congress abolished the Menominee Indian Reservation and ceased virtually all federal support. The State of Wisconsin then turned the lands into Menominee County, and several thousand acres were sold into white ownership. The social, economic, and cultural consequences of the reservation's termination for the Menominee were all negative. In addition to the loss of tribal lands, taxes were high, unemployment was high, proper medical care was lacking, and much of the housing became substandard (L. Spindler, 1978:723). In response to the efforts of the DRUMS movement (Determination of Rights and Unity for Menominee Shareholders) and other opponents of termination policies across the country, the policies were rescinded, and Congress restored tribal trust status to the Menominee in 1973, re-establishing the Menominee Indian Reservation. Following restoration, the tribal rolls were updated, a new constitution was drafted, and a number of community improvements in the areas of housing, health, education, and general welfare were initiated (L. Spindler, 1978:723). The Menominee continue to repurchase white-owned property within the reservation boundaries as it goes back on the market.

Currently the Menominee are the largest tribe in Wisconsin, with the population concentrated in the reservation communities of Neopit, Keshena, Zoar, and South Branch. About half the tribes' 7,425 members live off the reservation. Many Menominee are Catholic although the Algonquian spiritual tradition remains strong, with five traditional drums, each representing a historical drum society with its attendant ceremony and ritual (Cleland, et al., 1995:28).

A bingo hall, gambling casino, and motel were established on the Menominee Reservation in Keshena adjacent to STH 55 in 1982. These and other tribally owned and operated enterprises have increased employment opportunities, tribal revenues, and the income of individual tribal members. According to Cleland, et al. (1995:27), in 1992 21 percent of tribal members were casino employees (315 people), and another 23 percent were employed in logging and at Menominee Tribal Enterprises.

Tourism has become a significant source of income for some tribal members, with fishing, rafting, and camping activities along the Wolf River. In 1993, plans and procedures were initiated to bring the sturgeon back to Wolf River waters on the reservation.

Tribal Territory

There is little doubt among scholars of the Menominee that the pre-contact Menominee occupied some part of what was to become northeastern Wisconsin (Hoffman, 1896; Skinner, 1921; Keesing, 1939; L. Spindler, 1978). Keesing notes that:

> Exactly how much of this area of northeast Wisconsin and the adjacent part of Michigan actually was the ancient territory and hunting ground of the Menomini cannot now be known . . . . The system of land holding, too, is rather obscure,

> though evidence from later days indicates that nothing like the western conception of individual rights in real property existed (1939:19).

Pre-contact Menominee occupied an unknown number of villages on or near the Menominee River. They are thought to have been fairly sedentary, although their economy was based on gathering wild rice and other wild plant foods, and fishing and hunting in season.

During the early part of the post-contact period in the 17th century, the French reported that the Menominee had one main village at the mouth of the Menominee River (Thwaites, 1869-1901:XVII:129). While there is a report of a Menominee settlement on the Fox River in 1689 (Lahonton, 1905:167-168), this location is considerably south of all other reports of the main Menominee village. Keesing concludes that the presence of Menominee so far south of their reported permanent village is a result of participation in trading activities (1939:64). Very little is known about the Menominee after the Jesuits left the area in 1684 until the early part of the 18th century when fur trading activity intensified. As close allies of the French, the Menominee prospered during the first decades of the 1700s and by 1736 emerged as one of the dominant tribes in the area (L. Spindler, 1978:719).

While the early records do not document a movement away from the first large reported village at the mouth of the Menominee River, sometime between 1730 and 1752 the Menominee moved south to settle on the Fox River, presumably to be near the French trading post. A small number of Menominee continued to occupy the Menominee River region, but most spread over a wider territory. As noted above, there was a split into two settlements, and by the end of the 18th century, both settlements had split into bands or hunting units. By the 1820s Menominee territory was considered to be the "Fox River to the south, as far as Winnebago Lake; Bay du Noquett to the north; Menominee River to the northeast, and Mississippi to the west" (Morse, 1822:470).

In three major treaties signed in 1831, 1836, and 1848, Menominee lands passed into the hands of the American government and thence into private ownership. This period culminated in the 1852 removal of those members of the tribe residing in the Poygan Lake region, and in the Fox and Wolf River valleys. These Menominee were relocated to the upper Wolf River valley, an area coincident with the present Menominee Indian Reservation.

Settlement Patterns

Early Menominee settlement reflects the Menominee practices of planting small gardens near their villages while maintaining a significant dependence on fishing, hunting and gathering. Wild Rice was an important gathered food. Summer settlements were larger, stable in make-up, and near areas suitable for fishing, planting gardens, harvesting wild rice, and collecting berries and other seasonally available wild foods. After harvesting planted gardens, the Menominee broke up into smaller band-like groups for the purposes of winter hunting and fishing. Several bands might come together for collecting maple syrup in the spring.

With increasing participation in the fur trade, nearby areas became over-hunted and the Menominee had to range farther in pursuit of fur-bearing animals. These hunting groups claimed territory along family lines. Individual family units became increasingly important as the Menominee tribe ranged further afield during the winter hunting months.

When the Menominee began occupying their reservation, a more sedentary type of settlement and subsistence was required. Band leaders of both the Poygan group and the Lake Michigan group chose locations on the reservation that appealed to them and members of their respective bands settled near those areas. Groups that were less isolated from one another tended to lose their cohesiveness, while those groups which remained isolated maintained a stronger identity (Keesing, 1939:150). Louise Spindler (1978) argues that the old pre-contact dualism persists in the reservation division of pagan vs. Christian Menominee. Even more strongly reflected dualism can be seen among the Thunderer and Bear divisions of the traditional (non Christian) Menominee (L. Spindler, 1978:714). Present day settlement is concentrated in the communities of Keshena, Neopit, and Zoar.

Subsistence and Technology

The Menominee are considered to have been hunter-gatherers during pre-contact time although they did maintain one or more semi-sedentary villages around which they planted small gardens of squash, beans, and corn. Fishing was an extremely important part of Menominee subsistence and both river and lake species of fish were harvested. Seasonal gathering of wild rice, acorns and berries, as well as spring collection of maple sugar was also economically important. Keesing (1939) argues that fishing was the major winter activity prior to the Menominee participation in the fur trade at which point hunting became an important winter activity. Most hunting was done by individuals or small groups.

Presently, there is considerable occupational diversity, although many of those occupations are related to the lumber industry. Even those with full-time jobs also hunt and fish (L. Spindler, 1978:721). Berry season involves the labor of entire families. Among traditional Menominee, hunting and gathering, as well beadwork and other handicrafts, was extremely important through the 1970s.

A detailed account of historic Menominee material culture can be found in Skinner (1921). Pre-contact Menominee material culture is poorly documented but presumably was similar to that characteristic of the Woodland adapted people in the region. The Menominee manufactured dugout and birchbark canoes. Hunting and fishing equipment and weapons and "sacred" artifacts were manufactured by men. These items included bows and arrows, wooden clubs, stone, bone, and copper knives, axes made of stone, drums, and pipes. Women manufactured household utensils, tanned and sewed hides, and made mats and pottery.

By the reservation period, copper was no longer used and ceramic vessels were no longer manufactured. Pre-contact technologies such as tanning of hides, manufacture of clay pipes, and the use of bone and antler for tools were utilized by only a few Menominee. By 1890 the canoe was no longer in use, and the bow and arrow only occasionally (Keesing, 1939:28).

Seventeenth and 18th century Menominee houses consisted of a domed lodge of mats or bark used for winter and a rectangular bark cabin for summer. Additional structures included women's menstrual huts, sweat lodges, dreaming and fasting lodges, and a structure erected for a shaman's activities. By the late 19th century, log or frame structures were being erected for winter use and a conical-shaped residence constructed of sapling and bark was used in the summer (Hoffman, 1896:253-256). Bark houses were reported by Skinner (1921), and Louise Spindler notes that a few bark houses were used as late as the 1950s (1978:709).

Social and Political Organization

According to Keesing (1939), Skinner (1913), and Hoffman (1896), both the early documents pertaining to the Menominee and the origin or creation myth of the Menominee suggest the existence of a dual organization or moiety system made up of the Bears and the Thunderers. These two groups were subdivided into patrilineal totemic descent groups or clans. This system began to disintegrate in the 17th century. By the late 19th century, Hoffman's informants were unable to relate the organizational principles underlying the original descent system. Keesing attributes this breakdown of the old system to a Menominee reorganization of social relations in an attempt to more efficiently respond to the demands of the European fur trade.

Skinner classifies the Menominee kinship system as an Omaha-type system with a classificatory system of terminology. In this system, father and father's brother were given one term and father's brother's children or mother's sister's children (parallel cousins) are given the same terms as brothers and sisters. According to Skinner, prescribed joking relationships were maintained between many classes of relatives, but tabooed between cousins (1913:20). Further, rigid distinctions were maintained between cross-cousins and parallel cousins.

The formal sociopolitical structure of the pre-contact Menominee was marked by a system of hereditary chiefs drawn from the heads of descent groups. The hereditary chief of the Bear clan, considered the first and most influential Menominee clan, served as overall tribal chief. Additional leadership was provided by individuals who were accorded prestige through dreams (a great source of power) or special prowess. Individuals gaining such status could act as keepers of the war medicines, masters of ceremonies during public events, and spokesmen for hereditary leaders (Keesing, 1939:40). This system linked to a relatively sedentary village life. The former village/clan system changed with the arrival of French traders in 1667 to be replaced by a more mobile band system that favored smaller hunting parties that ranged widely in search of furs.

The band system of the fur trading era began to disintegrate when the Menominee reservation was formed in 1854 and was replaced by a more sedentary system. As populations began to nucleate and become increasingly sedentary, unity among members of bands disintegrated and the nuclear family became important.

Religion and Ritual

The Menominee belief system is dualistic with an on-going conflict between good spirits above the earth and bad spirits below the earth. These concepts, recorded by Hoffman (1896) and Skinner (1921) are reflected in early accounts of fur traders and missionaries. Early accounts also emphasize that the gaining of power was essential to the Menominee. Power was obtained by securing a guardian spirit through a dream revelation induced by fasting. The central experience of the Menominee religion was the dream revelation. Once achieved, power was maintained and guarded through a series of taboos. Skinner argues that the basic beliefs regarding power and associated taboos were in operation in 1913. Fasting among Menominee was documented by the Spindlers through 1960 (L. Spindler, 1978:715).

There are four major traditional cultural religious groups which have persisted among the Menominee into the latter half of the 20th century. They are the *Midewin* or Medicine Lodge Society, the Dream Dance or Drum Dance, the War or Chief's Dance, and the Peyote religion known as the Native American Church. The production of items related to the ceremonies of

the Medicine Lodge, Dream Dance, and Peyote religion persisted into the 1960s (L. Spindler, 1978) and may continue to the present day. In addition to these traditional religious groups, there are also some Menominee who are Christians. A segment of the community is affiliated with the Catholic Church.

Among tradition-oriented members of Menominee society within the last 35 years, ordinary dreaming has also been a significant activity, as well as the securing of a guardian spirit and a strong belief in the power of witchcraft. As of 1960, most of the men and boys of the tradition-oriented groups hunted and fished and a few used a variety of charms such as "hunting bundles" to ensure the cooperation of the special powers and guardian spirits. Many individuals and families picked ferns and evergreen boughs. A few even traveled to Minnesota to gather wild rice each year (L. Spindler, 1978).

Tradition-oriented individuals are primarily persons who are members of the Medicine Lodge or Dream Dance organizations. They have sometimes been called native-oriented. Some of these persons are descended from Potawatomi who intermarried with Menominee. Most lived near Zoar, but others were scattered elsewhere throughout the reservation. Very few now identify as Potawatomi and all spoke the Menominee language which is also used at ceremonies. In the 1950 to 1960 period, membership of the group totaled about 70 adults, but in the mid-1970s, there was evidence of a strong, tradition-oriented revival (L. Spindler, 1978).

Life Cycle and Mortuary Practices

Information on Menominee life cycle and burial practices is based on Hoffman (1896), Keating (1824), and Spindler and Spindler (1970). Children and elders were considered important and close to the supernatural due to their closeness to the otherworld (recent birth and impending death). Division of labor along the lines of sex as related to tasks called for men to hunt and fish and women to manage the household and the children. However, both boys and girls fasted at puberty and both men and women practiced witchcraft. The care of small children was the responsibility of the mother although as children grew older there was more reliance upon other members of the group, particularly elders, for the transmission of cultural values.

Among the Menominee, burial took place within a day of death, and early observers reported burials on scaffolds, beneath logs on the ground, and occasionally in mounds. In certain instances, three logs were reportedly put over shallow graves to prevent animals from getting at the body. This practice changed through time, until actual structures were built over the grave with windows or holes through which food for the deceased was placed.

Burials were also reported as being enclosed in birch bark or slats of wood, except in instances when suitable materials were unavailable. Occasionally, an individual was buried in a section of a dugout canoe. Early graves were marked by a pole; later graves had low fences built around them. Grave goods seem limited to utilitarian items, particularly things perceived as necessary to survive in the afterlife. Food and tobacco are the most frequently mentioned items placed with the deceased.

The Menominee are noted as preferring high hills and natural and artificial mounds as burial locations. There does not seem to be a close association between burial locations and large permanent villages. Burials are more closely associated with smaller campsites and individual habitation sites. Menominee burials could be expected to be located on prominent landforms,

have few grave goods associated, and at least in some cases not be associated with larger habitation sites.

3.2.2.3.3 Summary

Considerable detail on the historical and cultural context of the Chippewa, Potawatomi, and Menominee was described in this section to provide the setting for the identification, documentation, and evaluation of cultural sites in the Crandon Project study area and vicinity. Some of these cultural sites may meet the requirements for potential or actual listing on the National Register of Historic Places as Traditional Cultural Properties. The following section uses the information derived from this and related research to discuss the kinds of cultural sites which might be found in the study area and vicinity.

3.2.2.4 Potential Cultural Site Types in the Study Area and Vicinity

3.2.2.4.1 Introduction

This section pulls together the results of the ethnographic and archaeological research which has been conducted in the region to develop a listing of potential cultural site types which are most likely to be found in the study area and vicinity. Some of these cultural site types, in turn, could meet traditional cultural properties requirements as set forth in National Register Bulletin 38 (Parker and King, 1990).

3.2.2.4.2 Cultural and Behavioral Correlates of Cultural Sites

The location and scale of Native American utilization within the project area is expected to be a reflection of the specific cultural adaptive strategies and settlement systems adopted by the Indian inhabitants of the region. With the exception of the Potawatomi, who were relatively late immigrants into the project area (Clifton, 1977:310-311; 1978:727), the native inhabitants of northern Wisconsin followed lifeways that were continuations of highly effective cultural adaptations to specific Upper Great Lakes biotic communities. At the time of European contact, these cultural adaptations were already in place for hundreds of years (Fitting and Cleland, 1969:292).

The Upper Great Lakes region contains three major biotic zones: the Canadian biotic province located in northern Wisconsin and Minnesota, and the Upper Peninsula of Michigan; the Carolinian biotic province located in southern Wisconsin and Michigan; and the Canadian-Carolinian transition zone which covers much of northern Wisconsin and the middle third of Michigan's Lower Peninsula (Fitting and Cleland, 1969:290-291).

Each of the biotic provinces found in the Upper Great Lakes region is characterized by plant and animal communities which are distinctive to that particular province. The Carolinian biotic province is characterized by southern plant and animal communities, and both soils and climate are well suited for agriculture (Fitting and Cleland, 1969:289). The Canadian biotic province contains a combination of the southern plant and animal communities of the Carolinian biotic province, and those of the more northerly Hudsonian biotic province. This mixture of plant and animal communities is unique to the Canadian biotic province (Fitting and Cleland, 1969:291). Between the Canadian and Carolinian biotic provinces is a zone of transition containing plant and animal species found in both the northern and southern provinces. An important reason for

the existence of the transition zone is the so-called "Lake Effect," which causes milder temperatures and a longer growing season along the shores of Lakes Michigan and Huron (Fitting and Cleland, 1969:291).

The native inhabitants of northern Wisconsin possessed cultural systems which were effectively adapted to the resources and challenges of these biotic provinces. Fitting and Cleland (1969) have identified settlement pattern types among late prehistoric archaeological manifestations in the Upper Great Lakes region which closely correlate with distinct biotic zones. These settlement pattern types have produced archaeological correlates and material remains which are recognizable in the archaeological record.

The project area is contained entirely within the Canadian biotic province. As a result, archaeological resources within the project area are expected to reflect utilization of the resources unique to the province. The most important of these wild resources include wild rice, maple sugar, white tail deer, and the extensive inland fisheries of the region. Subsistence and settlement patterns of the inhabitants of the Canadian biotic community are indicative of a general hunting and gathering adaptive strategy which was practiced to some degree by all Native American groups who may have utilized the project area. Later adaptations include varying degrees of low-level horticulture as well.

Because this general cultural pattern was typical of all the groups within the project area, assignment of tribal or cultural affiliation to most archaeological or ethnographic sites in the region is extremely difficult. Two separate strategies are possible when attempting to assign group affiliation to project area cultural resources. The first strategy assigns cultural association according to temporal parameters reflecting reported Native American use of the region. The second involves an attempt to associate functionally specific site types with particular groups. Unfortunately, available data is rarely detailed enough to support use of this latter approach. Consequently, the following discussion is based on a tripartite temporal classification of Upper Great Lakes history.

With regard to the current discussion, it is sufficient to identify three periods in Wisconsin history with particular relevance for identifying the tribal affiliation of archaeological or ethnographic resources in the project area. These periods include a Late Prehistoric and Protohistoric Period, a Historic Period, and a Reservation Period. This information is summarized from similar and more complete discussions focused on the history of the three tribes provided in the Ethnographic Setting (Section 3.2.2.3). Each period is briefly discussed below and results are incorporated into a temporal categorization of the archaeological and ethnographic resources of the project area.

3.2.2.4.2.1 Late Prehistoric and Protohistoric Periods (AD 1000 - 1634)

The Late Prehistoric Period refers to the time when the lifeways and culture of Native American groups were yet to be affected by European influence. The Protohistoric period refers to the earliest period of European presence in North America, prior to the actual arrival of Europeans in the Great Lakes region. Certainly, Great Lakes Indian groups were aware of the presence of Europeans during the Protohistoric Period, as material goods were traded inland by eastern groups already in contact with Europeans (Mason, 1986:370). The cultural systems of the Late Prehistoric and Protohistoric periods are believed to have been similar to those of Historic Indian groups observed by the earliest European arrivals in the Upper Great Lakes region.

Therefore, the writings and descriptions of early European observers can be utilized to suggest parallels between early Historic Period cultural patterns and Late Prehistoric and Protohistoric Periods practices (Fitting and Cleland, 1969:292).

One of the challenges faced by North American archaeologists is the general difficulty in affiliating Late Prehistoric and Protohistoric archaeological and ethnographic sites with current Native American groups. This is particularly true for the Upper Great Lakes region, where a number of "peculiar historic circumstances" (Mason, 1993:258) have prevented a more detailed understanding of the cultural milieu of the region at the end of prehistory.

Chief among these circumstances was that by the time the Indian inhabitants of the Upper Great Lakes were encountered by Europeans in significant numbers, events far to the east had already profoundly altered the social environment of the region. By the close of the 17th century, the Upper Great Lakes had become a vast refuge for eastern groups fleeing warfare and other social pressures occurring further to the east (Mason, 1993:259). At present, affiliation of Late Prehistoric and Protohistoric archaeological and ethnographic sites with known Native American groups has been successful on a limited scale [see for example (Mason, 1986; Wittry, 1963)], but no consensus exists on the efficacy of the approach in identifying sites attributable to ancestral Menominee, Chippewa, or Potawatomi (Mason, 1976; 1993). Because of this, the present study will not attempt to identify tribal affiliation of Prehistoric and Protohistoric archaeological and ethnographic sites beyond a purely speculative level.

Current evidence suggests that Late Prehistoric and Protohistoric Period archaeological sites encountered in the project area are probably not referable to either Chippewa or Potawatomi presence. This is because prior to the late 16th and early 17th century migration of the Chippewa into the southern Lake Superior region, the project area appears not to have been utilized by Chippewa groups. Likewise, the Potawatomi did not settle in the region until well into the 19th century. However, the project area is coincident with a portion of Wisconsin known to have been historically utilized by the Menominee (Ourada, 1979:4). Consequently, ancestral Menominee are likely to have occupied the vicinity of the project area, although the extent and duration of this occupancy is at present unclear.

It is probable that ancestral Menominee utilization of the project area was focused on the harvesting of the abundant wild rice of the region, a staple known to have had an important role in Menominee subsistence. The importance of wild rice to the Menominee is reflected in the very term "Menominee," which is derived from the Algonquian *Mano min ini niwûk,* meaning Wild Rice People (Ourada, 1979:7-8). At the time of European arrival in the Upper Great Lakes, the Menominee were primarily located east of the project area, living in villages along the western shore of Green Bay and on rivers flowing into it (Ourada, 1979:4). Jesuit Father Claude Allouez encountered the Menominee in this area between 1669-1670, where he found them "almost exterminated" by warfare (Draper and Thwaites, 1855-1911:66). Ourada (1979:11) has suggested that Allouez's visit coincided with a period when the Menominee were at war with the Chippewa. It is possible that Menominee displacement from the project area was a consequence of territorial conflicts with the Chippewa, who began arriving in northern Wisconsin in the late 17th century (Danziger, 1979:7; Warren, 1885:90).

In any event, with regard to Late Prehistoric and Protohistoric occupation of the project region by the groups targeted in this study, it is most likely that ancestral Menominee groups were present during this time period. However, it should be stated that Late Prehistoric and

Protohistoric archaeological and ethnographic sites may also be referable to project area utilization by unknown groups not related to the present day Menominee Indians.

3.2.2.4.2.2 Historic Period (1610-1820)

The beginning of the Historic period in the Upper Great Lakes region is difficult to define. Various scholars have proposed definitions which more often than not are related to the first European contact. Unfortunately, the historical records with regard to the earliest European trader or explorer to visit various parts of the region are not clear. Some suggest that the first white man to enter the western Great Lakes was Etienne Brule in 1610 (Nesbit, 1989:20; A. Smith, 1985:6). Others prefer Jean Nicolet's documented arrival in Green Bay in 1634 as the beginning of the Historic Period in the Upper Great Lakes region.

Conventionally, the Historic period in Wisconsin is divided into Early, Middle, and Late stages. The Early Historic period (1610-1670) is characterized as a time when trade goods were scarce and only first arriving in the area. Early Historic period trade goods include iron knives, brass bracelets, glass bottles, glass trade beads, religious medals, and brass kettles (Mason, 1986:373). The Middle Historic period (1670-1760) was a time defined by the French domination of New World trade. In addition to the trade goods already mentioned, a Middle Historic period artifact assemblage may also include types of Jesuit rings, baling seals, iron kettles with three legs, muskets, lead shot, rectangular gin bottles, hoes, brass projectile points, spall gunflints, catlinite pendants, Jew's harps, and a great variety of glass trade beads (Mason, 1986:374).

The Late Historic period (1760-1820) is characterized by a shift to British influence. French knives and guns, Jesuit rings, and many varieties of glass beads were no longer traded. British trade goods included silver utilitarian and ornamental items such as spoons, earrings, wristbands, bracelets, brooches, gorgets, armbands, headbands, crosses, and lockets. Other items include patent medicine bottles, increased use of European ceramics, prism-shaped gunflints, and multi-faceted glass trade beads. By this time, most of the native arts and crafts had been modified or had disappeared completely (Mason, 1986:376-378).

Documentary records indicate that there was an overriding Chippewa presence in the vicinity of the project area during the Historic period (Henry, 1809; Thwaites, 1869-1901). Beginning with a foothold established at Sault Ste. Marie in the middle 17th century, Chippewa groups steadily expanded their territory into interior regions of Wisconsin and Minnesota. This expansion coincided with the growing Chippewa participation in the Great Lakes fur trade, and French expansion of the trade into western Wisconsin and northern Minnesota (Ritzenthaler, 1978:744). By the end of the 17th century, the Chippewa had established major settlements at locations near French trading centers. The largest of these settlements was located at Chequamegon Bay, on the south shore of Lake Superior, where an estimated population of 1,000 Ojibwa were resident by the close of the 17th century (Ritzenthaler, 1978:744).

Chippewa occupancy of the vicinity of the project area intensified during the 18th century. By the middle part of the century, a commercial alliance that had existed between the Chippewa and the Dakota Sioux had deteriorated to the point that the two groups were engaged in active warfare as each group attempted to expel the other from the region (Richards and Watson, 1995). Initial Chippewa success in these skirmishes strengthened their position in the Lake Superior region, and enabled them to drive the Dakota west of the Mississippi River. By the end

of the 18th century, the Chippewa had succeeded in establishing ascendancy in the region, and established village sites in the once contested territory.

In light of the well-documented Chippewa expansion into northern Wisconsin during the Historic Period, it is probable that the majority of archaeological and ethnographic sites encountered in the vicinity of the project area which are datable to the Historic period are referable to a Chippewa presence. Following their migration into the region in Early Historic times, the Chippewa expanded their territorial holdings relatively quickly, displacing other Native American groups in the process (Richards and Watson, 1995). The strength of the Chippewa's belief to their claim over the region encompassing the project area is demonstrated by the tenacity with which they defended it against other Native American groups, particularly the Dakota Sioux. Therefore, with regard to Historic Period occupation of the vicinity of the project by the groups targeted in this study, it is most likely that the majority of archaeological and ethnographic sites are attributable to Chippewa groups. However, it should be noted that some sites may also be referable to utilization of the region by other groups not found in the region today.

3.2.2.4.2.3 Reservation Period (1820-Present)

Beginning in the early 1800s, white settlement throughout the Upper Great Lakes region steadily increased, prompting the United States government to enter into land cession negotiations with the various Indian tribes in the region. The first of these treaties, the Prairie du Chien Treaty of 1825, attempted to end hostilities between the Indian groups of the Upper Great Lakes region, particularly the Chippewa and the Sioux, by establishing territorial boundaries for each group (Danziger, 1979:75-76). At the treaty proceedings, a boundary was established between the Chippewa and Sioux which ran southeast through Minnesota and into Wisconsin. The Sioux were to remain south of the line, and the Chippewa to the north. The treaty officially conferred to the Chippewa nearly the entire northern portions of Minnesota and Wisconsin, areas which had recently been contested with the Sioux (Danziger, 1979:75).

Additional treaties between Chippewa groups and the United States resulted in the transfer of much of the territory granted to the tribe by the Treaty of Prairie du Chien to the government. In a treaty concluded in July of 1837, the Chippewa ceded a large portion of their holdings in Wisconsin and Michigan to the United States in return for annuity payments spread out over a twenty year period (A. Smith, 1985:147). Five years later, the Chippewa were persuaded to sell their remaining territory in these states (A. Smith, 1985:149). In both treaties, the Chippewa specifically retained the right to hunt, fish and gather wild rice from the ceded territories (A. Smith, 1985:147) on certain public lands in northern Wisconsin. Eventually, however, these rights were restricted, and the various bands of Chippewa were assigned to reservation lands set aside for their use by the 1854 Treaty of La Pointe.

The Sokaogon Chippewa have lived in the general Crandon vicinity for many generations, and historically had their villages along Pelican Lake, Post Lake, Rice Lake, Mole (Swamp) Lake, and other lakes in the region where ricing and other subsistence activities were readily available to them. In the 19th century they were known to non-Indians as the Post Lake bands. The name Sokaogon derives from the Ojibwa term for Post Lake, meaning roughly "people of the post in the lake." Other terms applied to the Sokaogon during this time included Rice Lake band, Lakes band, Pelican Lake band, and Lost band. Denied a reservation of their own, and refusing relocation to one of the other Chippewa reservations, the Sokaogon Chippewa remained in the area. The federal government provided them with 1,680 acres of land in 1934. The

reservation was established in 1939, and the acreage increased to 1,800 in 1982. The Sokaogon Chippewa Community has the privilege under the 1842 treaty to engage in usufructuary activities such as hunting, fishing, and gathering on certain public lands in northern Wisconsin. Also referred to as the "miners' treaty" and the "copper treaty," the 1842 treaty establishes that mining development has a treaty-based right to proceed in peaceful, cooperative existence with Native American occupancy and use of the area.

Coincident with the Sokaogon occupancy of the vicinity of the project area during the Reservation Period was a Potawatomi utilization of the same region. The Potawatomi came into the region in the 1890s, eventually forming two communities in Forest County, one at Stone Lake and the other at Wabeno. Congress gave them scattered lands in 1913, both groups adopted tribal constitutions under the Indian Reorganization Act of 1934, and their lands placed in federal trust in 1988.

Based on these documented trends in Native American migration and utilization of the vicinity of the project area during the Reservation Period, it is probable that the majority of archaeological and ethnographic sites encountered in the region from the Reservation period represent a continued Chippewa utilization of the region with a limited and territorially bounded Potawatomi presence. The territorial circumscription of Native American groups brought on by the establishment of reservations precluded easy migration of other groups into the region, with the exception of the historically documented relocation of the Potawatomi.

3.2.2.4.3 Discussion

A wide variety of reported archaeological and ethnographic site types are documented in the study area and vicinity. Based upon this information, additional sites may reasonably be expected to occur in this same area. Some of these site types are specific to one or more of the temporal periods discussed in the present study, although, most known or predicted site types have analogs in all three time periods. Table 3.2-1 below lists site types which might reasonably be expected to occur within the study area and vicinity, and illustrates the predicted association with each of the temporal periods used in the present study. Site types are broadly categorized as follows: habitation, resource procurement, event, special purpose, ritual/sacred, mortuary, or place. Each category is briefly discussed below.

3.2.2.4.3.1 Habitation Sites

This category references both larger, multi-seasonal villages and smaller, seasonally occupied camps. Year-round Late Prehistoric/Protohistoric period occupations are likely rare or nonexistent in the study area and vicinity. Later Historic Period occupations and Reservation era sites are expected to include more permanent, year-round occupations.

Well-documented archaeological contexts are not known from the study area and vicinity; consequently, Late Prehistoric/Protohistoric site morphology can only be predicted with reference to Lakes Phase Late Woodland sites in adjoining areas of north central Wisconsin. Such sites, dated between A.D. 800 and A.D. 1400, vary widely. For example, habitation sites may range from less than one acre in size to well over 40 acres in extent (Salzer, 1974:49). Site distribution appears to correlate strongly with inland lake settings. Riverine locales were less frequently selected and location tends to be restricted to stream confluences and areas of rapids or falls (Salzer, 1974:49).

Table 3.2-1

Potential Cultural Site Types in the Study Area and Vicinity

Potential Cultural Site Types in the Study Area and Vicinity	Late Prehistoric & Protohistoric (AD 1000-1634)	Historic Time Period (1610-1820)	Reservation Time Period (1820-present)
Habitation Sites			
Village	yes	yes	yes
Camp	yes	yes	yes
Resource Procurement Sites			
Hunting Camp	yes	yes	yes
Ricing Camp	yes	yes	yes
Sugaring Camp	yes	yes	yes
Fishing Station	yes	yes	yes
Historical Events			
Battleground	yes	yes	no
Payground	no	yes	yes
Special Purpose Sites			
Garden/Farm Plots	yes	yes	yes
Lithic Extraction	yes	no	no
Fish Weir	yes	yes	yes
Trading Post	no	yes	yes
Ritual/Sacred Sites			
Dance Ground	yes	yes	yes
Midewin	no	yes	yes
Feast of the Dead	yes	yes	no
Puberty/Naming	yes	yes	yes
Sturgeon Ceremony	no	yes	yes
Other Ceremonial	yes	yes	yes
Spirit Stone	no	yes	yes
Rock Art	yes	yes	yes
Mortuary Sites			
Single Interment	yes	yes	yes
Formal Cemetery	yes	yes	yes
Ossuary	yes	yes	no
Other Places or Sites			
Ricing Locations	yes	yes	yes
Maple Sugaring Grove	yes	yes	yes
Spawning Ground	yes	yes	yes

Prepared by: CW
Checked by: JWS

3.2.2.4.3.2 Resource Procurement Sites

Small, seasonally occupied sites, situated so as to allow efficient exploitation of a particular resource or set of resources are typical of sites in this category. Specific resources targeted include white-tail deer, wild rice, maple sap/sugar, and freshwater fish. Site location is expected to be a function of resource availability. Although the introduction of European trade goods may have increased the efficiency with which resources could be harvested, basic exploitative strategies probably varied little from the Late Prehistoric/Protohistoric Period to recent times.

3.2.2.4.3.3 Historical Events

This category references historically documented occurrences such as battles or skirmishes and allotment disbursements. Although Late Prehistoric/Protohistoric battle sites are not reported for the study area, the well documented series of Chippewa-Dakota hostilities during the Historic period may well have analogs in earlier times. As noted in Richards and Watson (1995) the precise location of the various Historic Period Chippewa-Dakota battles is not known. However, the legendary Battle of 1806 likely occurred in the Rice Lake-Mole Lake area.

3.2.2.4.3.4 Special Purpose Sites

Included in this category are a variety of functionally specific properties including farming related sites, kill sites or meat processing stations, lithic extraction sites such as quarries or outcrops, fish weirs and traps, and trading post locations. Garden plots, corn hills and variations on the theme of raised-bed horticulture were probably typical of Late Prehistoric/Protohistoric and Historic period subsistence regimes in the region. For the most part, locations are expected to coincide with the immediate environs of larger villages. Kill sites and lithic extraction sites are likely to occur wherever such resources might be encountered. Fish weirs or other stationary entrapment devices have not been documented from the study area. However, the use of such features is widely documented from Archaic times to the present in most of the Eastern United States and Canada (Richards, et al., 1991; Rostlund, 1952). Trading posts are documented for the historic and reservation periods, and other examples may reasonably be expected.

3.2.2.4.3.5 Ritual/Sacred Sites

This category references a set of poorly documented site types relating to the conduct of spiritual life, curing activities, and various rites of passage. While several of the site types listed (i.e., dance grounds, spirit stones, or rock art) can be expected to produce relatively unequivocal archaeological signatures, the remaining site types are difficult to confidently associate with documented archaeological manifestations. For example, various rites of passage related ceremonies may leave little or no trace of the specific activity involved. In other cases, ceremonial behaviors were likely integrated into community life in such a way as to be virtually indistinguishable in the archaeological record. Some ritual/sacred site locations can be expected to coincide with habitation sites. Other ceremonial behaviors were likely associated with specific traditionally significant locales. Two dance-related sites are reported on Lake Metonga and on Rice Lake. None of the remaining listed site types have known archaeological or ethnographic expressions in the study area. However, a spirit stone is reported from the Menominee Indian Reservation southeast of the study area and a Potawatomi spirit stone was formerly located near Wabeno, well east of the study area.

3.2.2.4.3.6 Mortuary Sites

Study area mortuary sites include examples of earthen burial mounds, single interments, and cemetery use. Multiple burial or ossuary contexts were not reported. Mound site locations appear to correlate with lake margin settings. Although not all prehistoric mounds contain human burials, human remains were reported at the Nemec site on the west side of Lake Metonga. Single interments are relatively rare in the study area. Only two instances are known and one of these, the reported location of the grave of Great Marten at Post Lake is unconfirmed. Consequently, it is possible that Great Marten's grave site harbors additional interments. The predominant type of burial context within the study area appears to be interment in cemeteries containing 20 to 200 individual graves. Cemetery locations appear to correlate with the location of former and modern habitation sites.

3.2.2.4.3.7 Other Sites or Places

Places identified in the present study tend to be associated with exploitation of various significant resources in the study area. Sites in this category are differentiated from resource procurement sites by the non-specificity of their location. Examples include lakes and rivers known to harbor stands of wild rice, groves of mature sugar maples, and stretches of area streams recognized as important spawning grounds for freshwater fish. Consequently, these sites are less specific locations than contexts or settings for resource procurement and related activities.

3.2.2.4.4 Summary

Native American utilization of the study area and vicinity has resulted in a diverse set of archaeological and ethnographic site types associated with various aspects of Indian life. Two site types are likely restricted to association with a single temporal period. Lithic extraction sites are probably related to Late Prehistoric/Protohistoric use while trading posts are likely restricted to Historic Period associations. Three site types (battles, feast of the dead, and ossuaries), may span the Late Prehistoric/Protohistoric and Historic Periods. Four site types (paygrounds, *Midewin*, sturgeon ceremony, and spirit stones) are likely restricted to association with the Historic and Reservation Periods. However, the majority of the archaeological and ethnographic site types expected within the study area and vicinity, may have analogs in all three temporal periods referred to in this research. Unfortunately, analysis of these data is hampered by a paucity of excavated archaeological data, well-documented ethnographic accounts, or established comparative contexts. Consequently, it is difficult to confidently associate a particular site or even site type with specific Native American tribal affiliation. Nonetheless, the extensive Native American utilization of the study area and vicinity from Prehistoric times to the present underscores the historical strength of the modern Native American presence in the region.

3.2.2.5 Inventory of Cultural Sites in the Study Area and Vicinity

3.2.2.5.1 Introduction

This section describes the methods and results of an inventory of cultural sites in the Crandon Project Native American cultural resources study area and vicinity. The inventory was developed from a review of the historical, ethnographic, ethnohistoric, archaeological, and other relevant sources which contain information about Native American occupation and utilization of the study area and vicinity defined for Native American cultural resources during and just prior to the

contact period. The term "cultural site" is used more frequently than "ethnographic site", although either term would be appropriate within this context.

The purpose of the inventory is twofold: (1) to identify cultural sites, including potential TCPs, which could be affected by the project, and (2) describe Native American occupation and utilization of the project area and vicinity.

3.2.2.5.2 Methods

The inventory reported in this study was compiled by conducting archival research and reviewing published literature pertinent to the study area cultural resource base. The sources reviewed are listed under Sources Consulted. Archival studies included a comprehensive review of the data housed at Great Lakes Archaeological Research Center, Inc. and at regional libraries and historical societies, mostly located in Madison, Wisconsin. Archives and serial file systems were also searched for site-specific information. Published literature sources consulted include: *The Wisconsin Archeologist*, a quarterly journal published since 1901; *The Wisconsin Magazine of History*, the journal of the State Historical Society of Wisconsin; *The Wisconsin Historical Collections* consisting of 20 volumes published between the years 1903 and 1920; and the *Bulletin of the Public Museum of the City of Milwaukee*, several of which detail archaeological investigations conducted in various Wisconsin localities. Also reviewed was the multi-volume planning guide to cultural resource management in Wisconsin compiled by the State Historical Society of Wisconsin (Wyatt, 1986).

Unpublished sources subjected to scrutiny are represented by four different formats: (1) serial entry files; (2) map files; (3) manuscript files; and (4) archaeological survey reports. Two serial file systems were consulted. The first of these is the Wisconsin Archaeological Site Codification File, copies of which are housed at the Anthropology Section, Milwaukee Public Museum and the Museum Division, State Historical Society of Wisconsin. This file consists of an inventory of previously reported archaeological sites from both prehistoric and historic times and provides information relating to site locations, cultural affiliation, artifacts, and literature sources. The second file consulted is the Historic Preservation Division inventory file housed at the Historic Preservation Division, State Historical Society of Wisconsin. This file includes both archaeological sites and standing structures that have been identified as possessing architectural and/or historical significance.

Several map files were reviewed. They include: (1) The Charles E. Brown Archaeological Atlas; (2) Government Land Office (GLO) survey records; (3) the Trygg map files; and (4) local plat and deed maps. The Charles E. Brown Archaeological Atlas provides the locations of sites on county plat maps. The prehistoric and historic sites include camps, villages, mounds, springs, rock art, workshops, quarries, cemeteries, trails and various other types of archaeological manifestations reported to Brown during his long tenure as editor of *The Wisconsin Archeologist* and as an employee of the State Historical Society of Wisconsin. The Government Land Office records consist of plats and survey notes that may provide information regarding presettlement vegetation, topography, and aquatic features, all important variables in determining potential site locations. In addition, dependent on the interests of individual land surveyors, cultural information such as the locations of Indian trails, camps and villages, maple sugar processing stations (sugar bushes), pioneer settlements, and early industrial improvements such as mills, roads, and early homes and farmsteads are frequently noted on these maps. Both map files are

housed at the Archives Division, State Historical Society of Wisconsin and the latter is available on microfilm at various repositories.

The maps prepared by Robert Bernsteen (1969) housed in the Archives Division of the State Historical Society of Wisconsin were also reviewed. Bernsteen's *Atlas of the Eight Counties of Forest, Florence, Iron, Langlade, Lincoln, Oneida, Price, Vilas* is based upon a review of historic plats, archaeology records, private collections, and records from the Wisconsin Historical Society and Milwaukee Public Museum.

The Trygg map file is a privately published composite of the USGS (GLO) land survey records. While the Trygg maps are less detailed in scale than the USGS (GLO) plats, the file is an important source for understanding the chronology and magnitude of regional development during the late historic period (ca. 1850). Finally, early plats and topographic maps were reviewed to assess historical settlement and development of the project environs.

Manuscript files investigated include the Charles E. Brown manuscript files and the State Archaeologist's county files. Both of these are housed at the Museum Division, State Historical Society of Wisconsin. The Brown manuscripts consist of 50 years of notes, correspondence, sketches, maps, and other data relating to historic and prehistoric archaeological sites. The county files include reports (unpublished), photographs, sketch maps, letters, and information derived from the Museum's highway archaeology program.

In addition, the research entailed review of the extensive collection of historical documents contained in the Sokaogon Chippewa Tribal Archives housed in the Wisconsin State Archives, Madison, Wisconsin. A search of the Human Relations Area Files was conducted using the microfiche copy maintained at the University of Wisconsin-Madison Memorial Library. Transcripts from the Crandon Mine EIR Scoping Meetings held in Keshena (Menominee), Crandon (Potawatomi), and Mole Lake (Sokaogon) were reviewed as were letters from the tribes which included their cultural concerns for the project.

Some of the archival sources referenced above and many others relevant to Chippewa occupation and utilization of the Crandon vicinity have been copied and catalogued by date and source in three lengthy appendices prepared by the law firm of Foley & Lardner in conjunction with *Sokaogon Chippewa Community vs. Exxon Corporation et al.* (Case No. 86-C-0599) (1991). Included in this collection are authenticated copies of Indian treaties, excerpts from historical and anthropological works such as memoirs, journal articles, monographs, books, and atlases; historical maps and plats; Annual Reports of the Commissioner of Indian Affairs; findings and testimony from the Indian Claims Commission; and records from the National Archives, Bureau of Indian Affairs, Court of Claims Archives at the National Records Center, State Historical Society of Wisconsin, and Sokaogon Chippewa Community Tribal Archives. Sources from this collection were used extensively to identify and document cultural sites for the inventory.

3.2.2.5.2.1 Sources Consulted

The major published and unpublished literature sources consulted to develop the cultural sites inventory are summarized below. Full citations are provided in the Bibliography.

F. Ackley, 1987; R. Ackley, 1994; V. Ackley, 1982; W. Ackley, 1948, 1962; W. Ackley and Polar, 1935; W. Ackley, et al., 1959; Anonymous, n.d.; Barrett and Skinner, 1932; Bennett, 1914, 1916,

1917, 1918, 1919, 1920; Bernsteen, 1969; Bernsteen and Bernsteen, 1968; C. Brown, n.d.a., n.d.b., 1908, 1924, 1925; D. Brown, n.d., 1937a, 1937b, 1938a, 1938b, 1938c, 1940a, 1940b, 1941; Campbell, 1900a, 1900b, 1910; Cleland, et al., 1995; Coleman, 1919; Creel, 1922; Curot, 1911; Danziger, 1979; Densmore, 1926, 1929; Duchac, 1908; Ehlert, 1974; R. Fay, 1984, 1986; Forest County Board of Supervisors, 1912; Forest County Map Company, 1900; Forest County Potawatomi Community, 1994; Geisler, et al., 1980; Glasgow, 1953; Goethem, 1979; Government Land Office, 1857, 1859; History Students of UW-Eau Claire, 1990; Hixson Map Company, 1924, 1925; Human Relations Area Files, (1968-present); Kuhm, 1928, 1952; Levi, 1956; Lurie, 1969, 1980; Marceil, 1955; McGinley, 1919; Me-gee-see, 1868a, 1868b, 1869; Moody, 1910; Moore, 1922; Morgan, 1994; Ogle, 1913; Oneida County Board of Supervisors, n.d.; Overstreet and Brazeau, 1982; Page, 1881; Rand McNally, 1896; Randall, 1964, 1966; Reddick, 1948; Richards, 1995d; Richards and Watson, 1995; Ritter, 1920; Rockford Map Publishers, 1958; Ross, 1937; Salzer and Birmingham, 1978; Scott, 1897a, 1897b; Shaw, 1897, 1899; Shepard, 1908; Skinner, 1853; E. Smith, 1994; N. Smith, 1993; Sokaogon Chippewa Community, 1982, 1995; Star Map Service, 1947; Stephens, 1879; Stowe, 1940; Tanner (ed), 1987; Tawah, 1941; Terney, 1890; Trygg, 1964; U.S. Army Corps of Engineers, 1995 [March], 1995 [June]; U.S. Dept. of Interior, n.d.; Unknown (maps), 1890, 1908, n.d., 1985; Vogel, 1991; Wambisk-ki-ba-nince, 1872; Wisconsin Department of Natural Resources (WDNR), 1986; Wisconsin State Planning Board, n.d.; Wisdom, 1936; Wooster, 1930a, 1930b; Wyatt, 1986.

3.2.2.5.2.2 Study Area

The *study area* for the cultural sites inventory, as described in the Introduction, includes the plant site (PS), tailings management area (TMA), a wastewater discharge corridor (WWDC), and a wetland compensation site (WCS). The proposed access road, tailings pipeline corridor, and railroad spur are also included. The PS/TMA study area encompasses a circular area eight miles in diameter centered over the Crandon ore body (a four mile radius from the ore body); the study area for the WWDC is defined as a two mile wide corridor centered over the approximate 38.3-mile length of the pipeline alignment; the study area for the WCS includes a one mile buffer zone on each side of the wetlands compensation location; the study area for the access road (ACR) is a one-half mile corridor centered on the access road; the study area for the tailings pipeline corridor (TPL) is a half mile corridor centered over the pipeline; and the study area for the railroad spur (RRS) is a one-half mile corridor centered on the railroad spur.

In practice, numerous sites situated well beyond the four mile PS/TMA study area boundaries are included in the inventory. This is done to provide a more complete picture of Native American occupation and utilization of the area in the vicinity of the project, and is in accord with the "cultural landscape" approach to cultural studies suggested by Kelly and Francis (1994). This approach is discussed in some detail in Section 3.2.2.6.3 below. In brief, the cultural landscape approach asserts that "the places where successive episodes of a particular story or set of interrelated stories occurred make up a culturally significant landscape just as the episodes make up the story (Kelley and Francis, 1994)." The significant cultural landscape of the Sokaogon Chippewa includes not only their contemporary residential and resource use areas, but other places associated with their historical occupation and utilization of the area. Many of these places are beyond the four mile study area. Additionally, references to cultural site locations are commonly vague, sources are sometimes contradictory, and actual site boundaries are often difficult to define. Considering this, the rule is to be generous with study area boundaries and sites so that nothing will be missed. Many of the Sokaogon Chippewa sites, therefore, were recorded well beyond the PS/TMA study area, and the Potawatomi sites were recorded well

north and east of the PS/TMA study area. Clearly, these sites situated well beyond the study area should not be affected by the project.

3.2.2.5.3 Results

Inventory results are provided below. They include a summary of some selected key references to Sokaogon Chippewa occupation and utilization of the project area and vicinity, a generalized inventory table, and a discussion of the inventory. Potentially sensitive descriptive and locational information is contained in two confidential appendices to be provided to relevant regulatory agencies upon request.

3.2.2.5.3.1 Summary of Selected Sources

The following summary of references is included to provide the reader with an overview of the kinds of sources available to document Sokaogon Chippewa occupation and utilization of the project area and vicinity. Additional references are included in the discussion of Sokaogon Chippewa history in Section 3.2.2.3.2.1. All of these references and many others are used to compile and document the inventory of cultural sites. Comparable information is not available for the Forest County Potawatomi, and Menominee activities during the late historic period were concentrated further to the south and east.

According to Sokaogon Chippewa oral history, by 1837 the *Suk-a-Aug-un-ing* had settlements at Post, Pickerel, Metonga (*Metawanja*), and Rice lakes in the Upper Wolf River (WDNR, 1986:113). In her story, tribal member Alice Randall relates that her people migrated from Madeline Island long before the treaties were made, and that their first chief, *Gitshee Ki-ji-wa-be-she-shi* (Great Marten) brought the band to Post lake, and also lived at Mole Lake and Pelican Lake (in Ehlert, 1974:1).

In the *Atlas of Great Lakes Indian History*, Tanner (1987) shows the project area to be on the western fringe of historic lands of the Menominee Indians, with the Wolf River separating Menominee from Ojibwa territory (1987:58, Map 13); On the map covering the period ca. 1810, however, Tanner shows an Ojibwa (Chippewa) village by the name of *Sukogonong* on the west side of the Wolf River and north of Post Lake (1987:98, Map 20), and this location is probably at Pelican Lake; The ca. 1830 map shows *Sukogonong* south of Pelican Lake, probably at Post Lake (1987:144, Map 27), and for the ca. 1850 period an Ojibwa settlement is shown on the east side of Post Lake (1987:169, Map 32); The map for the 1870 period shows *Sukaganong* (note spelling change) at the north end of Post Lake, another Ojibwa village northwest of *Sukogonong* in the vicinity of Pelican lake, and an Ojibwa village at the headwaters of the Wolf River, at the northern end of Pine Lake (1987:176, Map 33).

According to Sokaogon oral history as related by Chief Willard Leroy Ackley (W. Ackley, 1962), or *Ka-ba-is-goner-Bay-bay-shung*, the lakes, rivers, and streams included in the first reservation promised to Chief *Mi-gee-see* (Great Eagle) [and occupied and/or utilized by the Sokaogon Chippewa] included Post Lake (*Sokaogon*), Pelican Lake (*Sha-da-sa-ga-e-gon*), Rice Lake (*Mush-gig-kwa-wa-si-go-ga-ons*), Dry Lake [Bishop Lake], (*Bah-to-we-gum-mong*), Mole Lake (*Ke-bing-ka-ku-wa-si-go-e-ga-ons*), Rolling Stone Lake (*A-sin-a-bit*), Pickerel Lake (*Ka-mu-ji-gog*), Grand Lake (*Ma-no-sa-se-wong*), Mud Lake (*Bah-ya-go-ge-she-wa-gog*), St. Johns Lake (*Sa-cawe-a-gons*), Ground Hemlock Lake (*Na-ca-wa-she-gog*), Little Rice Lake (*Ma-no-menno-ka-nese*), Depot Lake (*Ma-shaw-be-she-kawk*), Oak Lake (*Me-to-me-ne-she-gog*), Big Sand Lake (*Me-tong-gog*),

Little Sand Lake (*Me-tong-gongse*), Wolf River (*Ma-ing-ga-se-beor*), Eau Claire River (*Na-go-an-da-se-be*), and Swamp Creek (*Mush-ga-mong-se-be*). Post Lake, Crane Lake, Big Sand Lake (Metonga), Little Rice Lake, and Pelican Lake were to represent the boundaries of said reservation. Chief Ackley noted the existence of Sokaogon Chippewa burial grounds at Rice Lake, Mole Lake, Dry Lake [Bishop Lake], Rolling Stone Lake, Pickerel Lake, Pickerel Creek, Post Lake, Pelican Lake, Big Sand Lake [Lake Metonga], Peshtigo River, and Eau Claire River.

There were trading posts in the Mole Lake-Rice Lake-Swamp Creek area during the historic period, although locations are not firmly established. Alice Randall was told that William Johnson (her grandfather) had a trading post at Wolf River Crossing and at Mole Lake at Johnson Falls (in Ehlert, 1974); Letters penned by Randall in 1964 explained that her grandfather William Johnson was supposed to have had a trading post at Post Lake and another on STH 55 near the inlet to Rice Lake, and that her grandfather had several trading posts, but that the number or location of them is not known. William W. Johnson, sometimes referred to as W.W. Johnston in written sources, was of Norwegian extraction, and married a full-blooded Chippewa, who was Alice Randall Ackley and Willard Leroy Ackley's maternal grandmother; Johnson served as an interpreter for the tribe on many occasions and supposedly was the recipient of a copy of the promised reservation map, subsequently lost. In an unpublished history of the Wolf River, J.L. Whitehouse (1947-49) recalls, that in the late 1870s, Tim Crain had a trading post two and one half miles north of Lily on the Military Road, Bill Johnson had a place one and one half miles north of Crain's where the Military Road joins the old Lake Superior Trail (acquired by Henry Strauss in 1881 after Johnson's death), Jim McLeod kept travelers at Twin Lakes two miles north of Johnson's, Hiram Polar had a place three miles north of Twin Lakes at Pickerel Creek on the old Lake Superior Trail, and Lou Monsfelt kept a place eight miles further on at Swamp Creek. Whitehouse recalls that Polar and Monsfelt had Chippewa wives, and that Polar was married but Monsfelt was "common law."

Sokaogon Chippewa oral history includes accounts of a battle in about 1806 in the Mole and Rice lakes area reported as the scene of the last major battle between the Chippewa and Dakota over control of the Wisconsin wild rice region, variously dated from the latter part of the 18th Century to the early part of the 19th Century; A historical marker on the reservation, erected in 1962 with the approval of Chief Willard Ackley, commemorates the battle: "About 1806 bands of Sioux from the north and west tried to gain control of the Rice Beds. A Fierce hand to hand battle resulted. The Indians, armed with bows and arrows and clubs, fought a long hard battle." The description continues with, "Over 500 Chippewas and Sioux were killed and were buried here in a common mound. The battle was expensive for the Sioux, who retreated westward and never again attempted to return."

The oral history accounts are based upon interviews with tribal members, including the "Mole Lake Battlefield Interviews" conducted at Mole Lake (W. Ackley, et al., 1959), and other accounts provided by Willard Ackley (1948) and Alice Ackley Randall in correspondence (1964), her personal story (Ehlert, 1974), and written accounts (1966); The battle was probably one of many that took place over about a 30 year period along the lakes and river banks in the area (W. Ackley, et al., 1959); The battle was so intense that the women and children were buried at night, and rags were put in the babies mouths to keep them from crying out and being slain by the enemy (W. Ackley, et al., 1959). In correspondence, Randall notes that "after we had the battle with the Sioux tribe in 1806 then we had a battle with the Menominee . . . (1964), a battle also referenced by Willard Ackley (W. Ackley, et al., 1959). Randall states that the battle of 1806 was fought to preserve the land, wild rice beds, and hunting, fishing, and trapping (in Ehlert,

1974), and that "coming here in the early 1700s they felt this land belonged to them and so they fought to preserve it for their posterity (1996)." George H. Reddick (1948) reported a battle site to Sokaogon Chief Willard Ackley located in and around Rice Lake territory which is probably a reference to the Battle of Mole Lake. Burials associated with the battle are reported at Mole and Rice lakes (W. Ackley, 1948; E. Smith, 1994) and Spirit Hill (N. Smith, 1993); A newspaper article based upon interviews with Willard Ackley and Alice Randall Ackley in May of 1963 states that the dead were buried in mounds and individual graves, and the main burial mound has been desecrated by relic hunters and leveled by agricultural use (Rhinelander Press, May 8, 1963).

In a review of published and unpublished literature sources, Richards and Watson (1995) could not identify the specific location or date of the Battle of Mole Lake, but note that this may have been one of many similar battles over contested territory fought between the Ojibwa and Dakota; that the battle presumably took place in the vicinity of Mole and Rice lakes, that the battle or battles were probably waged over a more extensive area; and that this particular battle is culturally significant in that the oral history accounts represent the success of the Ojibwa in defending their homeland and resources from an invading force (1995:43).

Charles Wisdom (1936) investigated the problems of landless Indians of the Great Lakes and made recommendations for the purchase of lands for them. His report, based upon oral history interviews, notes that "anciently, the Sakagan band occupied the three northern Wisconsin counties of Oneida, Forest, and Langlade [with] communities on the shores of the following lakes: Mole, Rice, Post, Pelican, Stone, Sand (now called Metonga, near the town of Crandon), Little Rice, Mud, Rat, Rich, Pickerel, Crane, Lily, Robert, Dry, Hunting River, and Pine." Mole Lake elders interviewed by Cleland and Nesper in 1994 (Cleland, et al., 1995:59) mentioned specifically Pickerel, Pelican, Rolling Stone, and Bishop lakes as places they had riced or had been riced in their memory. The COACT Report (Geisler, et al., 1980) also identifies Bishop Lake as a Wild Rice Lake.

In testimony before the Indian Claims Commission, Willard Ackley (1948:115) stated that his ancestors lived mostly at Rice, Mole, and Post lakes, but also at Rolling Stone, Pickerel, Pelican, Roberts, and Sand [Metonga] lakes, Wolf River, and a lot of other small lakes, streams, and rivers. Fred Ackley Jr. (1987) testified in SCC vs. Exxon that he picked berries around Mole Lake with his grandparents and parents sometime in the early 1950s, that around 1954 he traveled with his grandparents in the fall to harvest rice at Post Lake, the Wolf River by the old Ackley hoist, Pickerel Lake, down by Pickerel Creek, Rice Lake next to Mole Lake, and Mud Lake; that about between about 1850 and 1969 summer powwows were held at Post Lake, and at Elcho and Crandon during the Forest County Fair, that his grandparents and other older members of the tribe taught him how to get fish from the different lakes, mentioning Metonga, Pickerel, Rolling Stone, Rice, and Mole lakes; that most of their hunting and trapping areas were off the reservation, and that from 1950 to the present, he and other band members have gone to Post Lake, Lake Metonga, and Mole Lake to hold ceremonies and powwows. In SCC vs. State Historical Society of Wisconsin and CMC, Robert Ackley (1994) stated that there was wild rice at Lake Metonga, as well as Pickerel, Sand, Roberts, and Rolling Stone lakes, and on Swamp Creek. In his testimony for the same case, Earl Smith (1994) cited Joe Jackson as saying that at one time there were 500 to 1,000 Indians living around Pickerel, Metonga, Lily, Post, Pelican, and Rice lakes.

In a letter to the USCOE regarding "trust responsibility" policy, the Sokaogon Chippewa Community identified cultural and sacred areas as Rice Lake on the reservation, burial grounds, battle grounds, other archaeological sites, Spirit Hill, the Oak Lake Pits, and the Wolf River, especially where sweetgrass grows . . . Eagle nest locations are sacred (SCC, 1995:6). In his Interim Report, Andrews (1995:9) notes that sites of traditional cultural interest were mentioned by the SCC in public documents, including cemeteries at Pelican Lake, Post Lake, Pickerel Creek, the archaeology site near STH 55, Pickerel Lake, Crandon, and Lake Metonga, that could be associated with the SCC; Historic use hunting, fishing, and gathering sites were mentioned for Post Lake, Wolf River, Pickerel Lake and Creek, Lake Metonga, Rolling Stone Lake, and Mole Lake, as was the gathering of bark from birch trees in the general vicinity of the proposed plant site.

3.2.2.5.3.2 Cultural Sites Inventory

Results of the cultural sites inventory are provided in two formats, one generalized and one confidential. Even though the inventory was compiled from public documents, some of the descriptive and locational information may be considered sensitive by tribal members and others. As such, inventory data is included in confidential Appendix 3.2-18 and mapped in confidential Appendix 3.2-19. These appendices will be distributed only with permission of the tribes whose resources are described, and then only on a need-to-know, right-to-know basis for purposes of project planning and site preservation. A generalized version of this information, without potentially sensitive descriptive and locational information, is provided below as Table 3.2-2 (generalized). The site maps are available only in the confidential appendix.

Site locations are, for the most part, very general in nature. Specific locations are provided only where the geographic placename corresponds with the site (e.g., Mole Lake), or where the literature source includes a specific site location (e.g., the sites at Oak Lake). Even then, however, written site locations are given only to the closest section, and locations are mapped only in the general area. Specific on-the-ground site locations could only be determined with the aid of Native Americans and others (non-Indian "oldtimers" in the area) who are knowledgeable regarding Native American use of the area, combined with archaeological research and field investigations as appropriate.

The information in Table 3.2-2 and Appendix 3.2-18 is organized according to the following categories:

Site Number. The general site location or placename (where applicable) is preceded by CS (cultural site) and numbered from 1 to 40. Site types, or activities, are identified with lower case alpha letters as: a=habitation, b= resource procurement, c=mortuary, d=ritual/sacred, e=battle, f=trading post, g=trail, h=cultural use area, and i-Indian Reservation.

Study Area and Distance. The Study Area is identified as PS: plant site study area; TMA: tailings management area study area; WWDC: wastewater discharge corridor study area; WCS: wetland compensation site study area; ACR: access road study area; TPL: tailings pipeline corridor study area; and RRS: railroad spur study area. The distance in miles and direction of the site (confidential version only) from the PS (center of the ore body), TMA (center of the TMA), WWDC, or WCS (whichever is closest) is then provided. Where the site also falls within the study area defined for the ACR, TPL, or RRS (or WWDC) this distance and direction is also provided.

Site Type and Site Name. The site activity, or type, is described, and the placename or location is provided.

Affiliation. The ethnic affiliation of the site, based upon currently available information, is provided.

Site Description. The site is described in narrative form, particularly in terms of the kinds of activity/s which occurred at the location (confidential version only). Sources are included in the narrative where appropriate for clarification.

Site Location. The site location on USGS 7.5′ topographic quadrangles is given by Township, Range, and Section (confidential version only). Some sites are mapped only with the general placename location, while others are mapped at another, more specific, location. Each cultural site is mapped on USGS 7.5′ Topographic Quadrangles. Even though locational information was obtained from the public record and is general in nature, some of the site locations could be considered sensitive, and neither the detailed locational information in the confidential version of the table or the site maps will be distributed with the general report.

Source of Information. The source of information used to identify the site is provided, e.g., W. Ackley, 1962; Tanner, 1987; WDNR, 1986 (confidential version only). The full citation for these sources can be found in the Bibliography. On the generalized version of the table, the source of information is given as Archival (various unpublished sources), Literature (published sources), and Maps (published and unpublished).

3.2.2.5.3.3 Discussion

A total of eighty-six (86) cultural sites were identified for the project area and vicinity. The 86 sites are grouped under forty (40) site numbers, which represent general site locations and/or placenames (the placenames identify habitation and utilization of the area but are not included as sites). In terms of site frequency, twenty-three (23) of the eighty-six sites are associated with habitation, nineteen (19) with resource procurement, eighteen (18) with mortuary practices, and eight (8) are trails. Seven (7) are general cultural use areas, six (6) are associated with ritual/sacred practices, two (2) are battle sites, two (2) are Indian reservations, and one (1) is a trading post. Considering ethnic affiliation, seventy-seven (77) of the cultural sites are identified as Chippewa, three (3) are Chippewa and Menominee, two (2) are Potawatomi, two (2) are archaeology sites identified only as Native American, one (1) is Chippewa and Dakota, and one (1) is Menominee.

Thirty-eight (38) of the 86 cultural sites were identified within PS/TMA study area defined as eight miles centered over the ore body (four mile radius from the ore body). Included are the sites at Rice Lake (6), Mole Lake (5), the southern half of Lake Metonga (3), the southwestern tip of Lake Lucerne (1), Rolling Stone Lake (3), Oak Lake (4), Little Sand Lake (1), Ground Hemlock Lake (1), St. Johns Lake (1), Deep Hole Lake (1), Swamp Creek (6), the bur oak groves (1), the Mole Lake Indian Reservation (1), and the maple groves near Sherman Corners (1). Four trails also fall within the PS/TMA study area. Sites closest to the Plant Site are those at Oak Lake (0.8 miles), Little Sand Lake (0.2 miles), and Swamp Creek (1.2 miles);

Table 3.2-2

Inventory of Cultural Sites in the Study Area and Vicinity (Generalized)

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-1	PS 12	placename Pelican Lake *Sha-da-sa-ga-e-gon*	Chippewa	According to Sokaogon Chippewa oral history and written sources, Pelican Lake was an early Sokaogon Chippewa resource area.	Monico Elcho	Archival Literature Maps
CS-1a	PS 12	habitation Pelican Lake	Chippewa	According to Sokaogon Chippewa oral history and written sources, Pelican Lake was an early Sokaogon Chippewa habitation site.	Monico Elcho	Archival Literature
CS-1aa	PS 14.6	habitation Pelican Lake	Chippewa	A Chippewa village is mapped in this location.	Monico Elcho	Maps
CS-1aaa	PS 13.2	habitation Pelican Lake	Chippewa	A Chippewa village is mapped in this location.	Monico Elcho	Maps
CS-1b	PS 12	resource procurement Pelican Lake	Chippewa	Mole Lake elders mentioned Pelican and other vicinity lakes as places they had riced or had been riced in their memory.	Monico Elcho	Archival Maps
CS-1c	PS 12	mortuary Pelican Lake	Chippewa	Burial grounds are reported in the vicinity of Pelican Lake.	Monico Elcho	Archival
CS-2	PS 7.8	placename Post Lake *Sa-ka-ah-gon Sukogonong*	Chippewa	Sokaogon oral history and published sources consider Post Lake an important Sokaogon Chippewa resource area.	Post Lake	Archival Literature
CS-2a	PS 7.8	habitation Post Lake	Chippewa	Sokaogon tribal tradition tells of the first Sokaogon chief establishing the initial Sokaogon village on Post Lake, and literature sources report habitation sites at Post Lake.	Post Lake	Archival Literature
CS-2b	PS 7.8	resource procurement Post Lake	Chippewa	Post Lake has been identified as a fishing and wild ricing location.	Post Lake	Archival Maps
CS-2c	PS 8.6	mortuary Post Lake	Chippewa	Burial grounds are reported in the vicinity of Post Lake.	Post Lake	Archival Literature Maps

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-2d	PS 7.8	ritual/sacred Post Lake	Chippewa	Sacred places and ritual activities are reported at Post Lake.	Post Lake	Archival
CS-3	PS 2.5	placename Rice Lake (Swamp Lake) *Mush-gig-kwa-wa-si-go-ga-ons*	Chippewa	Rice Lake has been identified by the tribe and in the literature as an important resource area.	Mole Lake	Archival Maps
CS-3a	PS 2.7	habitation Rice Lake	Chippewa	A settlement of "some two hundred Indians" was reported at Rice Lake in 1900. See also 4a.	Mole Lake	Archival
CS-3b	PS 2.5	resource procurement Rice Lake	Chippewa Menominee	Sokaogon Chippewa and literature sources describe the importance of ricing at Rice Lake, and one literature source notes that the Menominee used to come regularly to the lake to harvest the grain.	Mole Lake	Archival Literature Maps
CS-3c	PS 2.5	mortuary Rice Lake	Chippewa	Burial grounds are reported in the vicinity of Rice Lake.	Mole Lake	Archival Literature
CS-3d	PS 2.7	ritual/sacred Rice Lake	Chippewa	Ritual activities are reported in the vicinity of Rice Lake.	Mole Lake	Archival
CS-3e	PS 2.5	battle site Rice Lake	Chippewa	A battle site was reported "in and around Rice Lake territory, Forest Co." It is probable that this is a reference to the Battle of Mole Lake (see CS-4e) since the two lakes are within one half mile of each other.	Mole Lake	Archival
CS-3f	PS 2.5	trading post Rice Lake Mole Lake Swamp Creek	Chippewa	One or more trading posts were identified in the vicinity of Rice Lake, Mole Lake, and Swamp Creek. Others were located along the Upper Wolf River	Mole Lake	Archival Literature Maps
CS-4	PS 2.5	placename Mole Lake *Ke-bing-ka-ku-wa-si-go-e-ga-ons*	Chippewa	According to Sokaogon Chippewa oral history and written sources, Mole Lake was an early Sokaogon Chippewa habitation and resource area.	Mole Lake	Archival Maps
CS-4a	PS 2.7	habitation Mole Lake	Chippewa	The Sokaogon band occupied communities on the shores of Mole Lake and other lakes in the vicinity.	Mole Lake	Archival

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-4b	PS 2.4	resource procurement Mole Lake	Chippewa	Sokaogon oral history, literature sources, and the historical marker at Mole Lake note that each summer the Sokaogon Band came to Mole Lake to fish and hunt, and in the fall they harvested the wild rice [probably at Rice Lake and other lakes in the area] before they followed the deer herds into the swamps of the Peshtigo River for the winter season.	Mole Lake	Archival Literature
CS-4c	PS 2.5	Mortuary Mole Lake	Chippewa	Burial grounds have been identified in the Mole Lake vicinity.	Mole Lake	Archival
CS-4cc	PS 3.2	mortuary Mole Lake	Chippewa	A historic Indian cemetery is located in the Mole Lake vicinity.	Mole Lake	Archival Maps
CS-4e	PS 2.5	battle site Mole Lake	Chippewa Dakota	Mentioned in several sources and commemorated by an historical marker located 1/2 mile north of Mole Lake Village on STH 55, Mole Lake is reported as the scene of the last major battle (ca. 1806) between the Chippewa and Dakota over control of the Wisconsin wild rice region.	Mole Lake	Archival Literature Maps
CS-5	PS 2.8	placename Lake Metonga (Big Sand Lake) *Me-tong-gong*	Chippewa	Lake Metonga [formerly Big Sand Lake] is included in oral history and written sources as an early Sokaogon Chippewa habitation and resource area.	Crandon	Archival Maps
CS-5a	PS 2.8	habitation Lake Metonga	Chippewa	According to oral history and literature sources, by 1837 the Sokaogon Chippewa had village sites at Sand Lake.	Crandon	Archival Maps
CS-5b	PS 2.8	resource procurement Lake Metonga	Chippewa	Lake Metonga was identified as a ricing and fishing site.	Crandon	Archival Maps
CS-5c	PS 2.8	mortuary Lake Metonga	Chippewa	Burial grounds have been identified in the Lake Metonga vicinity.	Crandon	Archival Maps
CS-5d	PS 2.8	ritual/sacred Lake Metonga	Chippewa	Ritual activities were reported in the Lake Metonga vicinity.	Crandon	Archival Maps

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-6	TMA 2.7	placename Lake Lucerne (Stone Lake) *Assinicagamak*	Chippewa	Lake Lucerne, formerly called Stone Lake, is identified in literature sources as an important habitation and resource area.	Lake Lucerne	Archival
CS-6a	TMA 2.7	habitation Lake Lucerne	Chippewa	A Chippewa village was reportedly located at Stone Lake.	Lake Lucerne	Archival
CS-6aa	TMA 4.0	habitation Lake Lucerne	Chippewa	A village and corn fields, inhabited in 1875, were identified at Lake Lucerne.	Lake Lucerne	Archival
CS-6aaa	TMA 3.2	habitation Lake Lucerne	Chippewa	A historic Chippewa village was located at Lake Lucerne.	Lake Lucerne	Archival
CS-6b	TMA 4.4	resource procurement Lake Lucerne	Chippewa	Garden beds and cache pits associated with a historic Chippewa village were reported at Lake Lucerne.	Lake Lucerne	Archival
CS-6bb	TMA 3.8	resource procurement Lake Lucerne	Native American	A large stone with a cavity on its top, possibly used for grinding corn; garden beds; and cache pits were reported at Lake Lucerne.	Lake Lucerne	Archival
CS-7	PS 2.9	placename Rolling Stone Lake *A-sin-a-bit*	Chippewa	Oral history and written sources name Rolling Stone Lake as a place known and used by the Sokaogon Chippewa.	Mole Lake	Archival Literature Maps
CS-7a	PS 2.9	habitation Rolling Stone Lake	Chippewa	Rolling Stone Lake was identified by oral history sources as an ancient Sokaogon Chippewa habitation area.	Mole Lake	Archival
CS-7b	PS 2.9	resource procurement Rolling Stone Lake	Chippewa	Mole Lake elders mentioned Rolling Stone Lake among the places they had riced or had been riced in their memory.	Mole Lake	Archival
CS-7c	PS 2.9	mortuary Rolling Stone Lake	Chippewa	Burial grounds were identified in the vicinity of Rolling Stone Lake.	Mole Lake	Archival

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-8	PS 4.8	placename Pickerel Lake *Ka-mu-ji-gog*	Chippewa	Pickerel Lake was identified as a place known and used by the Sokaogon Chippewa.	Mole Lake	Archival Maps
CS-8a	PS 4.8	habitation Pickerel Lake	Chippewa	Pickerel Lake was identified as an ancient Sokaogon Chippewa habitation area.	Mole Lake	Archival
CS-8aa	PS 5.4	habitation Pickerel Lake	Chippewa	Sokaogon sources indicate that there was a Chippewa village at Pickerel Dam around 1917.	Mole Lake	Archival
CS-8aaa	PS 4.8	habitation Pickerel Lake	Chippewa	A Chippewa village was identified at Pickerel Lake.	Mole Lake	Maps
CS-8b	PS 4.8	resource procurement Pickerel Lake	Chippewa	Mole Lake elders and others mentioned Pickerel Lake among the places they had riced or had been riced in their memory.	Mole Lake	Archival Maps
CS-8c	PS 4.8	mortuary Pickerel Lake	Chippewa	Burial grounds were identified in the vicinity of Pickerel Lake.	Mole Lake	Archival Maps
CS-9	PS 4.2	Bishop Lake (Dry Lake) *Bah-to-we-gum-mong*	Chippewa	Formerly known as Dry Lake, Bishop Lake has been identified as a place used in the past by the Chippewa because of the bountiful rice beds there.	Post Lake	Archival Maps
CS-9a	PS 4.2	habitation Bishop Lake	Chippewa	A 19th century Sokaogon Chief was born at Bishop Lake in 1885 attesting to habitation in the area at that time.	Post Lake	Archival
CS-9b	PS 4.2	resource procurement Bishop Lake	Chippewa	Mole Lake elders and others mentioned Bishop lake among the places they had riced or had been riced in their memory.	Post Lake	Archival
CS-9c	PS 4.2	mortuary Bishop Lake	Chippewa	Burial grounds were identified in the vicinity of Bishop Lake.	Post Lake	Archival
CS-10	PS 0.8	placename Oak Lake *Me-to-me-ne-she-gog*	Chippewa	Sokaogon Chippewa sources identify Oak Lake as an early habitation and resource area.	Mole Lake	Archival Maps

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-10a	PS 0.8	habitation Oak Lake	Chippewa Menominee	Chippewa and Menominee sources have expressed concerns for habitation sites in the Oak Lake area.	Mole Lake	Archival Literature
CS-10b	PS 0.8	resource procurement Oak Lake	Chippewa	Oak Lake was identified as a place where people lived, gathered, and harvested wild rice.	Mole Lake	Archival Maps
CS-10c	PS 0.8	mortuary Oak Lake	Chippewa	Sokaogon Chippewa sources indicate that there may be burials in the vicinity of Oak Lake.	Mole Lake	Archival
CS-10d	PS 0.8	ritual/sacred Oak Lake	Chippewa Menominee	Recent ritual activities have been reported in the vicinity of Oak Lake.	Mole Lake	Archival
CS-11	TMA 4.6	placename Roberts Lake	Chippewa	Roberts Lake was identified as a Sokaogon Chippewa habitation and resource site.	Roberts Lake	Archival Maps
CS-11a	TMA 4.6	habitation Roberts Lake	Chippewa	Sokaogon Chippewa sources indicate that their ancestors lived at Roberts Lake.	Roberts Lake	Archival
CS-11b	TMA 4.6	resource procurement Roberts Lake	Chippewa	Sokaogon Chippewa sources indicate that there was wild rice at Roberts Lake.	Roberts Lake	Archival
CS-11bb	TMA 5.0	resource procurement Roberts Lake	Chippewa	Garden beds were identified in the vicinity of Roberts Lake.	Roberts Lake	Maps
CS-11c	TMA 5.0	mortuary Roberts Lake	Chippewa	Burials were identified in the vicinity of Roberts Lake.	Roberts Lake	Maps
CS-12h	PS 0.2	cultural use area Little Sand Lake *Me-tong-gongse*	Chippewa	Little Sand Lake was named by Sokaogon Chippewa sources as a place known and used by the Sokaogon Chippewa.	Mole Lake	Archival Maps
CS-13h	TMA 1.1	cultural use area Ground Hemlock Lake *Na-ca-wa-she-gog*	Chippewa	Ground Hemlock Lake was named as a place known and used by the Sokaogon Chippewa.	Roberts Lake	Archival Maps

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-14h	TMA 2.4	cultural use area St. Johns Lake *Sa-cawe-a-gons*	Chippewa	St. Johns Lake was named as a place known and used by the Sokaogon Chippewa.	Mole Lake Roberts Lake	Archival Maps
CS-15h	TMA 4.1	cultural use area Crane Lake *Ba-be-ka-ma-me-go-kwak*	Chippewa	Crane Lake was named as one of the boundary markers of the reservation reportedly promised to the Sokaogon Chippewa by the federal government and identified as a Sokaogon Chippewa cultural use area.	Mole Lake	Archival Maps
CS-16h	TMA 1.1	cultural use area Deep Hole Lake	Chippewa	Deep Hole Lake was identified as a Sokaogon Chippewa cultural use area.	Mole Lake	Archival Maps
CS-17h	TMA 3.8	cultural use area Lily Lake	Chippewa	Lily Lake was identified as a place anciently occupied by the Sokaogon Chippewa.	Roberts Lake	Archival
CS-18	PS 7.5 8.0	placename Upper Wolf River *Ma-ing-ga-se-beor*	Chippewa	The Wolf River was identified as a place known and used by the Sokaogon Chippewa and a boundary of the reservation reportedly promised to the Sokaogon Chippewa by the federal government.	Post Lake Nashville Adjacent quads	Archival Maps
CS-18a	PS 8.0	habitation Upper Wolf River	Chippewa	According to Sokaogon Chippewa oral history and written sources, the Sokaogon Chippewa had settlements at Post Lake in the Upper Wolf River.	Post Lake Nashville Adjacent quads	Archival Literature Maps
CS-18b	PS 7.5 8.0 WWDC 0.0	resource procurement Upper Wolf River	Chippewa	According to Sokaogon Chippewa oral traditions and written sources, the Upper Wolf River was a ricing location.	Post Lake Nashville Adjacent quads	Archival Maps

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-18d	PS 7.5 8.0 WWDC 0.0	ritual/sacred Upper Wolf River	Chippewa	The Wolf River has been identified by the Sokaogon Chippewa tribe as an important cultural and sacred area.	Post Lake Nashville Adjacent quads	Archival
CS-19	PS 1.2 WWDC 0.0 ACR 0.0 RRS 0.0	placename Swamp Creek *Mush-ga-mong-se-be*	Chippewa	Swamp Creek is identified in Sokaogon Chippewa oral history and the literature as a place known and used by the tribe over the years. Included are habitation, resource procurement, burial places, and trading posts along different stretches of the creek.	Post Lake Mole Lake	Archival Maps
CS-19a	PS 2.4	habitation Swamp Creek	Chippewa	A large village site was identified along swamp Creek and Rice Lake. See also CS-19cc.	Mole Lake	Literature
CS-19aa	PS/TMA no data	habitation Swamp Creek	Chippewa	A Sokaogon Chippewa source reported the remains of a camp adjacent to Swamp Creek.	Mole Lake	Archival
CS-19b	PS 2.6	resource procurement Swamp Creek	Chippewa	According to Sokaogon Chippewa sources, Swamp Creek was an important hunting and gathering area, and the Sokaogon have made intensive use of the hunting land to the east, southeast, and south of the reservation.	Mole Lake	Archival
CS-19c	PS 3.4	mortuary Swamp Creek	Chippewa	Sokaogon Chippewa oral history sources identify a burial in the Swamp Creek vicinity.	Mole Lake	Archival
CS-19cc	PS 2.4	mortuary Swamp Creek	Chippewa	Historic Indian archaeology village site that extends along Swamp Creek and Rice Lake (see CS-19a).	Mole Lake	Literature
CS-19ccc	PS 2.4	mortuary Swamp Creek	Chippewa	Burials are reported along the vicinity of Swamp Creek.	Mole Lake	Literature
CS-20	PS 5.2	placename Pickerel Creek *Go-no-she-bu-shong-se-be*	Chippewa	Pickerel Creek is cited in Sokaogon Chippewa oral traditions as a place known for habitation, burial, and resource procurement activities.	Mole Lake	Archival
CS-20a	PS 5.2	habitation Pickerel Creek	Chippewa	Sokaogon sources indicate that there was a Chippewa village at Pickerel Dam and that Chippewa lived on Pickerel Creek. See also CS-8aa.	Mole Lake	Archival

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-20c	PS 5.2	mortuary Pickerel Creek	Chippewa	Pickerel Creek is identified in Sokaogon Chippewa oral history as flowing through an area used as a burying ground.	Mole Lake	Archival
CS-20cc	PS 7.0	mortuary Pickerel Creek	Chippewa	A Sokaogon Chippewa burial ground was identified on Pickerel Creek.	Mole Lake	Archival
CS-21	PS 1.5	placename Spirit Hill (Mole Lake Hill)	Chippewa	Spirit Hill is known in Sokaogon Chippewa oral traditions as an important cultural area.	Mole Lake	Archival
CS-21c	PS 1.5	mortuary Spirit Hill	Chippewa	Sokaogon Chippewa sources indicate that there may be burials in the vicinity of Spirit Hill.	Mole Lake	Archival
CS-21d	PS 1.5	ritual/sacred Spirit Hill	Chippewa	Sokaogon Chippewa sources attest to the cultural and sacred importance of Spirit Hill.	Mole Lake	Archival
CS-22i	PS 2.1	Indian Reservation Mole Lake	Chippewa	According to Sokaogon sources, the site of the Mole Lake Indian Reservation was chosen because of the rich rice beds in Rice Lake and the opportunities for hunting and gathering in the area.	Crandon Mole Lake Post Lake	Archival
CS-23i	TMA 4.7	Indian Reservation Forest County	Potawatomi	Section 2 is one of many scattered parcels of land which comprises the Forest County Potawatomi Indian Reservation.	Lake Lucerne	Archival Literature
CS-24h	TMA 5.4	cultural use area Devils Lake	Potawatomi	Potawatomi sources identify the Devils Lake area as an important cultural area.	Lake Lucerne	Archival
CS-25b	PS/TMA no data	resource procurement	Chippewa	Sokaogon sources identify an area extending between lower Post Lake and lower Lake Metonga as traditional Sokaogon hunting and fishing grounds.	Post Lake Mole Lake	Archival Maps
CS-26b	TMA 0.6	resource procurement	Chippewa	Bur Oak (Quercus macrocarpa), identified by the Sokaogon Chippewa as a species of considerable importance for food, dye, and medicine, is found in this area.	Mole Lake	Archival
CS-27c	PS 6.0	mortuary Crandon Area	Chippewa	According to Sokaogon Chippewa oral history, two of their chiefs are buried in the Crandon area.	Lake Lucerne	Archival

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-28b	WWDC 0.0	resource procurement	Chippewa	Maple groves identified here were reportedly used by the Sokaogon Chippewa to harvest maple sap and make sugar.	Crandon	Archival
CS-29g	PS 3.2	trail	Chippewa	Trail segment.	Mole Lake	Literature
CS-30g	TMA 2.8	trail Indian Super Highway	Chippewa	Trail segment.	Roberts Lake	Archival Maps
CS-31g	PS 2.3	trail	Chippewa	Trail segment.	Crandon Mole Lake	Archival
CS-32g	WWDC 0.0	trail	Chippewa	Trail segment.	Lake Julia Rhinelander Crescent	Archival
CS-33g	WCS 1.4	trail	Menominee	Trail segment.	Cecil	Archival
CS-34g	PS 1.4 WWDC 0.0 ACR 0.0	trail	Chippewa	Trail segment.	Crandon Mole Lake	Maps
CS-35g	TMA 2.8	trail	Chippewa	Trail segment.	Lake Lucerne Lake Roberts	Maps
CS-36a	WWDC 0.7	habitation Lake Julia	Chippewa	Historic Indian archaeology site associated with a Chippewa family.	Lake Julia	Archival Maps
CS-37a	WWDC 0.8 0.9	habitation Wisconsin River	Native American	Historic Indian archaeology site on the banks of the Wisconsin River.	Lake Julia	Archival Maps
CS-38	PS 7.0	place name Peshtigo Lake (Mud Lake) *Bah-ya-go-ge-she-wa-gog*	Chippewa	According to Sokaogon oral history, Mud Lake [Peshtigo Lake] was a Sokaogon Chippewa resource area.	Crandon	Archival

Table 3.2-2 *(Continued)*

CS-No.	Study Area and Distance	Site Type Site Name	Site Affiliation	Site Description	Site Location on 7.5 Quad	Source of Information
CS-38b	PS 7.0	resource procurement Peshtigo Lake (Mud Lake)	Chippewa	The historical marker at Mole Lake notes that the Sokaogon Chippewa followed the deer herds into the swamps of the Peshtigo River for the winter season.	Crandon	Archival
CS-39	PS 8.6	placename Little Rice Lake *Ma-no-menno-ka-nese*	Chippewa	Little Rice Lake was identified by Sokaogon sources as a place known and used by the Sokaogon Chippewa and a boundary of the reservation reportedly promised to the Sokaogon Chippewa by the federal government.	Nashville Crandon	Archival Maps
CS-40g	WWDC 0.0	trail	Chippewa	Trail segment.	Nashville Crandon	Maps

PS = Plant Site
TMA = Tailings Management Area
ACR = Access Road
RRS = Railroad Spur
WWDC = Wastewater Discharge Corridor
WCS = Wetland Compensation Site

Prepared by: CW
Checked by: JWS

sites closest to the Tailings Management Area are the bur oak groves (0.6 miles), Deep Hole Lake (1.1 miles) and Ground Hemlock Lake (1.1 miles).

Sites within the PS/TMA study area which also fall within the WWDC study area (2 miles centered on the pipeline corridor) include, Swamp Creek (0.0 miles at the crossing), the maple groves near Sherman Corners (0.0 miles at the crossing), and the trail identified as CS-34g (0.0 miles at the crossing). Sites within the PS/TMA study area which also fall within the ACR and RRS study areas (1/2 miles centered on the access road and railroad spur) include the trail identified as CS-34g (0.0 miles at the crossing) and Swamp Creek (0.0 miles at the crossing). Sites which occur only within the WWDC study area include the trail identified as CS-32g (0.0 miles) which crosses the western end of the pipeline, the trail identified as CS-40g (0.0) which crosses the eastern end of the pipeline, and the two historic Indian habitation sites identified as CS-36a (1.0 miles) and CS-37a (0.8 miles) situated at the eastern end of the pipeline. The only site close to the WCS study area (one mile buffer zone) is a trail identified as CS-33g (1.5 miles).

Considering the 38 sites identified within the PS/TMA study area, the 4 sites associated solely with the WWDC study area, and the one site associated with the WCS study area, a total of 43 of the 86 sites identified (50 percent) fall within the study areas specified for the cultural sites investigation. As discussed previously, the other 43 sites (50 percent), which are situated from 4 to 10 miles distant from the center of the ore body, provide cultural and historical background to Native American occupation and utilization of the vicinity. Additionally, they provide a buffer to help ensure that no important sites are missed in the inventory process.

3.2.2.5.4 Summary

A total of 86 sites or activities associated with 40 general cultural site locations or placenames indicative of Native American occupation and utilization of the study area and vicinity during the historic period were inventoried in the course of the archival research. The majority of the sites are habitation, resource procurement, and mortuary activities, although trails, cultural use areas, ritual/sacred sites, battle sites, Indian reservations, and a trading post are represented. As expected, the overwhelming majority of identified sites are associated with Chippewa utilization of the region. While this underscores the historically significant link between the Chippewa and the study area and vicinity, reporting bias may be present, and most of the sites represent fairly late historic occupation. As such, the results may not be representative of the regions actual utilization by the Menominee and other tribal groups over time. Fifty percent of the sites fall within the study areas defined for the cultural sites investigation.

3.2.2.6 Traditional Cultural Properties Investigations

3.2.2.6.1 Introduction

This section describes the background to the Crandon Project TCP studies. The theory and methods employed to plan and conduct the work are discussed, and potential TCPs in the study area and vicinity are identified from published and unpublished literature sources. Most of these sites overlap with the cultural sites previously identified in the ethnographic inventory described in Section 3.2.2.5. The section was prepared in large part by the Commonwealth Cultural Resources Group (CCRG) and was presented in the EIR submitted for review in May of 1995. James Robertson served as Principal Investigator and Wesley Andrews as Project Ethnologist to

conduct the Traditional Cultural Properties Investigation. The material has been revised to reflect changes which have occurred since the CCRG section was prepared and summarized for inclusion in the present document. The references to Andrews (1995) are to the *Interim Report of the Project Ethnologist* dated August 7, 1995.

3.2.2.6.2 Background

CMC was requested by the SHPO in 1994 (Appendix 3.2-1) to conduct a Traditional Cultural Properties Investigation to establish the presence or absence of TCPs within the APE of the proposed Crandon Project. TCPs are defined generally as historic properties that are associated with cultural practices or beliefs of a living community that are (a) rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community (Parker and King, 1990:1). TCPs therefore have significant historical time depth, typically more than 50 years, and refer to those ongoing beliefs, customs, and practices of a living community that have been passed down orally or through practice to the present day.

Commonwealth Cultural Resources Group, Inc. (CCRG) was contracted by Foth & Van Dyke to accomplish this study which included the investigation of both the Native American and Euro-American TCPs. In October of 1994, CCRG formulated a work plan (Appendix 3.2-10) in cooperation with CMC and Foth & Van Dyke. The work plan formalized the procedures and tasks necessary to complete the investigations.

The first step in the work plan was to establish contact with the SHPO and interested parties, including the Sokaogon Chippewa Community (SCC), Forest County Potawatomi (FCP), Menominee Indian Tribe of Wisconsin (MITW), City of Crandon, Lincoln and Nashville Townships, and Forest County. A letter and an accompanying informational brochure were sent detailing the nature and goals of study. A copy of the brochure is included in Appendix 3.2-11. An initial definition of the area that the proposed project might impact as a result of construction and operation, referred to as the area potential effect or APE was also developed and sent to interested parties.

Following issuance of the referenced letter, CCRG contacted tribal representatives directly to determine if the SCC, FCP, and MITW would be willing to participate in the Native American component of the study. Only the MITW agreed to participate. After repeated contacts, no indication has been received from either the SCC or FCP regarding their participation in the study.

A work plan summarizing the details of the MITW's participation is included in Appendix 3.2-12. Work commenced in early April 1995. The study includes interviews and field views with tradition-oriented individuals to identify potential TCPs. The potential TCPs were evaluated with respect to the interview data, field views and the Native American perspective, the published ethnographic literature, and federal guidelines applicable to TCPs. After review and approval of identified TCPs by representatives of the MITW, a report was prepared that documents potential TCPs, evaluates the significance of each potential TCP, and assesses potential impacts of the Crandon Project on potential TCPs. This report has been submitted to the Menominee Tribal Legislature for review and approval.

The TCPI employed ethnological, historical, archaeological, and cultural geographic methods and models in carrying out the work plan, as well as incorporating the regulatory standards and

guidelines as outlined in *National Register Bulletin 38* (Parker and King, 1990). The research design and work plan have been continually refined and adjusted as needed to meet changing conditions and needs surrounding the proposed project. A summary discussion of study methodology, including the preliminary definition of the APE and results of the investigations to date, are presented below.

3.2.2.6.3 Methods

3.2.2.6.3.1 Research Design

The creation of the research design for this project presented challenges to the investigators. The corpus of research on TCPs is a modest one. Few models exist and for those that do, there are important areas of contention between them. The majority of studies on this subject have focused on tribes located in the southwestern United States. For Native American groups in the Great Lakes region, TCP research has been almost completely absent. The following discussion examines the major issues and sources that were used to establish the final research design for the Crandon Project TCPI.

The Crandon Project TCPI focuses on how Native American people interpret the cultural resources that comprise their history and culture. The research design draws upon other Native American cultural resource studies, ethnographic theory, and federal regulatory standards. Euro-American science and Native American people have many differences in their perceptions of the world, including their concepts regarding cultural resources. The identification and interpretation of cultural resources has been shown to be primarily affected by differing world view concepts concerning space and land use. An important aspect of this type of study is that cultural resources are identified and interpreted by the society that perceives that they exist. The methodology used for most of the research on TCPs is not new and traces its roots to ethnological studies.

Compliance with Section 106 of the National Historic Preservation Act, however, raised complex issues. As outlined in *National Register Bulletin 38* (Parker and King, 1990), the resulting benefits to Native American people from this kind of study is to potentially afford protection for sacred sites or places which are significantly associated with the cultural beliefs and practices that are rooted in a tribe's history as a community. These sites are important in maintaining the continuity of that community's traditional beliefs and practices (Parker and King, 1990). Yet, they also mention that, for some Native Americans, to identify a sacred site is to threaten it. Another issue rests with the definition of "cultural resources." A recent study in Michigan (Andrews and Andrews, 1995) found that the term "cultural resources" as used by Native Americans refers to things not anticipated by Section 106 of the National Historic Preservation Act. For example, "cultural resources" for a Native American would embrace such things as ideas, beliefs, people, other-than-human-beings, and other phenomena not necessarily visible over the natural and built environments.

There are two principal and somewhat contrasting approaches to the study of places that are of cultural significance to Native Americans. One of these approaches is termed the "cultural landscape" approach (Kelley and Francis, 1994). This approach argues that "sacred places derive their significance from their position in the larger, culturally, constructed landscape," and that "sacred places may have different qualities that make them significant, but none can be ranked above another or singled out for preservation while the surrounding landscape which the place

both gives significance (power) to and takes significance from is destroyed (Kelley and Francis, 1994:50)."

According to Kelley and Francis (1994), the opponents to the cultural landscape approach call it holistic, and believe that it is politically unworkable. They also state that approaches such as that developed by Richard Stoffle and Michael Evans (1990) are "piecemeal" approaches which they collectively term "triage." Such an approach, in the opinion of Kelley and Francis (1994:102-3) focuses upon places ". . . without explicit reference to their relation to the landscape."

Stoffle and Evans (1990:97) believe that the cultural landscape approach, or as they have termed it the "holistic" approach, is ". . . often the most appropriate response to a development project." They are quick to point out, however, that ". . . experience demonstrates that such a response usually serves no more than to define the degree of anguish associated with cultural resource loss. Unless a project can be totally stopped, it is only at the cultural triage level of analysis where the Native American people can achieve a degree of protection of cultural resources."

The cultural landscape approach asserts that "the places where successive episodes of a particular story or set of interrelated stories occurred make up a culturally significant landscape just as the episodes make up the story." In addition, "the places where activities related to a particular ceremony occur make up a landscape just as the activities make up the ceremony (Kelley and Francis, 1994:43)."

Proponents of the cultural landscape approach have worked primarily with Navajo people and their studies have found that researchers are torn between developers who shape the "real politic" of historic preservation decision making and their professional responsibility to convey the concerns of the Native American people with whom they have consulted. This forces the researcher to ". . . compromise by focusing on places - not on whole landscapes, as the people want, but not on nothing, either (Kelley and Francis, 1994:101)."

They further assert that "The goal of the Navajo approach is to keep entire interacting cultural landscapes intact by keeping economic development from disrupting the full range of customary activities that keep these landscapes alive. The goal should be to find out how each place functions in the physical, social and conceptual landscapes of which it is a part, and how (or whether) a proposed development can be integrated into these landscapes, among these interrelated places, with the least disruption to the lives of the people . . . whose activities tie them together (Kelley and Francis, 1994:101)."

Despite these controversies, the primary method of analysis employed by Stoffle, et al. (1990) has, in fact, been developed from Native American perspectives regarding resource use. This interpretive method has been termed by some the "occupational complex model." It shares similarities with spatial analysis models of western social sciences. The occupational complex model suggests that Native American interaction with the cultural resources of an area is based on land use planning. This plan is influenced by land area size, physical resources and other variables. It specifically assumes that Native American groups "used large districts and local areas within those districts in terms of an overall district or area use plan (Stoffle, et al., 1990:13). Both the individual items and the locations where they are found may potentially be incorporated into a cultural activity and, hence, the world view of Native American peoples. Other elements to this approach include a holistic analysis, labor efficiency, life-force in nature, and holy lands (Stoffle, et al., 1990:12-19).

Critics of the occupational complex model believe that its reliance upon land use planning, although informative and useful, is inadequate. They claim that it dismantles the unifying themes such as land rights of all the people and individual families into details so distinct to each one that they cannot possibly achieve a consensus (Kelly and Francis, 1994:102).

Stoffle and Evans (1990:91) conclude that greater policy impacts are possible by pursuing both the holistic or Landscape Approach and the triage approach. They further believe that the research design is key to eliciting both types of responses from Native American participants. Finally, their research has found that Native American people experience emotional and social risks when they are involved in cultural triage, alone.

The disruption of the Native American cultural and religious bond to the earth as a result of contact with Europeans has previously been understood and described by scholars. ". . . the loss of ancient ancestral sites have disrupted the linkage between the North American Indian peoples and the land through which the power and meaning of their religious culture manifested itself." This process has been seen by some Native American religious leaders as "the severing of cultural and religious ties to specific geographical locations . . . (Grim and St. John, 1987:476)."

3.2.2.6.3.2 Methodology

The research design adopted for the Crandon Project TCPI combines the best and most workable elements of both the cultural landscape approach and the triage approach, while still falling within the guidelines established in *National Register Bulletin* 38 (Parker and King, 1990). From the cultural landscape approach it is believed that this perspective can document a wider range of information concerning tribal cultural resources (Stoffle and Evans, 1990), and that a place (cultural resource) is important because it is part of a larger whole, such as a cultural landscape (Kelley and Francis, 1994). Second, the cultural integrity and identity of the traditional cultural resources are potentially less likely to be compromised by maintaining their definition by the culture which values them within their cultural landscape. Third, the occupational complex model (triage approach), which others (Stoffle, et al., 1990:13-15) have used to examine the way in which Native Americans interpret cultural resources, is utilized here to gather information about how each of the three tribes interact with the physical and cultural resources of the land. It is used as an identification tool at the beginning of the identification process to discover individual and sets of related locations of resources rather than wholesale application of the model. Analysis of these data can then be conducted within the concept of the cultural landscape so that local cultural and environmental conditions are taken into consideration.

The interpretive context of the final research design is, therefore, embedded in the culture, history and environment of the specific people(s) and region(s) under investigation. It examines the cultural world view, history and physical environment pertinent to each of the three tribal groups. By so doing, the study incorporates the environmental and cultural attributes unique to the Crandon Project and northern Wisconsin.

To facilitate the evaluation of the potential effects of the Crandon Project on TCPs, a working definition of the APE, in accordance with 36 CFR Part 800, Section 800.4(a)(1), was developed. As a starting point, all areas where construction will disturb the ground surface were included in the APE. The vast majority of all overt environmental impacts are restricted to such areas. These include the proposed plant site; the tailings management area; the access roads, tailings

pipeline corridor, haul road, and railroad spur; the wastewater discharge pipeline corridor; the wetland compensation site; and disturbances associated with the construction of electrical and gas transmission facilities.

From the narrowest scientific point of view, the APE is limited to the areas of direct impact that invade the ground surface. Beyond construction of the proposed facilities, and based on the current understanding of the environmental impacts described in the FEIS issued in November 1986 (WDNR, 1986) and ongoing studies that are being prepared in advance of the proposed project, the vast majority of other measurable environmental impacts will occur within the project's area of disturbance. There are four primary environmental impacts, however, that may have effects on the cultural landscape beyond those itemized above: treated effluent, air emissions, groundwater quality, and groundwater drawdown.

Native Americans describe and explain cultural resources in terms of their own culture and knowledge. Generally, the Native American viewpoint holds that all elements of the world are functionally interrelated. From the Native American view of nature, the APE is unlimited in size and scope. If instruments of measurement were sensitive enough, we could extend these effects over a worldwide scale and fit them within the Native American world view. Such measurements are impossible and some boundaries must be established to be consistent with the parameters of *National Register Bulletin 38* (Parker and King, 1990) which requires that TCPs have boundaries and comprise definable entities. That is, physically observable items must be demonstrated to exist whether they are used as a subsistence resource, are accorded religious importance, or are considered to have significance in terms of other traditional activities and/or beliefs.

Data and models presented in the 1986 FEIS and in ongoing studies indicate that surface water, air, and groundwater quality will remain within accepted standards set by state and federal guidelines that protect the public health and safety and protect the environment. Only groundwater drawdown may require mitigative action and, therefore, its impacts to TCPs could be considered as potentially adverse. Yet, applying the Native American world view, if one aspect of the environment requires mitigation of adverse effects, then all others including minerals, air, water, flora, and fauna must be involved as well. Though one could argue for studying each body of water that may potentially be affected by groundwater drawdown, this approach would not have any clear boundaries given the interconnectedness of alluvial and lacustrine systems. In the broadest sense, this would require the examination of not only local water bodies and drainage systems, but also the entire Wolf River Drainage basin, into the Great Lakes, and beyond. Furthermore, the effects of groundwater drawdown at these wider scales is not measurable. Thus, and in lieu of other data, the APE for the initial application of the occupational complex model (triage approach) to identify locations of potential TCPs was narrowed to the area in which measurable groundwater drawdown could occur. This represented an area roughly four miles in diameter, with its central point the geographic center of the ore body.

Subsequently, the USCOE modified the definition of the APE stating that ". . . we have determined that the best strategy is to not specifically define the Area of Potential Effects. Rather, we will review all properties the [tribes] submit for consideration as TCPs (Wonsik, 1996, letter)." Accordingly, the tribe/s will need to show that the property is a TCP (eligible for listing on the National Register), and that the project would have a physical, visual, or auditory effect on the property.

In order to accommodate this concept, a wider study area was defined to ensure that potential TCPs situated beyond the area defined for water drawdown would be included in the analysis. This inventory study area, as defined in Section 3.2.2.2.3, includes an area roughly 8 miles in diameter, with its central point the geographic center of the ore body. Some potential TCPs situated beyond this 8-mile diameter are included in to ensure that all potential TCPs in the general vicinity of the project will be considered in the analysis. This is in keeping with the cultural landscape approach.

To be consistent with the theoretical and methodological underpinnings of the TCPI research design outlined above, which combines workable aspects of both the cultural landscape approach and occupational complex model (triage approach), both the specific locations of potential TCPs and more broadly defined cultural landscapes have been considered. Thus, if a specific resource is identified as being part of a traditional activity and is documented to occur within the study area, the role of this resource at this location must be analyzed within the context of other identified TCPs utilizing the resources that are potentially located at greater distances from the study area. The role of this set of TCPs must be analyzed with reference to the overall cultural landscape for this resource.

For example, assume that a grove of cedar is identified as a location where cedar for traditional craft activities has been gathered. Without considering the cultural landscape, adverse effects to such a location could be mitigated by identifying another cedar grove(s) of similar age, composition and size that would meet the needs of the people practicing the craft without disrupting the history and tradition of these activities. Yet, within the cultural landscape, cedar is known to be associated with activities of a religious society and is considered sacred. Thus, if avoidance is not possible, removing this resource from the cultural landscape may potentially represent a secondary effect and may need to be considered in the planning process. In other words, an adverse effect on a potential TCP within the study area may have secondary effects on related TCPs defined outside of the study area across the cultural landscape.

In summary, the methodology for the Crandon Project TCPI has been developed to identify and specify potential adverse effects of the proposed project by: (1) identifying TCPs within the study area and vicinity by providing the opportunity for active participation by the three Native American tribes potentially affected by the proposed project; (2) placing identified TCPs within the cultural landscape vis-a-vis the activities represented and phenomena that use the same type(s) of resource(s) documented as occurring within the study area and vicinity; (3) defining and evaluating each TCP in terms of a tripartite set of viewpoints including (a) the Individual Tribe's Culture (traditional Native American context), (b) the Academic (comparison with ethnographic and historic literature and published manuscripts), (c) the regulatory (application of National Register criteria set forth in *National Register Bulletin 38* [Parker and King, 1990] and other federal guidelines); (4) integrating each of the above viewpoints with respect to each TCP and the affected cultural landscape; and (5) identifying any conflicts regarding the definition and interpretation of each TCP and specify the impact of the proposed project in terms of both primary and secondary effects.

In addition, the evaluation of TCP significance within each tribe's cultural perspective shall be addressed from three points of reference: (1) the individual, (2) the sub-group, and (3) the tribe as a whole. Sub-groups are defined as traditional religious factions within the Native American community. The information from each of the three reference points can vary based on

differences in individual or collective knowledge and other factors. Viewed collectively, they can help establish the significance of the cultural resources within the each tribal group.

3.2.2.6.4 Potential TCPs in the Study Area and Vicinity

Of the few studies in the Great Lakes region on this topic, the study by Stoffle (1990), offers a preliminary overview of the potential range of cultural resources that may have cultural and religious significance to Native Americans in Michigan and is assumed to have general applicability to Wisconsin. Although this study was aimed primarily at identifying archaeological sites, Stoffle (1990) included other types of cultural resources. The categories of cultural resources that Stoffle identified included geological resources, wildlife, plants, sacred places, artifacts, and burials. He identifies five additional categories of sites that may constitute significant cultural resources. These include: (1) sites of villages or other settlements, (2) sites used for subsistence activities, (3) sites used for ceremonial activities, (4) burial sites, and (5) sites of significant historical events (Stoffle, 1990:61).

Potential TCPs for the three tribes could include not only the site categories identified above, but might also include locations where medicinal plants are gathered, where the manufacture of items used in traditional ceremonies took place, where traditional foods were prepared, and where manufacture of items that are important for the continuation of cultural identity, practices, and beliefs took place. Locations mentioned in the oral-historical and published literature that are associated with significant events, places that are inhabited by other-than-human-beings who are considered significant to a culture, locations that arise from personal dreams that are important to the individual and/or tribe, and places where religious and spiritual activities are held such as those associated with the religious groups among the three tribes also potentially exist across the landscape. It is also anticipated that a majority of the TCPs will be located in natural areas with little or no human disturbance to the landscape. A study of Odawa (Ottawa) TCPs in northern Michigan determined that the majority of TCPs existed away from areas of modern human activity such as roads, residences, commercial buildings, and other modern intrusions (Andrews and Andrews, 1995).

Parker and King provide fairly specific Guidelines for evaluating and documenting TCPs. As defined, a TCP is a property "that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community (1990:1)." To determine whether or not a property is eligible for inclusion in the National Register, it must be evaluated with reference to the National Register Criteria for Evaluation [36 CFR §60]. Parker and King (1990:9-16) define a series of sequential steps and considerations to follow in the determination process. Step One: Ensure that the entity under consideration is a property, Step Two: Consider the property's (a) integrity of relationship, and (b) integrity of condition, Step Three: Evaluate the property with reference to National Register criteria, and Step Four: Determine whether any of the National Register criteria considerations [36 CFR §60.4] make the property ineligible.

It is important to stress that the identification, documentation, and evaluation process described by Parker and King is dependent upon Native American input at every step in the process. TCPs are by definition, rooted in Native American cultural practices and associated beliefs. Since the SCC and FCP have not provided this input, the process of identifying TCPS within their

historical lands is conjectural, and must rely on the experience of the ethnographer in conducting and reviewing similar studies. The SCC and FCP may not agree with the results.

Field data derived from ethnographic interviews and oral accounts have been gathered for the MITW. Acquisition of traditional cultural knowledge through interviews and oral histories is important to thoroughly documenting and understanding Native American TCPs. Such documentation will be possible for the MITW, since they have been conducting a program of oral history that will be employed in the current study to guide and/or supplement the interviews. Since the SCC and FCP have elected not to participate, the study must rely upon the published literature and other available evidence to identify potential traditional resources present and activities that may have taken place within the study area and vicinity. The following summary of potential TCPs is based upon sources consulted during ongoing research that have been used to evaluate and construct interpretive contexts and ethnographic backgrounds.

3.2.2.6.4.1 Sokaogon Chippewa

Many elements of the traditional Chippewa culture survive in religious rites and concepts, folklore, medical practices, the use of clan names, games, arts, crafts, subsistence activities and the value system. The Chippewa language is also active, especially among the elders.

The *Midewin* or Medicine Lodge, also known as the Medicine Dance, has persisted, with local variations among the Chippewa of northern Wisconsin, to the present day. It is an ancient religious society which draws on Chippewa traditional cultural knowledge for promoting health through balanced living, herbal medicine, and visions. The *Midewin* can be found among almost all tribes in the Great Lakes region, however, it is believed to have been principally Chippewa in origin. Because of the *Midewin's* focus upon health, a prominent feature is the use of many species of native and introduced plants. Historically, among Wisconsin Chippewa bands, there are two ritual meetings per year. One is held in the late spring and the other in early autumn. These ceremonies are held on a specific site where a special lodge is constructed and a cedar pole is erected. The *Midewin* membership use bags made of only certain animals such as mink, otter, muskrat, beaver, owl, hawk, snake, fox, wildcat, and bear. The origin story of the Chippewas also assumes a significant role within *Midewin* belief and ritual. Members of the *Midewin* have historically served as the official spiritual leaders and healers of the community, as well as presiding over other ceremonies and feasts (Hickerson, 1970:54-9; Ritzenthaler, 1978:754-5; Tanner, 1992:27-9).

Midewin belief and practices are solidly based in Chippewa traditional culture and have served, among other things, to bind the people together and maintain the culture (Tanner, 1992:31). As such, TCPs associated with the *Midewin* are potentially significant cultural resources. Examples of potential TCPs that might exist within or near the study area include sites where *Midewin* ceremonies are conducted; locations where plants used specifically for medicine prescribed by *Midewin* practice and belief are gathered; the place where a specific animal gave up his life for a *Midewin* member's medicine bag; a place where *Midewin* members frequent to obtain visions; and/or the location where cedar poles are gathered for the ceremonies.

Other tradition-oriented groups include the Dream Drum religion. The Dream Drum religion is found among members of the various Chippewa communities of northern Wisconsin. It originated in the Plains and was brought into Wisconsin during the late 19th century. A major feature is the drum which plays a central role, but the activities are also functional and social,

such as those for the performance of marriages. Singing and dancing and use of the sacred pipe are also key elements but, overall, the Drum Religion has fewer organized beliefs and ceremonies than does the *Midewin* (Ritzenthaler, 1978:755-6).

The Peyote religion also had a small following during the 1960s among the Chippewa in northern Wisconsin for curative purposes; however the *Midewin* or Medicine Lodge is the prevailing religion among the tradition-oriented Chippewa. There have also been other religious activities such as the Chief Dance and Bear ceremonialism which are known to exist but with an unknown distribution (Ritzenthaler, 1978:756-7). Potential TCPs associated with these groups and activities would be similar to those hypothesized for the *Midewin* and would include various plants and animals involved in these ceremonies that might have been procured within the study area, locations where ceremonies took place, or other sacred places associated with these activities.

The Chippewa also maintain a rich oral literature dating from the time of European contact to the early 20th century that contains much information that might have a bearing on potential TCPs. The oral literature of the Chippewa is primarily a religious concept and should be understood as that above all else. Certain stories in the oral literature serve as a link to the ceremonies/rituals and as a model for human behavior. They also identify the role and nature of other-than-human beings in the cosmology of the culture. No one story, however, embodies all that is considered to be religious by the Chippewa (Hultkrantz, 1981:15-9). An example of a potential present day TCP based in recent oral history (Smith, 1993; Ackley, 1987) and that maintains community beliefs near the Crandon Project is Spirit Hill (CS-21) which is traditionally known as a burial ground and is important for its spiritual power to influence dreams and its views of the surrounding area (SCC Transcripts, 1994). This location is approximately 1.5 miles west of the center of the Crandon ore body.

The locations of rituals, ceremonies, dances, and pow wows also potentially represent TCPs. An area between Rice Lake and Mole Lake (CS-3d) was identified as a ritual location used around the turn of the century, as was a site at Lake Metonga (CS-5d). Since 1950, members of the SCC have gone to Post Lake (CS-2d), Lake Metonga (CS-5d), and Mole Lake to hold ceremonies and pow wows. Pow wows were held at Elcho and Crandon during the Forest County Fair from 1952 to 1968.

Sites important in maintaining the history of the Chippewa of northern Wisconsin are also potential TCPs. A long term series of wars with the Dakota (Sioux) tribes who resided on their western borders resulted in the Chippewa gaining control of the region by the mid-18th century (Tanner, 1987:39-43). This warfare persisted during historic times and was prominent in history for its intensity, duration, and geographic extent. It also has a basis in ecological issues such as competition for similar resources as proposed by Hickerson (1970:74-75, 100). The site of the battleground between the Sioux and Chippewa (CS-3e/CS-4e) is variously located (Richards and Watson, 1995:40-1), although Chippewa oral history places it in the area between Rice and Mole lakes. Situated approximately two miles from the center of the ore body, this battle site is an example of a potential TCP representative of this aspect of Chippewa culture and history.

Areas where plants, animals, and other resources occur are likely to have been and may continue to be important in maintaining Chippewa traditions. Many native and introduced species of plants have been gathered from the reservation as well as adjoining lands. Traditional hunting and fishing practices also have occurred within lands adjacent to the reservation. In the 1980s

about 86 percent of the Mole Lake Chippewa relied somewhat on hunting and fishing for food, while about 90 percent used gardening, ricing, and picking wild plants for some of their subsistence, as well as wild plants for medicine. Wild rice is an important religious, social and economic pursuit which has considerable time depth in the vicinity of the project area (Jenks, 1900). Many plants have been documented as having been gathered from reservation lands as well as adjoining lands (WDNR, 1986:108,110,202). Gathering sites identified in this general area listed in the inventory include Swamp Creek (CS-19b) and an area between lower Post Lake and Lake Metonga (CS-25b) without specific gathering locations. Potentially, many other plants could exist within the study area, the use of which was documented for the Chippewa in the early 20th century (H. Smith, 1932). Identification of such use areas within and beyond the study area could result in the identification of potential TCPs.

As shown in the Inventory of Cultural Sites, the SCC have documented their habitation and utilization of the study area and vicinity in oral history interviews and testimony, and this documentation is supported for the most part by the available archival sources. Areas of long-term, intensive use within the study area include Rice Lake (CS-3), Mole Lake (CS-4), Swamp Creek (CS-19), Rolling Stone Lake (CS-7), the lower half of Lake Metonga (CS-5), and the southern tip of Lake Lucerne (CS-6); Other important locations are Little Sand Lake (CS-12h), Deep Hole Lake (CS-16h), Ground Hemlock Lake (CS-13h), and St. Johns Lake (CS-14h). Places of long-term, intensive use beyond the study area include the northern half of Lake Metonga (CS-5), most of Lake Lucerne (CS-6), Bishop Lake (CS-9), Pickerel Lake (CS-8) and Pickerel Creek (CS-20), Post Lake (CS-2), the upper Wolf River (CS-18), and Pelican Lake (CS-1); Other important locations beyond the study area are documented at Little Rice Lake (CS-39), Roberts Lake (CS-11), Lily Lake (CS-17h), and Crane Lake (CS-15h).

Most of these traditional use areas represent multiple activities. Rice harvesting is specifically mentioned as a historic activity at Pelican Lake (CS-1b), the Wolf River (CS-18b), Post Lake (CS-2b), Peshtigo Lake (CS-38b), Pickerel Lake (CS-8b), Roberts Lake (CS-11b), Bishop Lake (CS-9b), Lake Metonga (CS-5b), Rolling Stone Lake (CS-7b), Rice Lake (CS-3b), and Oak Lake (CS-10b). Fishing, predominantly spearing during the spring spawning season, is known to have taken place historically at Pelican Lake (CS-1b), Rice Lake (CS-3b), Pickerel Lake (CS-8b), Lake Metonga (CS-5b), Rolling Stone Lake (CS-7b), and Mole Lake (CS-4b). Specific hunting locales are not documented so precisely, but are known to have occurred off of the present reservation.

Although burial grounds are specifically excluded from National Register eligibility, they can contribute to the eligibility of other associated sites. Historically known burial grounds other than Spirit Hill are documented for unspecified locations at Pelican Lake (CS-1c), Post Lake (CS-2c), Pickerel Creek and STH 55 (CS-20cc), Pickerel Lake (CS-8c), Crandon (CS-27c), Lake Metonga (CS-5c), Rolling Stone Lake (CS-7c), Bishop Lake (CS-9c), and Roberts Lake (CS-11c). In addition, tribal testimony and archaeological evidence (Fay, 1986; Nepton, 1992) indicate the presence of burials that may be related to the Sokaogon Chippewa near the site of the Chippewa-Sioux battleground around Mole Lake and STH 55 (CS-4c)

In summary, the potential for Chippewa TCPs within or near the study area is high given the proximity of the reservation and the presence of potential TCPs, such as Spirit Hill and the site of the Battle of Mole Lake, located within two miles of project area. The majority of potential TCPs, however, are situated well beyond the area of potential mine disturbance and should not be affected by the project.

In terms of the types of individual TCPs expected, it can be suggested that most will be associated with the oral traditions of the SCC, with their religious beliefs and practices, or with habitation and traditional subsistence practices, as outlined above. In addition, the TCPI may identify other sites which although not definable as potential TCPs according to federal guidelines, may require additional study.

In keeping with the cultural landscape approach (Kelley and Francis, 1994), some of the sites identified through SCC oral history and archival sources may comprise one or more potential Traditional Cultural Property Districts. Parker and King note that a culturally significant natural landscape may be classified as a site, as may the specific location where significant traditional events, activities, or cultural observances have taken place. They define a TCP District as "A concentration, linkage, or continuity of such sites or objects, or of structures comprising a culturally significant entity . . . (1990:9)." In the SCC case, evidence of the linkage and continuity of places, activities, and beliefs might be shown in the Rice Lake-Mole Lake-Swamp Creek area (CS-3, CS-4, CS-19), the Rolling Stone Lake-Pickerel Lake-Pickerel Creek area (CS-7, CS-8, CS-20), and/or the Post Lake-Upper Wolf River area (CS-2, CS-18). All of these areas, or potential TCP Districts, contain habitation, resource procurement, mortuary, ritual/sacred, and historic trail sites. The Rice Lake-Mole Lake-Swamp Creek area also contains evidence of trading posts (CS-3f) and the historic Chippewa-Sioux battle site (CS-3e, CS-4e).

In his Interim Report, Andrews (1995) discusses four potential SCC TCPs to include Spirit Hill, Swamp Creek, the Chippewa-Sioux Battlefield, and Rice Lake. He also mentions other sites of traditional cultural interest which might be evaluated as TCPs if additional information was available, including cemeteries at Pelican Lake, Post Lake, Pickerel Creek, Pickerel Lake, Crandon, Lake Metonga, and the archaeology site near STH 55; Historic hunting, fishing, and gathering areas at Post Lake, Wolf River, Pickerel Lake, Pickerel Creek, Lake Metonga, Rolling Stone Lake, and Mole Lake; and possible bark gathering activity in the vicinity of the Crandon Mine site.

3.2.2.6.4.2 Forest County Potawatomi

The FCP are situated to the east of the Crandon Project area. The present-day population is comprised of several groups of Potawatomi who moved to this location beginning ca. 1894 until ca. 1914 (Ritzenthaler, 1953:107). Most have maintained the basic elements of their traditional culture into the present day and it is expected that they have TCPs in the general area. For the most part, the traditions already described for the Chippewa exist for the Potawatomi, with slight local variations. Included are the *Midewin* (Medicine Lodge or Medicine Dance), Dream Drum religion, Peyote religion, War Dance, and Sacred Bundle ceremonies. Incidence of the practice of these traditional activities is not known.

The FCP have been historically divided into two communities. One group is called the Wabeno Community, living primarily in the vicinity of the town of Wabeno; and the second group is known as the Stone Lake (Lake Lucerne) Community, who reside primarily east of the City of Crandon. As of the early 1950s, both of these communities shared many of the same cultural characteristics, however the Peyote Religion was most prevalent at the Stone Lake Community, and the *Midewin* (Medicine Dance or Medicine Lodge) was prominent with the Wabeno Community (Ritzenthaler, 1953:111).

Like the Chippewa, there is some evidence for the continuation of traditional subsistence and craft activities. For example, many native and introduced species of plants are used for food, medicine and the arts. About 30 percent of the Potawatomi relied somewhat on hunting and fishing for food in the 1980s, while about 26 percent used gardening, ricing, and picking wild plants for some of their subsistence (WDNR, 1986). Again, the vast majority of documentation itemizing specific usages of naturally occurring material resources pertains to plant resources documented in the early 20th century (H. Smith, 1933).

The fact that the FCP are somewhat later arrivals to the immediate area limits their direct historic association with the land. In support of this hypothesis, there are no potential TCPs which were mentioned in the sources examined for this summary. There is mention, however, that the FCP were involved in recording an inventory of their cemeteries in the 1980s. They have maintained a continued presence in the area and the range and types of Potawatomi TCPs expected to be present in or near the study area might be expected to be similar to those examples described, above, for the Chippewa, especially those related to traditional groups such as the *Midewin*. The FCP have identified the Devils Lake area as an important cultural area based upon the uniqueness of the area, the archaeological sites there, and their cultural ties to the area (FCP, 1994). The Devils Lake area, located on Potawatomi reservation lands approximately 6 miles northeast of the Crandon ore body, is identified as CS-24h in the cultural sites inventory.

In his Interim Report, Andrews (1995) discusses the Devils Lake area as a possible TCP. He notes, however, that there is insufficient information available at this time to evaluate the site's designation as a TCP. Andrews also discusses the concern of the Potawatomi tribal government about preserving spiritually significant vistas as seen from reservation hilltops, which are referred to as Native American Pictographs by the tribal government. To date, the FCP have not provided the necessary primary source data to evaluate the Devil's Lake area designation as a TCP, although the FCP may be conducting their own studies.

3.2.2.6.4.3 Menominee Tribe of Wisconsin

The Menominee reservation is located south of the Crandon Project area in Menominee County and, among the three tribes included in the TCPI, is situated at the greatest distance from the Crandon Project area. The Menominee did, however, occupy parts of the general study area and vicinity in the 18th century (Tanner, 1987:58-9, map 13).

There are four major traditional cultural religious groups which have persisted among the Menominee into the latter half of the 20th century. They are the *Midewin* or Medicine Lodge Society, the Dream Dance or Drum Dance, the War or Chief's Dance, and the Peyote religion known as the Native American Church. The production of items related to the ceremonies of the Medicine Lodge, Dream Dance, and Peyote religion persisted into the 1960s (L. Spindler, 1978:715-17), and may continue to the present day. In addition to these traditional religious groups, there are also some Menominee who are Christians. A segment of the community is affiliated with the Catholic Church.

Among tradition-oriented members of Menominee society within the last 35 years, ordinary dreaming has also been a significant activity, as well as the securing of a guardian spirit and a strong belief in the power of witchcraft. As of 1960, most of the men and boys of the tradition-oriented groups hunted and fished and a few used a variety of charms such as 'hunting bundles'

to ensure the cooperation of the special powers and guardian spirits. Many individuals and families picked ferns and evergreen boughs. A few even traveled to Minnesota to gather wild rice each year (L. Spindler, 1978:709-17).

Tradition-oriented individuals are primarily persons who are members of the Medicine Lodge or Dream Dance organizations. They have sometimes been called native-oriented. Some of these persons are descended from Potawatomi who intermarried with Menominee. Most lived near Zoar, but others were scattered elsewhere throughout the reservation. Very few now identify as Potawatomi and all spoke the Menominee language which is also used at ceremonies. In the 1950 to 1960 period, membership of the group totaled about 70 adults, but in the mid-1970s, there was evidence of a strong, tradition-oriented revival (L. Spindler, 1978:709).

The Menominee belief system is dualistic, with a continuing cosmic conflict between good spirits above the earth and evil spirits below. These specific and basic beliefs about the universe and its inhabitants persisted among Menominee in the tradition-oriented groups in the 1950s (L. Spindler, 1978:712).

An example of a potential Menominee TCP is Spirit Rock. Spirit rock is the place where a person once dreamed for hunting power but became greedy for everlasting life and was transformed into a rock (Fay, 1965:5). The Wolf River has particular significance to the Menominee who maintain many cultural usages of it which can be interpreted as TCPs such as the Dells on the Wolf River, which are the site of a battle between good and evil beings. Each waterfall on the Wolf River also has a direct reference with a sacred story. Some tribal members consider the Wolf River so sacred that they will not use it for recreational purposes (Greene, 1994:20-1). In addition, the Wolf River is home to plants used today among the Menominee for medicinal, food and ceremonial purposes. The knowledge about the use of these plant resources was acquired through dreams or passed down from ancestors and the ethnographic record provides extensive documentation of plant resources utilized by the Menominee people during the early 20th century (H. Smith, 1923).

There is a possibility that TCPs specific to the Menominee are located within the study area and vicinity. David Grignon (1996) has stated that the Oak lake prehistoric-historic occupation sites with probable storage pits could be potential TCPs significant to the Menominee Tribe. While the Oak Lake sites are probably eligible for the National Register for their archaeological values under Criterion (d) (Overstreet and Richards, 1995:26), it is doubtful that they meet the TCP requirements outlined in National Register Bulletin 38 (Parker and King, 1990). Secondary effects to cultural landscapes may be also identified. The Wolf River, for example, or parts of the Wolf River situated at a considerable distance from the project area, may qualify as potential TCP Districts. In addition, and as a byproduct of the TCPI, historically known or documented sites may exist within the study area that, although not definable as TCPs according to federal guidelines, may require additional historical or archaeological studies.

In his Interim Report, Andrews (1995) discusses the Menominee concern for cultural sites along the Wolf River and notes that the Wetland Mitigation [Compensation] Area should also be considered as within the Menominee TCP study area.

3.2.2.6.5 Summary

In summary, the cultural traditions of the three tribes are primarily expressed through the religious beliefs and activities of the individual, sub-group, and tribe. Other facets of these tribal cultures that may serve to maintain cultural traditions include events and places recounted through oral history and traditional subsistence and craft activities. The range and types of potential TCPs and potential TCP Districts within the region have been discussed above. In addition, historically known or documented sites may exist within the study area and vicinity that, although not necessarily definable as TCPs, may require historical or archaeological research. The identification of such properties and the consideration of the cultural landscapes of which they are an integral part, however, is ultimately dependent upon the participation of the tribes whose cultural resources may potentially be affected by the proposed project.

The three tribes whose cultural sites may be affected by the proposed project have been consulted. Although CCRG and WCRI have not been able to work directly with the SCC and FCP, the tribes have communicated and met with the USCOE, the lead federal agency for the project. In writing and public meetings, both the SCC and the FCP have been given the opportunity to express their cultural and other concerns for cultural sites and the project. Additionally, the USCOE has provided the tribes with the necessary guidelines to conduct and submit their own TCP studies, and the SCC and FCP are reportedly conducting their own studies. CCRG and WCRI have been afforded the opportunity to work directly with the MITW.

3.2.2.7 Traditional Cultural Properties Inventory

3.2.2.7.1 Introduction

The Introduction to this section which discusses efforts to involve the study area tribes in the TCP studies was first prepared by CCRG and subsequently updated by WCRI to include efforts to contact the tribes by WCRI beginning in November of 1995 and WCRI interaction with the MITW in completing the TCP studies.

The initial effort to implement the work plan involved contacting each of the three Native American Indian Tribes to inform them about the Crandon Project TCPI and provide the vehicle to involve them in the planning process. The chairpersons of the SCC, the FCP, and the MITW were sent letters and brochures that introduced the project and its personnel by CCRG in October of 1994. The letters were then followed up with telephone calls. Similar procedures were followed by WCRI beginning in November of 1995. The record of interaction that documents all CCRG and WCRI correspondence and interaction related to the TCPI and the project is included in Appendix 3.2-13.

The initial response from the tribal council members and staff of each of the Native American communities was that they wished to confer with their legal counsel, environmental specialists, and/or their respective tribal councils/legislatures before making a decision about participation in the Crandon Project TCPI. During these initial telephone contacts, CCRG requested that the SCC, FCP, and MITW consider granting permission to CCRG to address their respective tribal legislatures to present and discuss the TCPI. The MITW tribal legislature is the only group to date which has granted that request. A presentation and discussion about the TCPI was made at their tribal legislature meeting of December 1, 1994. A motion was passed in which the MITW agreed to participate under specific conditions, and the conditions were accepted by CMC. The

MITW segment of the project was initiated by CCRG in early April 1995 and assumed by WCRI in November of 1995. This work has been completed and a draft report has been submitted to the Menominee Tribal Legislature for review and approval.

Additional telephone contacts and letters were sent to the SCC and the FCP to disseminate information about the TCPI and to determine if a decision had been made concerning their participation. The response from both groups was that no decision had been made.

A further effort was made to contact and involve the Native American groups with the TCPI at a meeting of the Nii Win Intertribal Work Group held at the MITW tribal offices on January 25, 1995. Representatives from a number of tribes from Wisconsin, Minnesota, and Michigan were present, including the three tribes (SCC, FCP, MITW) that are the focus of the TCPI for the Crandon Project. Representatives of CCRG also attended. At this meeting, discussion ensued which provided an opportunity for all those attending to ask questions and discuss their opinions regarding the Crandon Project TCPI.

No decision was made about the involvement of the FCP or the SCC communities at the meeting. The chairman of the Nii Win Intertribal Work Group requested that a decision be made by the councils of both tribes and submitted within 10 days. Subsequent to the January 25, 1995 meeting, additional contacts by letter and telephone were made to learn of any decision to participate in the Crandon Project TCPI on the part of the FCP and the SCC. Based on the conversations with the chairman of the Nii Win Intertribal Work Group, no apparent decision was made. He also reported that decision-making appears to have reverted back to the individual tribes (see Appendix 3.2-13, telephone conversation dated February 19, 1995).

When WCRI took over the responsibility for the Crandon Project TCPI work in November of 1995, additional efforts were made to contact the SCC and FCP through telephone and written correspondence. The USCOE also referred the tribes to WCRI for help with the TCP studies. There has been no response from the SCC or the FCP. Since the SCC and FCP have declined to participate in the TCPI, the preliminary identification of potential TCPs that has been completed and summarized above, comprises the extent of potential TCP identification work for the two tribes. As noted above, WCRI and the MITW have completed the Menominee TCP study.

3.2.2.7.2 Sokaogon Chippewa

The Mole Lake Sokaogon Chippewa have not participated in the Crandon Project TCP Investigations. As such, no TCP data is available. An inventory of Sokaogon Chippewa cultural sites identified from literature sources is provided in Section 3.2.2.5, and Table 3.2-2. A discussion of potential Sokaogon Chippewa TCPs is provided in Section 3.2.2.6.

3.2.2.7.3 Forest County Potawatomi

The Forest County Potawatomi have not participated in the Crandon Project TCP Investigations. As such, no TCP data is available. An inventory of Potawatomi cultural sites identified from literature sources is provided in Section 3.2.2.5, and Table 3.2-2. A discussion of potential Potawatomi TCPs is provided in Section 3.2.2.6.

3.2.2.7.4 Menominee Tribe of Wisconsin

The TCP studies for the Menominee Tribe of Wisconsin have been completed (Woods and Grignon, et al., 1996), and a draft report has been submitted to the Menominee Tribal Legislature for review. The report consists of a general report and confidential appendices. If approved, the general report will be included in this section. The confidential appendices will be distributed for purposes of project planning and preservation on a need-to-know, right-to-know basis, and only with permission of the Menominee Tribal Legislature.

3.2.2.7.5 Summary and Conclusions

The theory and methods employed to conduct the Crandon Project TCP studies have been discussed. The record of interaction with the tribes (and agencies) regarding the conduct of the studies is provided in Appendix 3.2-13. In order to provide background for the TCP studies, the ethnographic setting for each tribe was discussed in Section 3.2.2.3, a listing of potential cultural site types which might be found in the study area and vicinity was provided in Section 3.2.2.4, and an inventory of cultural sites identified in the study area and vicinity was provided in Section 3.2.2.5. The Traditional Cultural Properties Investigations are discussed in Section 3.2.2.6, potential TCPs are discussed in Section 3.2.2.6.4, and inventory of TCPs is described in Section 3.2.2.7. While a number of potential and actual cultural sites, including potential TCPs and TCP Districts, were defined for the SCC and the FCP, these properties could not be evaluated for National Register eligibility since neither of these groups participated in the studies. By definition, TCPs are historic properties that are associated with cultural practices or beliefs of a living community that are: (a) rooted in that community's history, (b) important in maintaining the continuing cultural identity of the community, (c) have significant historical time depth, typically more than 50 years, and (d) refer to those ongoing beliefs, customs, and practices of a living community that have been passed down orally or through practice to the present day (Parker and King, 1990). As such, the identification, evaluation, and evaluation process can not be done without the very active participation of the community, and this report contains no TCP evaluations for either group. It has been suggested in several contexts that the SCC and the FCP may be conducting their own TCP work.

The Menominee tribal legislature considered and approved the tribe's participation in the TCP studies based upon their concerns for potential impacts to the Wolf River. The study was conducted by the Menominee Historic Preservation Department, CCRG, and WCRI. CCRG initiated this work with the Menominee in April of 1995. WCRI assumed this responsibility in November of 1995. The TCP studies for the Menominee Tribe of Wisconsin have been completed (Woods and Grignon, et al., 1996), and a draft report has been submitted to the Menominee Tribal Legislature for review and approval prior to any use by WCRI or CMC.

Potential project impacts to Native American cultural resources, including potential TCPs, are presented in chapter 4, Section 4.2.1.2.

3.2.3 Euro-American Component

Crandon Mining Company was requested by the Wisconsin SHPO in 1994 to conduct a traditional cultural properties inventory (TCPI) to establish the presence or absence of traditional cultural properties (TCPs) within the area of potential effect (APE) of the proposed Crandon Project. Commonwealth Cultural Resources Group, Inc. (CCRG) was retained by

Foth & Van Dyke to accomplish the Euro-American component of the investigations. A detailed report, *Traditional Cultural Properties, Euro-American Component, Crandon Project, Crandon, Wisconsin*, prepared by CCRG (Robertson and Robinson, 1996) is included in Appendix 3.2-16 (Volume IIIb). An overview of the work completed and its results follows.

3.2.3.1 Research Design

Traditional Cultural Properties research focuses on identifying historic properties that are associated with "cultural practices or beliefs of a living community that are (a) rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community" (Parker and King, 1990:1). The non-white population of Forest County is almost exclusively Native American and subject of a separate TCP investigation, while the white population is descended from European ethnic groups. As such, the investigation of Euro-American TCPs within the Crandon Project Area of Potential Effect (APE) focused on Euro-American expressions of ethnicity and traditional practices and locations where distinct Euro-American groups settled (Robertson and Robinson, 1996).

The key to identifying Euro-American TCPs is determining whether cohesive ethnic and/or traditional communities persist as a definable element of the present population (Levine and Merlan, 1993). Four primary sources of information and community expression are considered. The first is the documentation of population movements, land ownership, patterns of land use through historical research to determine if ethnic/traditional population enclaves ever existed in the past. By conducting such research, the time depth of traditional communities can also be precisely defined as TCPs must have significant historical time depth (typically more than 50 years) and, at the same time, refer to the ongoing beliefs, customs, and practices of a living community that have been passed down orally or through practice to the present day.

The investigation of historically important institutions that persist to the present day are a second source for identifying cohesive communities and their expression through local traditions and traditional activities. The single most dominant institution where knowledge of ethnically distinct practices may be maintained among Euro-Americans is the church. Studies indicate that ethnic communities can maintain distinct identities for long periods of time (Locher, 1986). This is particularly true of religious communities. Linebaugh (1993) discovered that German Lutheran settlers in the Valley of Virginia maintained an intact identity that expressed itself in the material culture nearly a century after their entrance into the valley. Bavarian Lutheran immigrants in the Saginaw Valley of Michigan also established a cohesive community that maintained both sacred and secular lifeways for over 100 years after the founding of the settlement (Robinson, 1994).

The reason for this is that certain Christian denominations had strong associations to their European progenitors. Although ethnically distinct, the various denominations organized by European immigrants in the United States shared a common ideology. All were Christian churches that laid claim to being part of an universalizing religious system. Such a universalizing system is "considered by its adherents to be proper to all mankind" and has "mechanisms to facilitate [its] transmittal" (Sopher, 1967:86-87).

For many of these immigrant denominations, the competitive system of denominationalism in the United States was an unfamiliar situation. State churches with only a few dissenting church bodies prevailed in most European countries. This new environment led to high social self-

consciousness among the immigrant church bodies and to emphasis on characteristics peculiar to each church. In most cases, leaders of immigrant churches believed that the only way to be sure of survival was to insist on the rigid preservation of the whole. Initially, most foreign-language immigrant churches used cultural rather than doctrinal grounds to maintain their individuality (Handlin, 1951:129; Meyer, 1975:180-181).

Smith (1986:109-110) notes that this is particularly true of diasporic communities. Once a community is separated from its homeland, the sacred and religious factors within the community's culture may increase in importance. This process may proceed to a point where these factors act as guardians and transmitters of the "myth-symbol complex" of the community and of its historic culture. In extreme instances, this myth-symbol complex can replace the distant homeland as the major mechanism for the maintenance of the ethnic identity. Andrus (n.d.) goes so far to state "the church is the heart of community consciousness and discipline. When it ceases to function as such, fragmentation of the community is merely a matter of time." For this reason, the local religious community is the primary institution emphasized in the TCP research.

A third focus of TCP research are fairs, ethnic festivals, foodways, and other traditional activities that may be associated with particular locations. Except when these activities are taking place, however, they are not observable on the landscape. The existence of such "non-material" cultural traditions, beyond those associated with the religious community, is best investigated by means of interviews with individuals knowledgeable about local history and individuals that maintain knowledge of their ethnic heritage.

A fourth avenue of research that can potentially reveal TCPs are the material expressions of ethnicity. Studies of the material aspects of Euro-American ethnicity have focused on the presence of distinct architectural styles, land use patterns, and, more recently, cemeteries. Cultural geographers have studied the ways in which cemeteries were planned, located, named, subdivided, and used. The study of cemeteries, known as necrogeography, falls into two broad categories: (1) architectural style and content analysis of gravemarkers, and (2) the cemetery as an element of local land use patterns (Francaviglia, 1971:501; Norris, 1988:123).

Cemeteries serve a dual purpose for an ethnic group. They, of course, provide for the internment of the dead, but their importance to TCP research rests with the fact that they act as an interface between current and past generations (Francaviglia, 1971:501). As such, cemeteries and the material culture within them represent valuable indicators of both past cultures and traditional values within a cultural landscape. They also reflect ethnic values and identity (Anderson, 1993:1-2; Kniffen, 1967; Stone, 1991:1-30).

Ethnic expression also manifests itself in architecture and land use. Oszuscik (1987:25) states that "anywhere there was a high concentration of Germans in the United States, Germanic influences appeared in local structures." With their many regional differences in history, dialect, religion, and architecture in their homeland, Germans brought a diversity of building traditions to the Midwest. In larger, more homogeneous enclaves, building traditions reflected customary Old World building patterns. Elsewhere, German builders were influenced by local environmental conditions and elements derived from the dominant culture or other ethnic groups in the area (Linebaugh, 1993; Marshall, 1986:92-3; Milspaw, 1983:82; Oszuscik, 1987:25; Tischler, 1986:142; Wilhelm, 1980:24).

In certain cases, especially among rural farmers, traditional building forms were transported wholesale by some ethnic groups. For example, the sparsely settled coniferous and mixed forest lands of the upper Midwest allowed Finnish immigrants to use their vernacular log building traditions to construct buildings that were essentially continuations of the five basic types common in nineteenth-century Finland (Kaups, 1986:124-125). On the other hand, certain ethnic building traditions appear to have no recognizable foreign antecedents. The brick-veneered log houses built almost exclusively by Belgian immigrants in Wisconsin were unknown in Belgium (Calkins and Laatsch, 1986:100; Upton, 1986:9).

Ethnicity may also be expressed in the spatial organization of a farmstead. Outbuildings (typically log-constructed) on Finnish farmsteads typically followed an L-shaped or nearly square pattern with the hallmark feature being the *savusauna* or smoke sauna. The sauna was typically located away from the primary grouping of farmstead structures as it was considered a fire hazard (Kaups, 1986:127). The traditional Belgian-American farm, in contrast, is typically expressed in a U-shaped configuration of the barnyard, numerous log buildings, and outlying fields (McClelland, et al., 1990:30). In Michigan, the layout of a farmstead settled by a Russlanddeutsch (Russian-German) Mennonite family reflects that of a Volga German farmstead with its identifiable *fehderhof* and *hinnerhof* spatial subdivisions (Demeter and Robinson, 1995).

The Euro-American TCP research design for the Crandon Project, therefore, employs a multi-faceted approach. It combines historical data on settlement with the investigation of extant institutions, local traditions and practices, and material culture. By doing so, both the time depth of a potential TCP and its location can be established.

3.2.3.2 Methodology

Following Levine and Merlan (1993), the first step in documenting TCPs in non-Native American communities is defining the communities and their traditions. The research effort focused on determining if traditional communities exist in the Crandon area and what traditions these communities may be practicing. Also, the investigations sought to identify community members who could provide information about these traditional practices and their meaning (Levine and Merlan, 1993:56-57).

Determining the presence of definable ethnic communities was achieved by using a combination of the avenues of information outlined above. Census data for Forest County from 1890 to 1940 was analyzed with respect to immigration patterns and ethnic affiliation. Cartographic data was also sought that might shed light on ethnicity. To this end, land ownership was traced for the APE with a special emphasis on the project lands surrounding the proposed mine complex in Sections 19, 20, and 28 through 33 of T35N/R13E, Sections 23 through 25 and 36 of T35N/R12E, and Sections 5 and 6 of T34N/R13E. Tax records were also examined for selected parcels. Secondary sources pertaining to Forest County history were consulted, including Davis' (1990) seminal work on Forest County in the 1920s. General works on historic ethnic settlement in Wisconsin (e.g., Wyatt, 1986) were also consulted.

A reconnaissance survey to identify material expressions of ethnicity across the built environment was also undertaken. Because the built environment within the APE revealed little that could be construed as elements of ethnic expression, all areas accessible by road within the 3-mile radius of the center of the ore body were inspected to establish the nature of ethnic expression on a community-wide basis. Also included was a pedestrian survey of the city of Crandon to establish

the nature of ethnic expression on a community-wide basis. In addition, four cemeteries (Lakeside [Crandon], Pine Hill [Armstrong Creek], Town of Crandon, and Town of Nashville) were examined by means of pedestrian survey to ascertain the presence and nature of material ethnic expression.

Finally, interviews were conducted with knowledgeable community informants to ascertain the presence and coherence of ethnic communities and traditions in the area. The religious leaders of the churches in the community were interviewed, and, based on their recommendations, local residents were identified who might provide additional information on ethnicity and TCPs. Informants who are knowledgeable about the history and ethnicity of the area were also interviewed.

The APE for the Euro-American TCPI differs from that defined for the Native American TCPI. The latter takes into account Native American explanations of cultural resources in terms of their own culture and knowledge. The Euro-American TCPI is, instead, based on late nineteenth and twentieth century Euro-American concepts of ownership and tangible resources with well defined boundaries such as property, structures, and community facilities used by civic, religious, fraternal, and/or ethnic organizations (e.g., parks, fairgrounds, church facilities and cemeteries, lodges, etc.).

As a working model, direct parallels can be drawn with APEs developed for above-ground resources surveys which consider historic structures and districts, including rural landscapes which are anticipated to occur within the project area. As with above-ground resources surveys, all areas where construction will disturb the ground surface are included in the APE. The vast majority of all direct environmental impacts are restricted to such areas. These include the proposed plant site; the tailings management area (TMA); the access road, TMA access road, and railroad spur line; electrical and gas transmission facilities; the treated wastewater discharge pipeline corridor; and a wetland compensation parcel. Second, all lands owned by CMC in the project area (see Section 2) are included in the APE since access to a TCP would, potentially, be impeded.

Above and beyond direct impacts, cultural landscapes are taken into account by considering the construction and/or restriction of access as an impact on not just the specific parcel of land and/or structure(s) but also any logically associated parcel and/or structures using criteria such as ownership, ethnic affiliation, and/or functional association. An example from a hypothetical above-ground resources survey can serve to illustrate this point. For example, assume that a project impacts one historic above-ground structure. This structure, however, is associated with several others of the same architectural style and of similar age reflecting the early settlement of an area. In this case, a potential historic district is indicated and the survey would necessarily include all the structures that make up the potential district even though only one would be impacted by the hypothetical project.

As described below, efforts to identify ethnic communities and traditions went beyond the limits of the APE, as defined above. It should be noted, however, that the treated wastewater discharge pipeline corridor occurs within existing rights-of-way and the wetland compensation parcel is an isolated, rural cultivated field with no standing structures. As such, neither was considered to have any potential for impacting a Euro-American TCP and therefore are not discussed further as part of this report.

3.2.3.3 Results

Following the research design and methodology described above, the effort to identify Euro-American TCPs that potentially would be impacted by the proposed Crandon Project first focused on identifying extant traditional communities in Forest County and the Crandon area. Research pertaining to the existence of potential TCPs within the APE demonstrated that the ethnic population was historically small in the towns of Nashville and Lincoln and may not have been large enough to have sustained a traditional community. The fragility of small ethnic communities is demonstrated by the Croatian settlement of Velebit which was abandoned within 15 years of its founding (Project Plan: Historical Investigations of Velebit, ms. on file Nicolet National Forest office, Rhinelander, Wisconsin).

Analysis of the pattern of land ownership and development demonstrated that the vast majority of land within the APE was owned by commercial enterprises and government agencies prior to 1960 and, therefore, was unlikely to have been a location for a TCP. Of the land owned by private individuals, only three structures (possibly farmsteads) and a few summer cottages were present on the landscape in 1936. By 1958, this figure had not appreciably changed. The pattern of land ownership does not provide any evidence of a past or historically viable ethnic community or enclave. Surnames associated with the land are not indicative of any one ethnic group. The ethnic surnames that do occur are almost exclusively German and Polish and are few in number and are not spatially clustered. The field view of the APE did not identify any material elements of ethnicity as expressed in architecture and land use. Expressions of ethnicity in local cemeteries was surprisingly weak and nearly absent.

Research and interviews with local residents and people knowledgeable about the history of settlement in Forest County and/or the Crandon area support the contention that few traditional communities exist in Forest County. The only strong evidence for the existence of a viable traditional community is the Polish settlement in the town of Armstrong Creek, which was established by Polish immigrants in the 1920s. This community, however, is located a considerable distance from the Crandon Project. Here, material expressions of ethnicity observed are manifested in the active Polish Catholic Church and Cemetery and the clustered pattern of land ownership by families with Polish surnames.

Other potential traditional communities considered for this project include German populations and groups who migrated from Kentucky, known locally as Kentucks. Research demonstrated that the German population was dispersed and quickly absorbed into the mainstream of Forest County socioeconomic life. Material expressions of German ethnicity are rare and no on-going ethnic traditions could be demonstrated, even within the context of the Evangelical Lutheran Church which has served the community since the early twentieth century.

The Kentuck population of Forest County may, at one time, have comprised one or more traditional communities. Though their pattern of settlement was largely dispersed and occurred over a long period of time throughout Forest, Vilas, and Oneida counties, the Kentuck settlement in the town of Alvin appears to have been concentrated and established quickly in the early twentieth century. The Kentuck community in Alvin, located well to the north of the Crandon Project, even gained a good deal of political and economic influence which, though somewhat conjectural, may be indicative of what was, at one time, a close-knit, traditional community. Their cohesion as a community, however, appears to have disappeared with the decline of moonshining and their eventual absorption into the mainstream of society.

Based on the foregoing, it is concluded that no definable traditional communities can be associated with the project area. Consequently, no Euro-American TCPs are present within the project area and no additional research is recommended or warranted.

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Crandon Mining Company

Environmental Impact Report

Section 3.3

Transportation and Utilities

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Figures

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Figure 3.3-1 Regional Transportation System and Survey Locations
Figure 3.3-2 Existing Peak Hour Traffic Volumes Measured on January 18, 1995
Figure 3.3-3 1994 Average Annual Daily Traffic Volumes
Figure 3.3-4 1994 Base Traffic Volumes

Appendices

Appendix 3.3-1 TURNS Program Output

3.3 Transportation and Utilities

The study area for transportation includes the City of Crandon and the area extending 10 miles to the east, west and south. The Crandon Project site is located in the south-central portion of this study area. Figure 3.3-1 illustrates the current network of town, county, state and federal roadways in the study area.

3.3.1 Methods

The goal of the transportation analysis was to define current study area traffic movements in terms of the volume of vehicles and directional distribution at intersections. The Wisconsin Department of Transportation (WisDOT) has a significant current data base defining the volume of vehicular movement for the major highways in the study area. It was necessary to collect specific traffic movement data to provide a more complete traffic data base.

To obtain data regarding the current directional distribution of traffic in the study area peak-hour traffic counts were conducted on January 18, 1995 at the following six intersections. The location of the traffic count points are shown on Figure 3.3-1.

1. STH 55 at USR 8 (west)
2. STH 55 at USR 8 (east)
3. STH 55 at CTH S
4. USR 8 at CTH S
5. STH 55 at Airport Road
6. STH 55 at CTH K

Traffic movement counts were conducted from 6:00-9:00 a.m. and 3:00-6:00 p.m. The counts were obtained manually by tallying each vehicular movement and recording them on mechanical counters in 15 minute intervals for both the a.m. and p.m. periods. The data was then downloaded into a personal computer. TURNS (Strong, 1993), a turning movement summary program, was used to produce a detailed volume summary of the collected data for 15 and 60 minute intervals at each intersection. The output from the TURNS program is contained in Appendix 3.3-1. The volume summaries were plotted and balanced, and are shown in Figure 3.3-2. Due to the seasonal variation of traffic in this area, it was necessary to develop base traffic volumes for this study which reflect the higher traffic levels typically associated with the summer months. Using Average Annual Daily Traffic (AADT) volumes (two-way) shown on Figure 3.3-3 collected from the WisDOT, base traffic volumes were determined as follows.

Step 1: Determine the existing directional distribution based on the traffic volumes collected on January 18, 1995.

Step 2: Factor the WisDOT AADT volumes into peak-hour two way volumes using WisDOT provided peak-hour factors (K factors) for state and county highways (WisDOT, 1991). The K factor represents a percentage of AADT volume present during a given hour of yearly traffic. For this analysis, the thirtieth highest hour (K_{30}) was used because it is the most common design hour for roadway design. The peak-hour factor (K factor), for STH 55 and USR 8 is K_{30}=167, and for CTH S is K_{30}=134.

Step 3: Using the directional distribution from the collected peak-hour volumes, the base AM and PM (K_{30}) peak-hour volumes were determined.

The base volumes are shown in Figure 3.3-4.

3.3.2 Roads

For northern Wisconsin, the study area has a well-developed system of federal, state, and county highways. All lands within the study area are within two to three miles of a county highway. Additional access is provided by numerous town roads (Figure 3.3-1).

The primary roadway that will service the plant site is STH 55. This roadway is a north-south arterial consisting of one lane in each direction. The most immediate population centers on STH 55 are the city of Crandon, north of the proposed plant site, and Mole Lake, west of the plant site. The speed limit on STH 55 in the vicinity of the proposed plant site entrance is 55 miles per hour.

United States Route 8 (USR 8) is an east-west major arterial consisting of one lane in each direction. The majority of traffic traveling east to the plant site from the Rhinelander area and west to the plant site from the Laona area will use USR 8. The posted speed limit of USR 8 in the city of Crandon is 35 miles per hour, outside of the city the posted speed limit is 55 miles per hour.

County Trunk Highway S (CTH S) is a north-south collector consisting of one lane in each direction. The majority of traffic entering the site from the west on USH 8, and exiting the site traveling west will use this segment of CTH S, rather than traveling on STH 55 to the city of Crandon and connecting with USR 8. The posted speed limit on CTH S is 55 miles per hour. Other major collectors in the study area include County Highways M, B, W and Q.

Based on the January, 1995 traffic counts the weekday morning peak hour of traffic occurred from 7:30 to 8:30 a.m., and the evening peak hour from 4:00 to 5:00 p.m.. Figure 3.3-2 illustrates the existing peak hour traffic counts. Additional AADT volume data was gathered from the WisDOT. These traffic volumes, based on WisDOT data collected during 1994, are shown on Figure 3.3-3.

Seasonal traffic levels fluctuate in the region because of tourist traffic. According to WisDOT the average daily traffic in the summer months may range from 30 to 45 percent greater than average annual daily traffic volumes (WisDOT, 1991).

According to Chapter 348 Wisconsin Statutes, the statewide highway weight limit is 80,000 pounds per vehicle. However, this may vary depending upon conditions. During the spring thaw, for instance, reduced weight limits are often imposed at the county and town level. In Langlade and Forest Counties, the posted spring weight limits are 36,000 and 24,000 pounds gross weight, respectively (Monnot, 1995; Campbell, 1995). In the towns of Lincoln and Nashville, Forest County, the spring posted weight limits are 7,500 and 14,000 pounds gross weight, respectively (Hobbs, 1995; Vollmar, 1995).

The County Highway Improvement Program for Forest County (NCWRPC, 1993) assessed the county highway system by describing and analyzing existing conditions and identifying highway

improvement priorities for budgeting purposes. The report indicated that the surface condition on 48 percent (approximately 52 miles) of the Forest County highways were rated a "6" or below on a 1-10 rating system, with "10" being excellent (new construction), and "1" being failed (total reconstruction necessary). The additional 52 percent (approximately 57 miles) were rated "7" or above. The highest priority roadway improvement project identified in the study area was segments of CTH "Q" (approximately 5.5 miles) which were recommended for seal coating. No roadways were recommended for total reconstruction.

3.3.3 Airports

The only airport in the study area was the Crandon Municipal Airport, located approximately three miles north of the plant site. It is classified as a small utility airport and does not have commercial service. The longest runway is asphalt surfaced, 3,100 feet long, and oriented west-northwest to east-southeast. A second runway consists of turf, and is 2,700 feet in length oriented in a north-south direction. The main asphalt runway is open year round, while the turf runway is open from April 1 to December 1. The main runway has low intensity lighting. There is no regularly scheduled passenger service to the Crandon Municipal Airport (WisDOT, 1993).

The closest commercial airport offering regularly scheduled passenger service is in Rhinelander, located 35 to 40 miles west of the plant site.

3.3.4 Railroad

The only railroad within the study area is a main line branch of the Wisconsin Central Limited Railroad, located 2.5 miles northeast of the ore body. This line begins at Wisconsin Junction, five miles north of the city of Crandon, passes through the city, extends south to Milwaukee, and ultimately Chicago. The track is estimated to handle five to seven million tons of freight per year. The line had one train a day in each direction in 1994. Plans are to increase the number to two trains per day in the next one to two years. This line also provides access to Upper Michigan and the cities of Superior and Minneapolis. At Wisconsin Junction, this railroad track joins another branch of the Wisconsin Central Limited Railroad that traverses Wisconsin from east to west (Tebell, 1995). The line also passes through both the Stockbridge-Munsee and Menominee Indian Reservations located approximately 30 miles south of the project site. The line also parallels the Wolf River approximately between Lily and Langlade south of the project site.

3.3.5 Utilities

Electrical and natural gas distribution service is provided in the study area by Wisconsin Public Service Corporation (WPSC). Electric is the only utility currently supplied to the Crandon Project site. This is supplied from the 115 kV Venus Substation located approximately one-mile south of Monico,Wisconsin. ANR Pipeline Company owns a six-inch natural gas transmission pipeline that is located approximately two miles north of Crandon, where it extends easterly to Laona and westerly to Rhinelander. WPSC provides local natural gas distribution.

The project and immediate surrounding area is served by individual private water supply wells and on-site sanitation systems. A community water system with at least one well is reportedly located on the Mole Lake Indian Reservation. The City of Crandon maintains a public water supply system and municipal wastewater treatment facility. Telephone service is supplied by Crandon Telephone Company in Crandon, Wisconsin. Although no telephone service is currently supplied to the plant site, overhead lines exist along Little Sand Lake Road.

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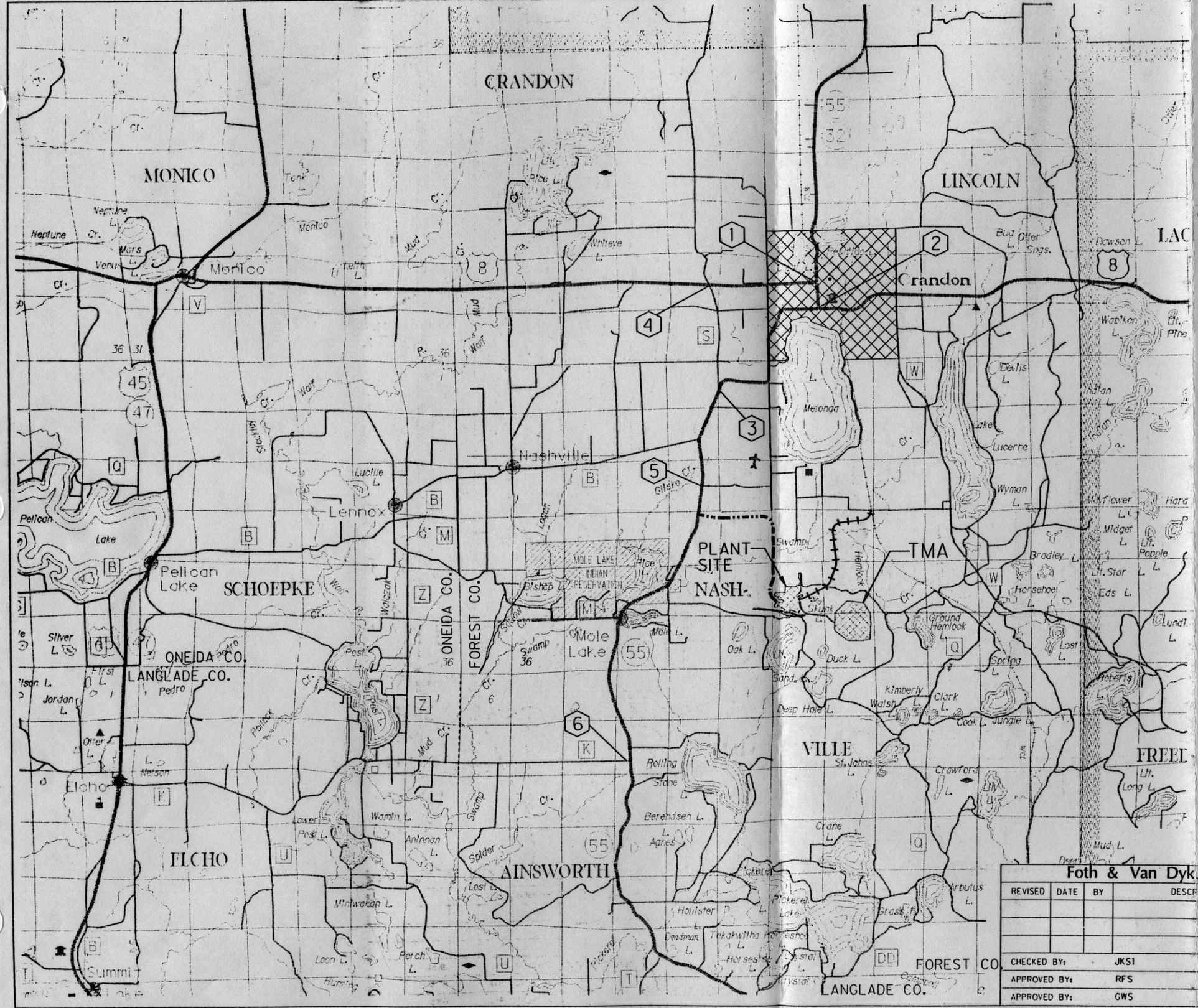
FIGURES FOR SECTION 3.3


CRANDON
MONICO
LINCOLN
Monico
Crandon
Nashville
Lennox
Pelican Lake
SCHOEPKE
ONEIDA CO.
LANGLADE CO.
FOREST CO.
MOLE LAKE INDIAN RESERVATION
PLANT SITE
NASH.
TMA
VILLE
AINSWORTH
ELCHO
FREED
Pelican Lake
Mole Lake
Summit
Elcho
Neptune
Mars
Venus
Monico
Mud
Wolf
Rice
Whiteye
Bug Otter Sngs.
Dawson
Washkon
Dr. Pine
Devils
Melonga
Lake Lucerne
Wyman
Mayflower
Hard
Midget
Lit. Popple
Bradley
Horseshoe
Lit. Star
Eds
Ground Hemlock
Last
Spring
Robertg
Lundt
Swamp
Oak
Duck
Sand
Deep Hole
Kimberly
Walsh
Clark
Cook
Jungle
Crawford
Long
Mud
Rolling Stone
Berenhisen
Agnes
Crane
Pickerel
Pickerel Lake
Brask
Arbutus
Hollister
Deatman
Tokatwitha
Horseshoe
Crystal
Lucille
Gilbert
Logan
Stolts
Whalzak
Post
Lower Post
Jordan
Silver
Nelson
Pedro
Patrick
Wanda
Antinnan
Spider
Lost
Minkwakan
Loon
Perch
Hunter
Swamp
Hemlock
Cr.
Lk.
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Dr.
Crk.
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Ft.
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Ctr.
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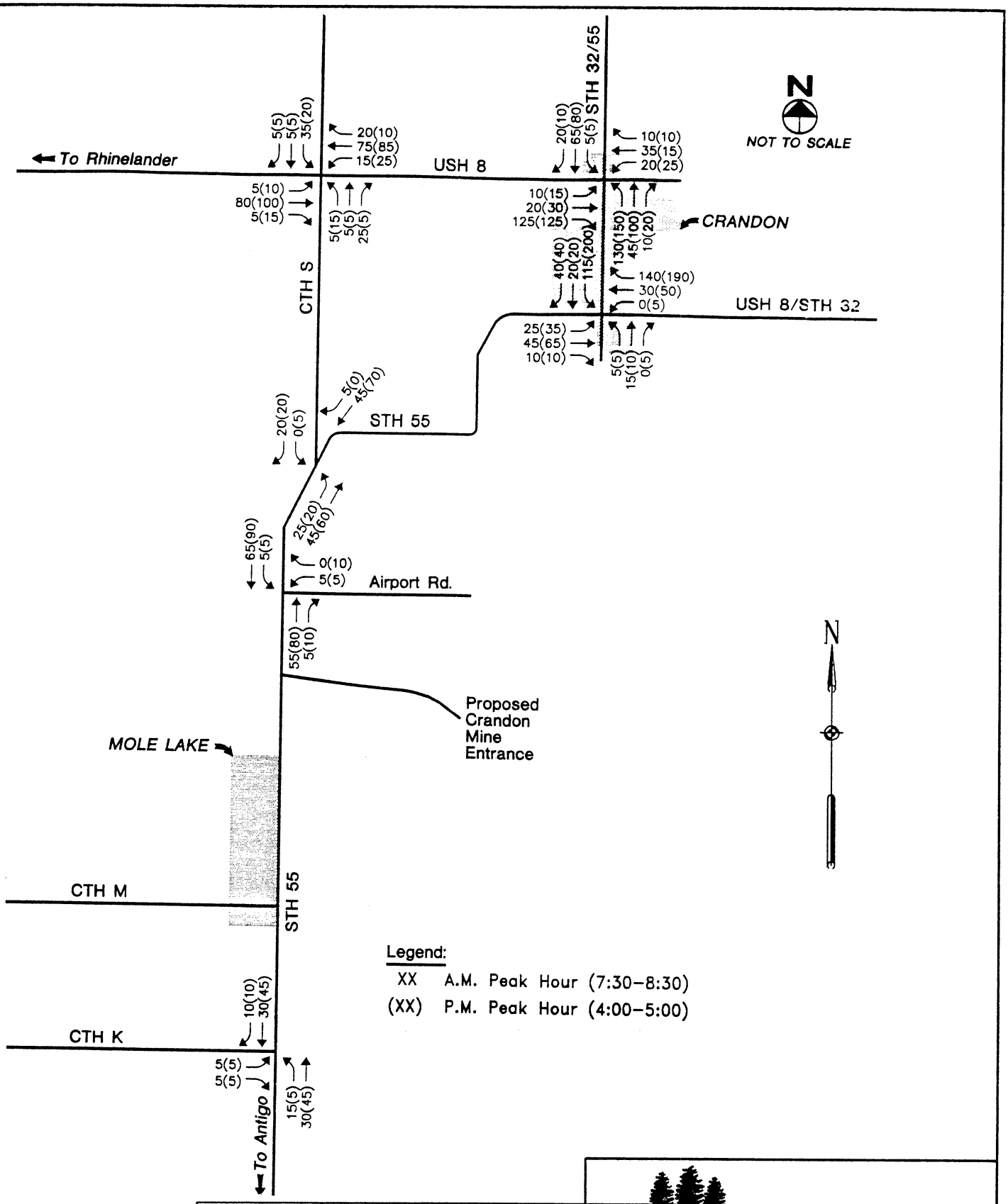

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	RFS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.3-2

EXISTING PEAK HOUR TRAFFIC VOLUMES
MEASURED ON JANUARY 18, 1995

Scale:	N.T.S.	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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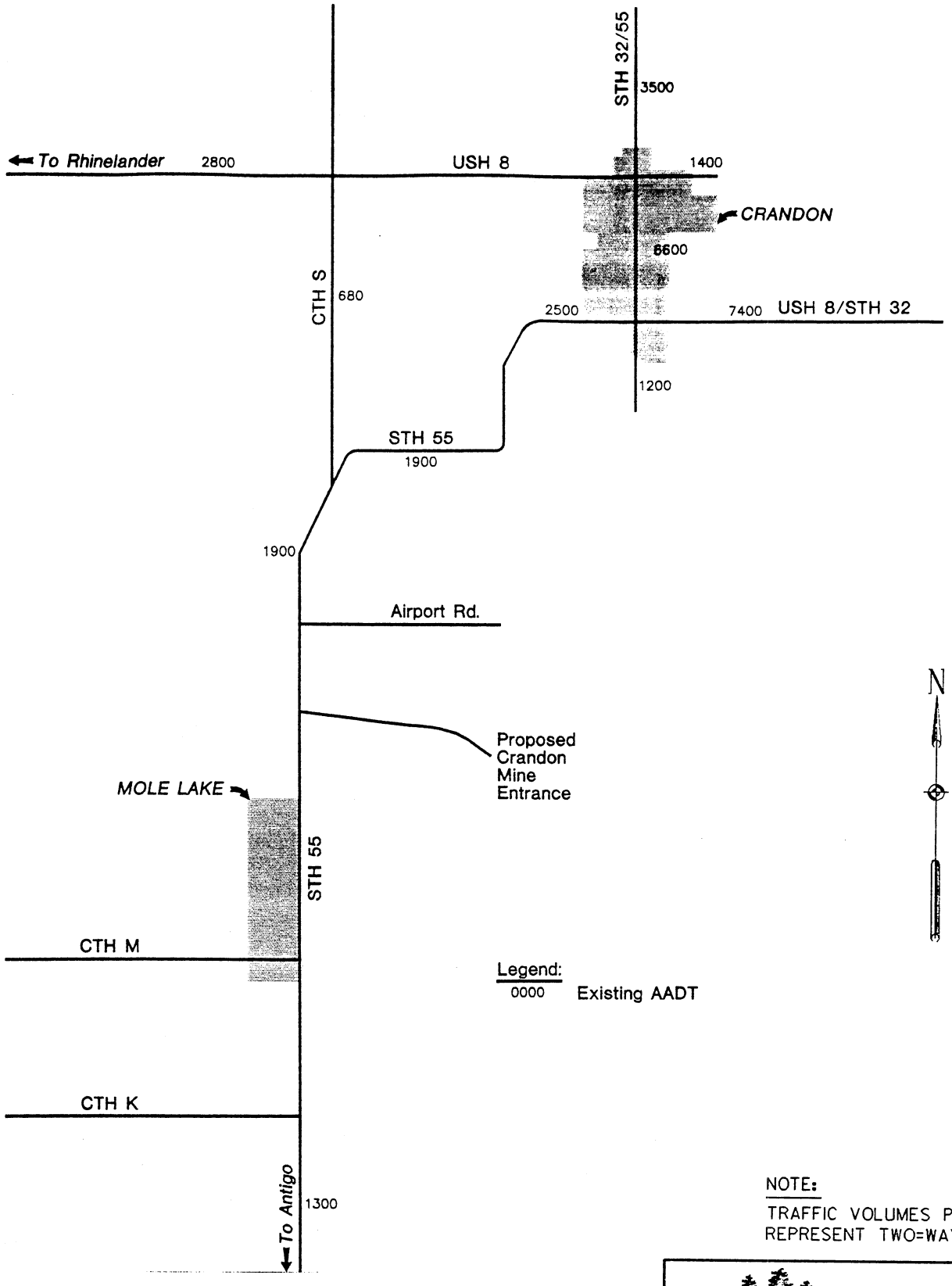
93C049



NOTE:
TRAFFIC VOLUMES PRESENTED REPRESENT TWO=WAY TRAFFIC

SOURCES: WDOT 1994

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	RFS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.3-3
1994 AVERAGE ANNUAL DAILY TRAFFIC VOLUMES

Scale:	N.T.S.	Date:	MARCH, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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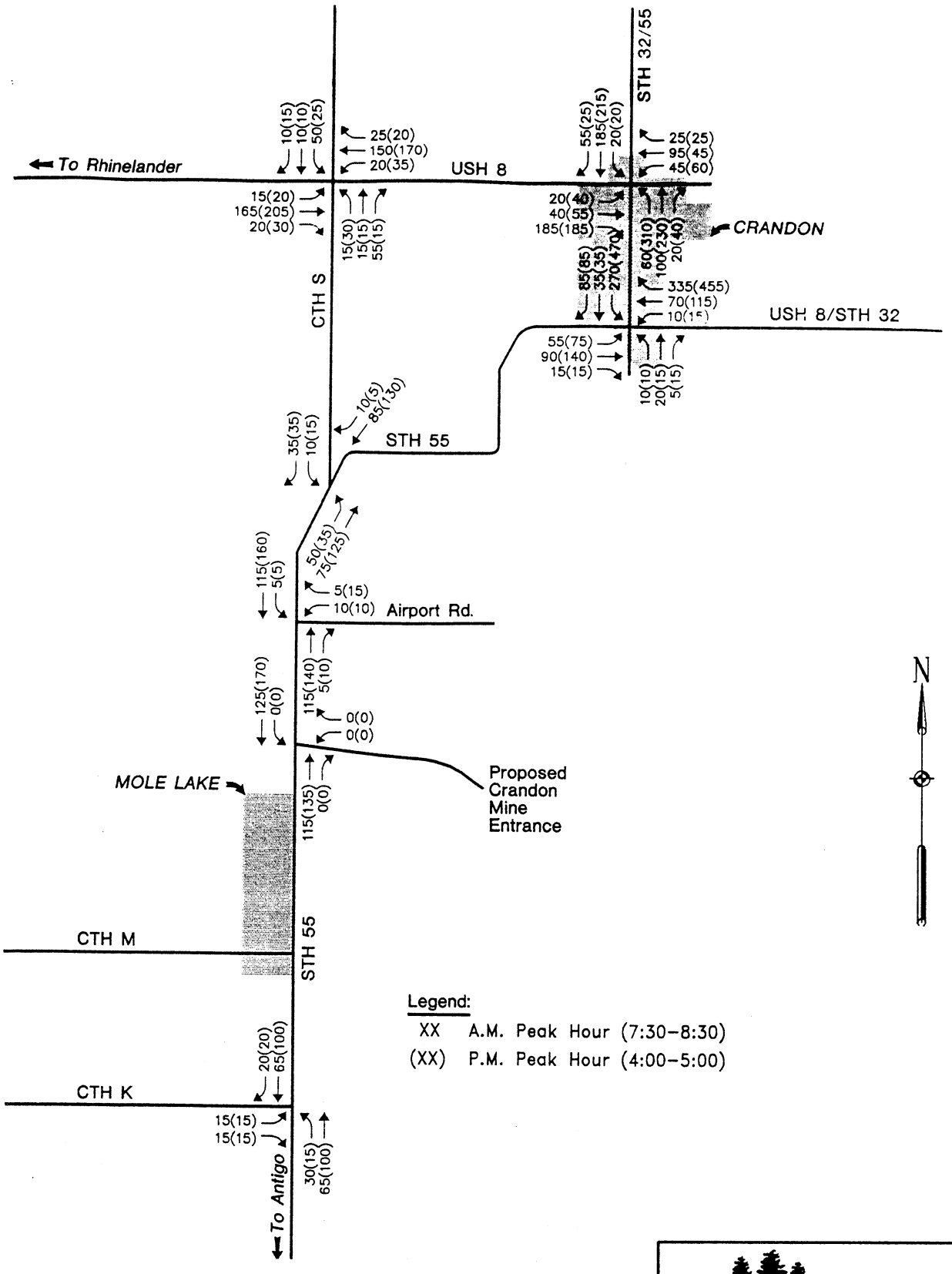

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	RFS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.3-4

1994 BASE TRAFFIC VOLUMES

Scale:	N.T.S.	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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Crandon Mining Company

Environmental Impact Report

Section 3.4

Climatology, Meteorology and Air Quality

Crandon Mining Company
Environmental Impact Report

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3.4 Climatology, Meteorology and Air Quality

A site specific ambient air monitoring program was developed for the Crandon Project. Details of the program are contained in the May 1994 document titled *Revised Ambient Air Monitoring Quality Assurance/Quality Control Plan* (air monitoring plan), which is included in Appendix 3.4-1. The plan discusses available background data concerning the project area, outlines the sampling program, defines sampling sites, provides a description of monitoring equipment, presents a data reduction and reporting program and presents quality assurance and preventative maintenance programs. The project air monitoring plan was reviewed and accepted by WDNR. Plan approval, WDNR audit results, and air monitoring plan updates are included in Appendix 3.4-2.

Air monitoring began in July 1994. The air monitoring data presented in this section of the EIR includes information collected over the period of July 1994 through June 1995.

The remaining portion of Section 3.4 provides an overview of field and laboratory methods and discusses the results of ambient air monitoring work completed along with existing WDNR ambient air data. A more detailed explanation of field and laboratory methods can be found in Appendices 3.4-1 and 3.4-2.

3.4.1 Field and Laboratory Methods

General field and laboratory methods used to evaluate the existing meteorological conditions and air quality of the area surrounding and including the proposed mine site include monitoring for particulate matter less than 10 microns in diameter (PM10); total suspended particulate (TSP); and for meteorological parameters such as wind speed, wind direction, temperature, relative humidity, and precipitation. In addition, particulate characterization in the form of size, distribution, and shape and metal trace element analyses were included in the program. Field monitoring equipment included in the program consists of PM10 and TSP high-volume air samplers and meteorological instruments.

As shown on Figure 3.4-1 three sampling sites were selected to collect ambient air monitoring data. The location of the three sites provide the definition of the aerial extent of the ambient air monitoring study area. Site No. 1 is located west of the ore body, near the Mole Lake Indian Reservation. Site No. 2 is located northeast of the ore body, near Lake Lucerne. Site No. 3 is located southeast of the ore body near Walsh Lake. The site locations were selected based on their terrain, accessibility for installation and servicing of equipment, availability of electric power, distance (at least 100 feet) from unpaved roads, lack of vertical obstruction and the prevailing wind direction.

The following monitors were located at the identified sites:

Site No. 1: Meteorological Station (Monitor No. 1)
PM10 Sampler (Monitor No. 5)
TSP Sampler (Monitor No. 2)

Site No. 2: TSP Sampler (Monitor No. 3)

Site No. 3: TSP Sampler (Monitor No. 4)

An additional fourth TSP monitoring site has been set up by the WDNR at Rolling Stone Lake. Details regarding that monitoring station are not addressed here.

Routine field monitoring activities generally involve filter recovery, filter installation, chart replacement, and routine maintenance, as well as filter shipment to the laboratory for analysis. Other required activities include conducting calibrations of the PM10 and TSP samplers and motor brush replacements. Activities are documented in a written record kept in field notebooks dedicated to each monitor. Visual observations and sample collection and handling notations are also documented in the field notebooks.

Particulate sampling occurred every third day for a 24-hour period. Filters were removed and installed the day after sampling. To avoid non-representative particulate loading, the exchange of filters occurred within 24 hours of completion of sampling. After being removed from the sampler, the filter samples were sent every 14 days to the laboratory to be weighed. Each of the PM10 quartz filters and the TSP glass fiber filters were conditioned and pre- and post-weighed in order to determine particulate loading.

The meteorological instruments were operated continuously over the year-long ambient air monitoring period. Meteorological data was reviewed on a weekly basis to verify proper equipment operation. Data was downloaded monthly through October, 1994. Due to mechanical problems with the meteorological equipment, data downloading frequency was increased to weekly from that point forward.

Laboratory analytical activities have been performed to determine the amount of particulate collected on the filters and, as a result, the ambient air PM10 and TSP concentrations. Originally, the air monitoring plan specified that composite filter samples be analyzed for various metals and that a microscopic analysis of the filter samples be performed on an every two-month basis. This program was followed for the first two compositing periods. Following discussions with the WDNR, the program was adjusted to include lower detection limits for laboratory analyses for selected metals and the performance of metal analyses and microscopic analyses on a four-month composite. The lower detection limits were specified so that test results could be more readily compared to other project baseline data. The increased composite time frame was specified to allow a larger sample to be available for analytical work so the lower detection limits could be achieved.

3.4.2 Climatology-Meteorology

The climate of the region is continental, modified slightly by Lake Michigan, which is located approximately 80 miles to the east, and Lake Superior located approximately 93 miles to the north. The region has moderately warm summers with prevailing westerly winds and long cold winters. Summer temperatures rarely exceed 95 degrees Fahrenheit (°F) during the day, while night temperatures range between 50°F to 60°F. Winter temperatures range from 0°F to 25°F during the day, and occasionally will fall below -30°F at night.

Historical monthly temperature and precipitation data, averaged from 1961 to 1990, were obtained from the State Climatologist (Anderson, 1995) for the North Pelican Lake Station, located approximately 15 miles west of the plant site. Data from the North Pelican Lake Station

was used due to its relatively close proximity to the project area. The data, presented in Table 3.4-1, shows that during the period of 1961 to 1990 the highest average temperature at North Pelican Lake, 77.2°F, occurs in the month of July. The lowest average temperature, 0.1°F, occurs in January. The highest actual temperature on record for North Pelican Lake over the period of 1950-1994 was 98°F in July 1955. In February 1967, the lowest actual temperature, -44°F, was recorded.

Daily high and low temperatures obtained from the meteorological station at Monitoring Site No. 1 were averaged for the months of July 1994 through June 1995. These averages are also presented in Table 3.4-1. A review of the table shows that monthly high and low temperatures based on the site specific data correspond reasonably well to the historical average monthly temperatures.

Average historical monthly precipitation at North Pelican Lake, as shown in Table 3.4-1 ranges from approximately one to four inches. The greatest monthly average, 4.14 inches, occurs in the month of August. The least precipitation occurs in February with an average of 0.82 inches. In total, the historical average annual precipitation at North Pelican Lake is 30.36 inches. Snow fall in the region averages between 40 and 60 inches per year. Total monthly precipitation data collected from the meteorological station at Site No. 1 is also presented in Table 3.4-1 for July 1994 through June 1995. Due to equipment problems, the site specific data does not correspond well to historical values.

Wind speed and direction can be effectively presented in the form of wind rose diagrams. Wind roses are used to depict the frequency of occurrence of wind direction and speed in each of 16 compass directions. Five wind roses have been prepared for the study area based on the data collected at the meteorological station at Monitoring Site No. 1. Figures 3.4-2, through 3.4-6 show wind roses for the periods of July 1994-June 1995 (annual), July-September 1994, October-December 1994, January-March 1995, and April-June 1995, respectively.

Wind roses depict the direction from which the wind originated. For instance, SW on the wind rose means the wind is coming out of the southwest. Figure 3.4-2 indicates that over the period of record in the study area, winds typically came from the west, south and southwest, with a smaller component from the northwest. July through September winds over the period of record typically originate from the south, southeast, southwest and west. October through December winds originated most frequently from the south, west and southwest; those during January through March typically originated from the west, northwest and southwest; and winds during April through June originated from the west, northwest, south and east.

3.4.3 Background Air Quality

3.4.3.1 National Ambient Air Quality Standards

The Clean Air Act requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) for air pollutants which may be injurious to public health or welfare. The following pollutants have NAAQS: Particulate matter less than 10 microns (PM-10), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and lead (Pb). These pollutants are collectively referred to as criteria pollutants.

Table 3.4-1

Meteorological Data

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature Data (°F)													
State Climatologist[1]													
Average High	20.1	25.8	36.9	51.9	66.2	73.2	77.2	73.6	64.4	54.0	37.8	24.1	50.4
Average Low	0.1	2.6	15.0	28.8	40.1	49.7	54.9	53.0	45.4	35.3	23.2	6.9	29.6
Meteorological Station[2]													
Average High	20.6	21.9	37.9	42.2	64.7	77.2	74.0	69.8	64.5	54.4	40.9	30.2	49.9
Average Low	5.3	4.4	19.9	23.0	39.3	51.5	51.2	48.6	42.6	32.8	24.3	11.9	29.6
Precipitation (in)													
State Climatologist[1]													
Normal	1.08	0.82	1.62	2.35	3.18	3.58	3.73	4.14	3.99	2.46	1.96	1.45	30.36
Meteorological Station[2]													
Total	0.04	0.05	0.79	1.69	3.63	0.66	0.67[3]	2.19	4.12	0.0[3]	1.26	0.07	15.17[3]

Note: [1] Monthly averages for 30 year period (1961-1990)as measured at North Pelican Lake.
[2] Measured data collected from July 1994 through June 1995.
[3] Partial data recovery due to equipment problems.

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Checked by: MAD1

The State of Wisconsin regulates the release of air pollutants under the Wisconsin Administrative Code Chapters NR 400 to NR 499. Ambient air quality standards are regulated under NR 404. The State of Wisconsin primary and secondary air quality standards are listed in Table 3.4-2.

Table 3.4-2

Wisconsin Ambient Air Quality Standards

Pollutant	Averaging Time[1]	Primary Standard ($\mu g/m^3$)	Secondary Standard ($\mu g/m^3$)
Total Suspended Particulate (TSP)[3]	Annual	N.S.	N.S.
	24-hour	N.S.	150
Particulate Matter Less than 10 Micrometers (PM10)	Annual[2]	50	50
	24-hour	150	150
Sulfur Dioxide (SO_2)	Annual[2]	80	--
	24-hour	365	--
	3-hour	--	1,300
Carbon Monoxide (CO)	8-hour	10,000	10,000
	1-hour	40,000	40,000
Nitrogen Dioxide (NO_2)	Annual[2]	100	100
Ozone (O_3)	1-hour	235	235
Lead (Pb)	Calendar Quarter[2]	1.5	1.5

$\mu g/m^3$ = micrograms per cubic meter
N.S. = No Standard

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Notes:

1 Short-term standards (i.e. 24-hour average or less) may not be exceeded more than once per year.
2 Arithmetic mean: the average of the collection of concentrations obtained by dividing the sum of the concentrations by the quantity of samples.
3 Total suspended particulate (TSP) standard is a Wisconsin standard only, the USEPA NAAQS has been revised from TSP to PM10 and the Federal TSP standard has been removed.

Primary air standards are defined as the level of air quality which provides protection for public health with a sufficient margin of safety. Secondary standards are defined in Wisconsin as the level of air quality which may be necessary to protect public welfare from unknown or anticipated adverse effects.

An area is non-attainment if the ambient air quality standards for a particular pollutant or pollutants are not met. The proposed mine site is located in an area classified as attainment for all criteria pollutants.

3.4.3.2 Prevention of Significant Deterioration

The Clean Air Act Amendments of 1977 established a national permitting program to prevent significant deterioration of air quality in areas where the existing air meets the NAAQS. The basic goals of the Prevention of Significant Deterioration (PSD) regulations are:

1. to allow economic growth and development to occur while preserving the existing quality of air;

2. to provide protection to the public health and welfare from adverse effects which might occur even at levels better than the NAAQS; and

3. to preserve the existing air quality in areas of special scenic or historical value.

The provisions of the PSD regulations apply to major new stationary sources and major modifications to existing major sources. A new source is subject to the PSD rules if it is located in an attainment area and will be a major stationary source under the definition in NR 405.02. Major stationary sources include both stationary sources in 28 categories which have the potential to emit 100 tons per year or more of any air contaminant regulated under the Federal Clean Air Act; and, stationary sources, not within the 28 categories, which have the potential to emit more than 250 tons per year of any air contaminant regulated under the Federal Clean Air Act. A major stationary source subject to the PSD rules requires a Best Available Control Technology (BACT) analysis, pre-construction ambient air monitoring, an ambient air quality impact analysis and a Class 1 impact study.

Mining is not one of the 28 category sources. Based on calculations contained in the August 1995 *Air Pollution Control Permit Application for the Crandon Project* (Foth & Van Dyke, 1995), the Crandon Project is expected to have the potential to emit, not including secondary emissions, less than 250 tons per year of any regulated pollutant. Therefore, the proposed Crandon Project is not subject to PSD rules as a major stationary source.

Once a source subject to PSD requirements has submitted a complete application in a given county, the PSD baseline is considered established or "tripped". If a PSD baseline has been established for a given pollutant by another source, all new projects, including minor sources, in the area are subject to operate within restricted concentration increments. Forest County is not one of the PSD counties in Wisconsin in which the baseline has already been "tripped" for any regulated air pollutants. As such, the concentration of air pollutants at the mine is not subject to the PSD increment limits.

As part of the PSD regulations, additional review is required for sources significantly impacting Class I areas. There are currently no areas designated as Class I within 100 miles of the project area. Therefore, a Class I impact study is not required.

3.4.3.3 Ambient Air Particulate Concentrations

Table 3.4-3 presents a summary of the highest PM10 and TSP concentrations measured at the three project background monitoring sites from July 1994 through June 1995.

Table 3.4-3

Ambient Air Sampling Results ($\mu g/m^3$) (July 1994 through June 1995)

Concentrations	Site No. 1 Monitor 5 (PM10)[1]	Site No. 1 Monitor 2 (TSP)[1]	Site No. 2 Monitor 3 (TSP)	Site No. 3 Monitor 4 (TSP)
Highest 24-Hour	37	58	56	52
Second Highest 24-Hour	33	45	50	40
Annual Arithmetic Mean	9.9	12.7	14.3	12.9

[1] June 23, 1995 exceptional event not included in the data analysis. See Appendix D of EIR Appendix 4.2-2 for details.

$\mu g/m^3$ = micrograms per cubic meter

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Figures 3.4-7 through 3.4-10 present graphs of the total PM10 and TSP information collected from each monitor. The scale has been set on these figures to show the relative PM10 and TSP site area data against the 150 $\mu g/m^3$ air quality standard. Measured concentrations are representative of rural areas with no significant industry nearby. Monthly summaries of sampling results and equipment calibrations were submitted to WDNR on a regular basis as per the air monitoring plan.

3.4.3.4 Particle Characterization

Particle characterization consisted of the determination of chemical composition (metals analysis) and particle size distribution. Chemical composition analyses were completed for two 2-month composites and for two 4-month composites as explained in Section 3.4.1. The highest individual metal concentration values measured during the 2-month and 4-month composite periods, as well as for the overall sampling program, are presented in Table 3.4-4. For metals which were not detected in any of the samples, metal concentrations presented in the table are conservatively based on the analytical detection limit. Results are presented in Table 3.4-4 over both the 2-month and 4-month periods because the original higher detection limits may bias the magnitude of the overall results.

Table 3.4-4

Ambient Air Monitoring
Trace Element Concentrations ($\mu g/m^3$)
July 10, 1994 through July 9, 1995

Element	Highest Concentration[1] ($\mu g/m^3$) July 10, 1994 - November 9, 1994	Highest Concentration[1] ($\mu g/m^3$) November 10, 1994 - July 9, 1995	Highest Overall Concentration[1] ($\mu g/m^3$)
Antimony	<0.02080	<0.00175	<0.02080
Arsenic	<0.03328	0.00034	<0.03328
Beryllium	<0.00208	<0.00018	<0.00208
Cadmium	<0.00208	0.00033	<0.00208
Chromium	0.00270	0.00153	0.00270
Cobalt	<0.00416	<0.00035	<0.00416
Copper	0.24011	0.08804	0.24011
Iron	0.15106	0.10596	0.15106
Lead	<0.01664	0.00200	<0.01664
Manganese	0.00466	0.00358	0.00466
Mercury	0.00004	0.00005	0.00005
Nickel	0.01789	0.00197	0.01789
Selenium	<0.02912	<0.00246	<0.02912
Silver	<0.00208	<0.00018	<0.00208
Tin	<0.06240	<0.00529	<0.06240
Uranium	0.00073	0.00002	0.00073
Zinc	0.46088	0.00891	0.46088

$\mu g/m^3$ = micrograms per cubic meter

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[1]Value after the less than sign (<) was calculated based on the detection limit for that sample.

A particle size distribution analysis was completed by Thresher & Son, Inc. (1996) for 11 filters, four each from Monitoring Stations No. 1 and No. 3 and three from Monitoring Station No. 4. Two subsamples were taken from each filter, referred to as stub A and stub B and five photomicrographs were taken of each subsample. The photomicrographs were used for characterization. Particle characterization consisted of recording the mean diameter of each particle ≥1 μm, recording the shape and character of each particle, and estimating the quantity of particles <0.5 μm mean diameter. For the square (or round) and rectangular (or oval) mineral particles, the mean number and standard deviation of particles counted in the photomicrographs were calculated. The mean number and standard deviations are summarized in Table 3.4-5.

Table 3.4-5

Mean Number and Standard Deviation of Mineral Particles by Size

	Stub A		Stub B	
Filter Date	<0.5 μm	>1 μm	<0.5 μm	>1 μm
Station 1 Monitor 2				
08/24/94	126 ± 60	58 ± 6.7	93 ± 23	68 ± 17
12/15/94	192 ± 81	32 ± 14	70 ± 49	24 ± 7.2
01/02/95	85 ± 82	14 ± 2.2	66 ± 30	9 ± 2.2
06/23/95	49 ± 9.6	105 ± 10	44 ± 14	114 ± 14
Station 2 Monitor 3				
07/31/94	68 ± 16	75 ± 6.6	88 ± 30	54 ± 14
12/03/94	148 ± 27	57 ± 13	77 ± 13	43 ± 5.2
06/17/95	87 ± 31	76 ± 25	42 ± 28	80 ± 18
Station 3 Monitor 4				
08/24/94	92 ± 26	96 ± 26	78 ± 24	79 ± 18
12/16/94	209 ± 42	35 ± 8.9	143 ± 51	30 ± 9.3
03/04/95	73 ± 33	82 ± 16	78 ± 60	71 ± 14
06/17/95	81 ± 44	95 ± 27	55 ± 23	82 ± 16

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Based on the particle characterization analysis, no fibrous minerals were observed in any of the photomicrographs. The photomicrographs showed primarily square (or round) and rectangular (or oval) mineral particles. A greater number of biologic particles as well as the square and rectangular mineral particles ≥1 μm were present in the filters from the non-winter months. This is to be expected since the warmer months tend to experience an increase in pollen, insect, and agricultural activities. Conversely, a greater amount of square and rectangular mineral particles <0.5 μm were present in the winter months.

3.4.3.5 Other Parameters

The WDNR determines background ambient air concentrations for other criteria pollutants based on information collected from monitoring stations located throughout the state. The criteria pollutant background concentrations for Forest County, obtained from the WDNR (Roth, 1994), are given in Table 3.4-6.

Table 3.4-6

Typical Background Concentration of Criteria Pollutants[1]

Pollutant	Concentration ($\mu g/m^3$)	Averaging Period
Total Suspended Particulate (TSP)	15.2 40.2	Annual 24-hour
Particulate Matter less than 10 microns (PM10)	17.7 44.2	Annual 24-hour
Sulfur Dioxide (SO_2)	10.4 39 143.9	Annual 24-hour 3-hour
Carbon Monoxide (CO)	4,913.7 6,919.7	8-hour 1-hour
Nitrogen Dioxide (NO_2)	11.0	Annual
Ozone (O_3)	-	-
Lead (Pb)	0.05	Calendar Quarter

[1]Data compiled by WDNR (Roth, 1994).

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Checked by: MAD1

In addition, the WDNR summarizes data collected at the various WDNR monitoring stations in published air quality data reports. State air quality trends, as well as highest recorded levels and exceedances at individual monitors, are included in the air quality reports. The exceedance data summarized below provides an indication of the air quality of the state and project area.

Based on the information presented in the 1994 Air Quality Data Report (WDNR, 1995), there were no exceedances throughout the state in 1994 for particulate matter less than 10 microns (including the Crandon Project site monitoring station), sulfur dioxide, carbon monoxide, nitrogen dioxide, or lead. Of the total suspended particulate (TSP) monitors throughout the state (including those at the Crandon Project site), 26 exceedances of the TSP standards occurred in 1994. The two measured exceedances in Wausau, at least one attributed to quarrying activities, are the closest reported to the project site.

Eighteen known ozone exceedances occurred in Wisconsin at 11 different sites on four separate days. The exceedances occurred primarily in the eastern part of the state along the Lake Michigan shoreline.

3.4.3.6 Other Emission Sources

Contributing to the air quality of an area are air emission sources located in or surrounding that area. Based on information obtained form the WDNR for Forest, Langlade, Marinette and Oneida Counties (Carter, 1995), direct stationary sources with reportable quantities of criteria pollutants per 1993 emissions data located within 30 miles of the plant site are shown in Table 3.4-7.

In addition to the direct facility sources, farm fields and construction sites impact the quality of ambient air in any area. Emissions from these sources have not been quantified within the study area, but they are believed to be minimal due to the limited amount of agriculture and the sparse population.

Indirect sources include stationary sources which convey or attract motor vehicles such as highways and roads. The primary roadway that is nearest the plant site is STH 55. The distance along STH 55 from CTH K to USR 8 is approximately 12 miles. Based on the current average annual traffic volume of 1,900 vehicles per day on this stretch, as presented in Figure 3.3-3, located in Section 3 of the EIR, approximate existing emissions of total suspended particulate, sulfur dioxide, carbon monoxide, nitrogen oxide, and hydrocarbons from vehicle exhaust were calculated and are listed in Table 3.4-8. It is also estimated that an additional approximate 140 tons per year (based on emission factors for paved roads contained in USEPA's "Compilation of Air Pollution Emission Factors") of TSP is currently emitted as fugitive dust from vehicle traffic on this roadway.

Table 3.4-7

Emissions of Existing Stationary Sources (tons/year)

Source	City	PM10	TSP	SO_2	CO	NO_X	HC
Forest County							
Nicolet Hardwoods Corporation	Laona	40.69	50.99	0.94	25.12	4.27	8.79
Bemis Mfg.	Crandon	0.04	0.05	0.00	0.16	0.81	3.76
Bemis Mfg.	Laona	0.00	2.14	0.00	0.00	0.00	23.51
Forest County Highway Department	Crandon	0.87	6.45	2.41	0.53	0.85	0.53
Langlade County							
Kretz Lumber Co.	Antigo	5.65	6.28	0.23	33.22	1.13	2.13
Vulcan Brunswick Bowling Pin Co.	Antigo	8.49	10.22	0.21	8.69	2.02	50.07
Robbins, Inc. DBA Yawkey-Bissell Plant	White Lake	6.49	58.84	0.57	15.25	2.59	13.99
Marinette County							
American Graphics	Goodman	0.00	0.00	0.00	0.04	0.16	70.44
Goodman Forest Industries	Goodman	98.55	109.51	1.06	28.38	19.86	9.44
Oneida County							
Howard Young Medical Center	Woodruff	.68	.68	.22	2.0	8.07	.19
Little Rapids Corp.	Rhinelander	8.37	11.89	0.39	10.79	1.77	5.48
Marplex, Inc.	Rhinelander	1.66	3.03	0.04	56.21	0.43	4.76
Pitlik & Wick	Eagle River	.16	4.89	5.98	1.25	3.65	.78
Printpack Enterprise	Rhinelander	0.01	0.01	0.00	0.06	0.30	156.48
Rhinelander Paper Co.	Rhinelander	19.89	234.34	3,868.74	238.60	1,960.81	560.64

Source: Carter, 1995.

TSP = total suspended particulate
PM10 = particulate matter less than 10 microns
SO_2 = sulfur dioxide
CO = carbon monoxide
NO_X = nitrogen oxides
HC = hydrocarbon

Prepared by: SAS1
Checked by: MAD1

Table 3.4-8

Estimated Existing Annual Vehicle Exhaust Emissions Along STH 55[1]

Emissions	Quantity (tons/year)
Particulate Matter[2]	1.3
Sulfur Dioxide[2]	1.0
Carbon Monoxide[3]	240.8
Nitrogen Dioxide[3]	30.8
Hydrocarbons[3]	24.4

[1] Calculated based on average annual existing traffic volume of 1,900 vehicles per day along STH 55 from CTH K to USR 8 (Figure 3.3-3 of EIR Section 3).
[2] Vehicle exhaust emissions based on USEPA's computer program part 5, EAA-AA-AQAB-94-2.
[3] Vehicle exhaust emissions based on USEPA mobile source emission rate program, Mobile 5A.

Prepared by: SAS1
Checked by: MAD1

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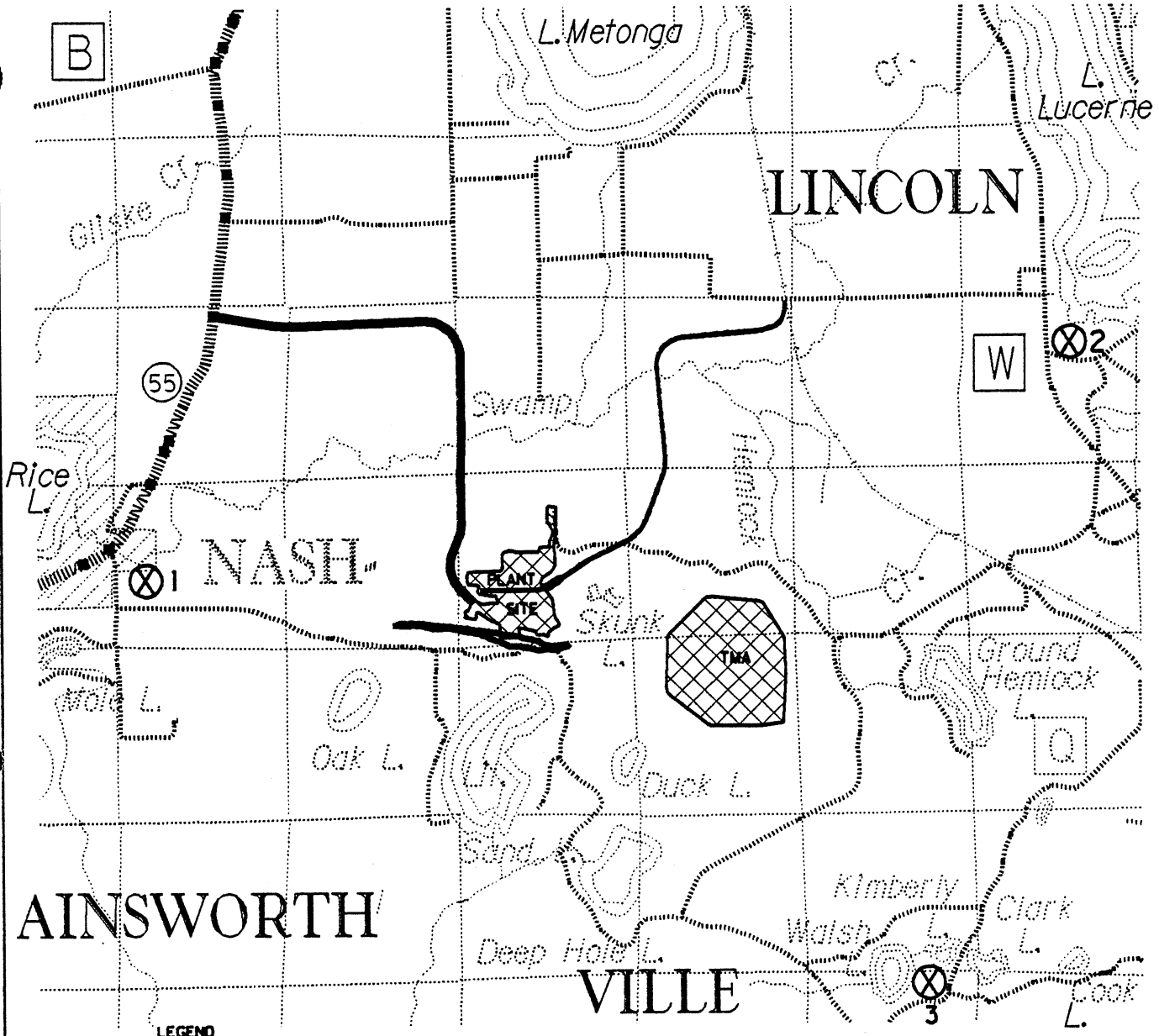
FIGURES FOR SECTION 3.4



LEGEND

- STATE HIGHWAY
- COUNTY TRUNK ROAD
- TOWN ROAD
- SECTION LINE
- STATE HWY NO.
- W — COUNTY HWY LETTER
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- ⊗1 AMBIENT AIR MONITORING SITES

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS	DATE:	APR.'95
APPROVED BY:	MADI	DATE:	APR.'95
APPROVED BY:	JWS	DATE:	APR.'95

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FIGURE 3.4-1

GENERAL LOCATION OF AMBIENT AIR MONITORING SITES

Scale:	1" = 5000'	Date:	APRIL, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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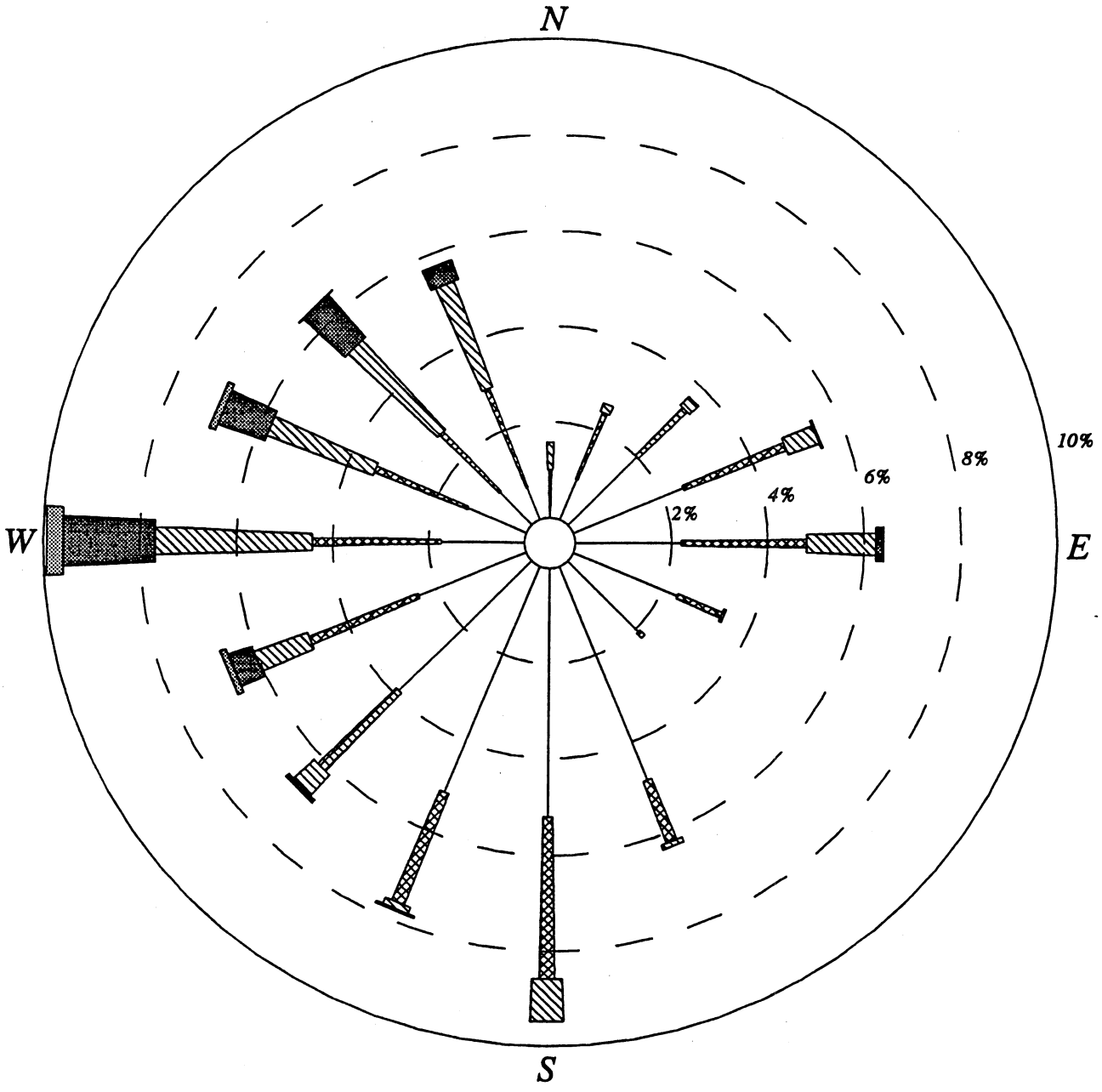
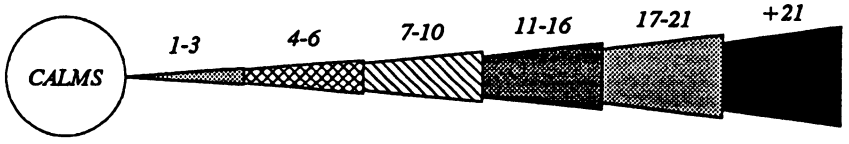


CALM WINDS 8.43%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)



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REVISED	DATE	BY	DESCRIPTION
1	5-96	MADI	UPDATED WIND ROSE

CHECKED BY:	JKS	DATE: APR.'95
APPROVED BY:	MADI	DATE: APR.'95
APPROVED BY:	JWS	DATE: APR.'95

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FIGURE 3.4-2
WIND ROSE
ANNUAL 1994-95

Scale:	NOT TO SCALE	Date:	APRIL, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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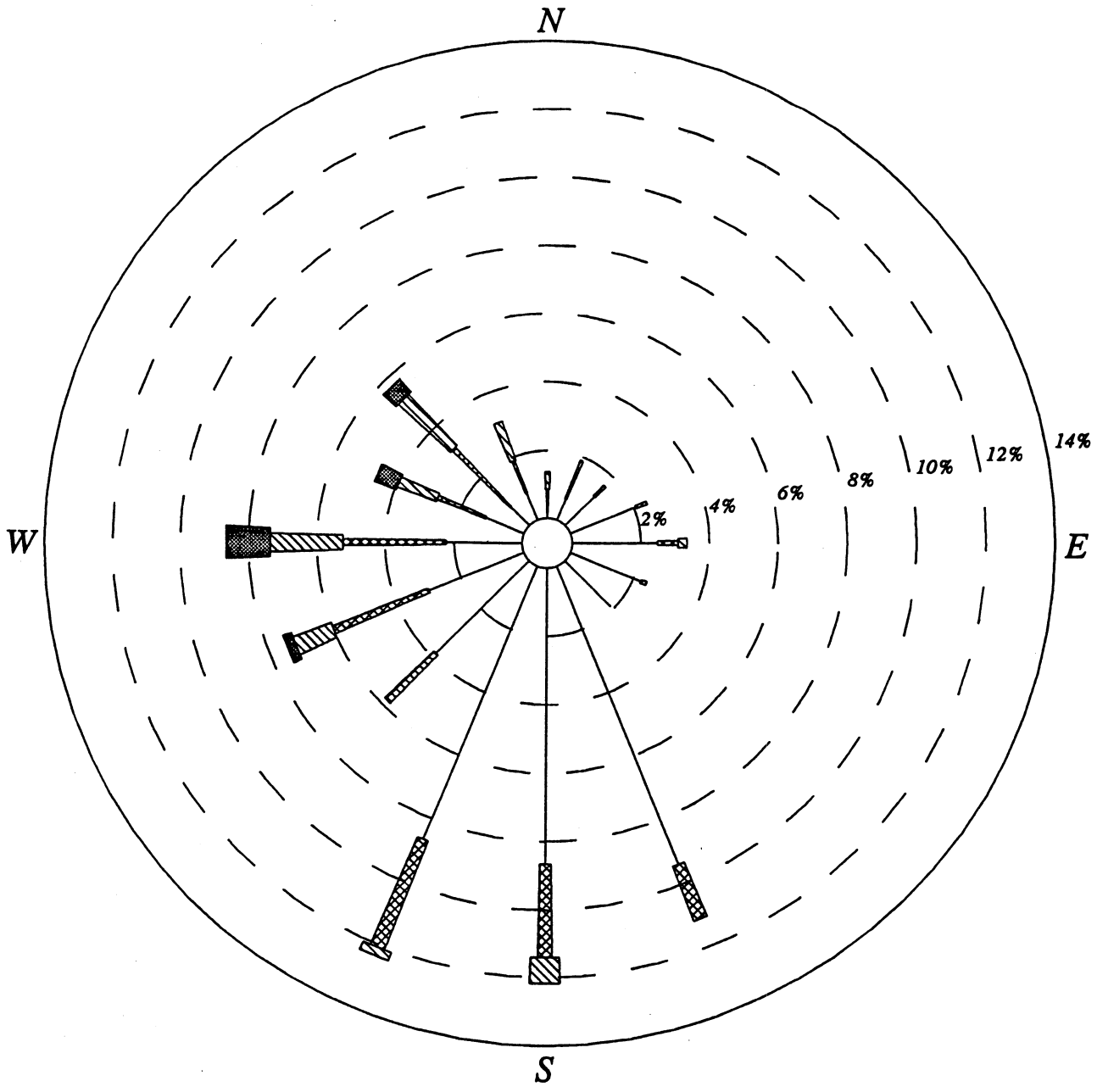
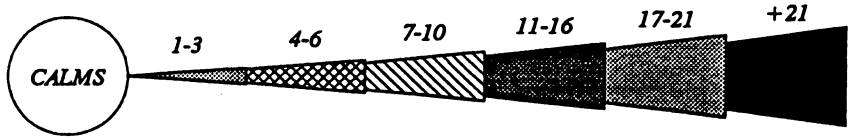


CALM WINDS 14.05%

WIND SPEED (KNOTS)

NOTE: Frequencies indicate direction from which the wind is blowing.



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5-96	MADI	UPDATED WIND ROSE

CHECKED BY:	JKS	DATE:	APR.'95
APPROVED BY:	MADI	DATE:	APR.'95
APPROVED BY:	JWS	DATE:	APR.'95

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FIGURE 3.4-3
WIND ROSE
JULY THROUGH SEPTEMBER, 1994

Scale:	NOT TO SCALE	Date:	APRIL, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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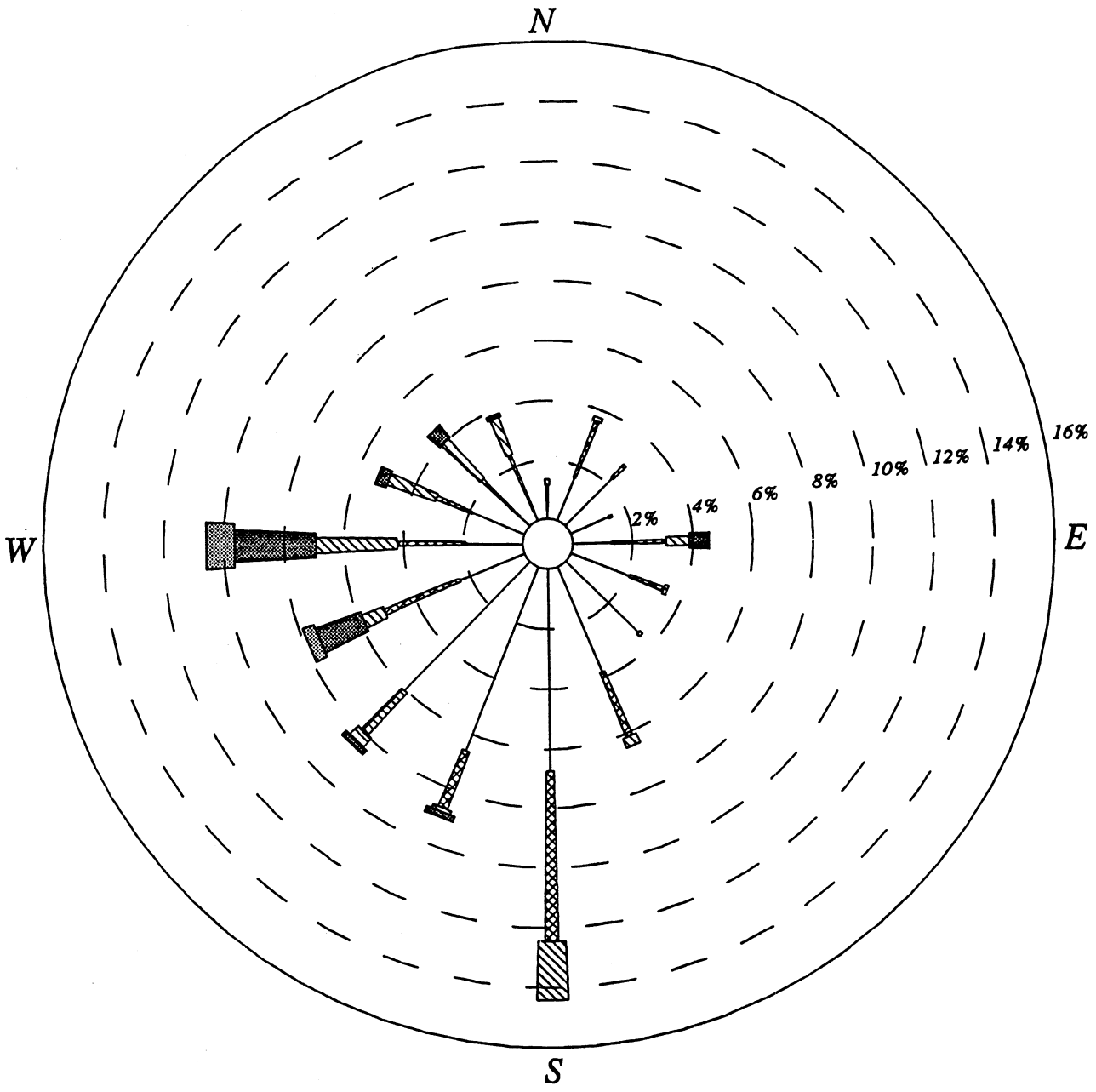
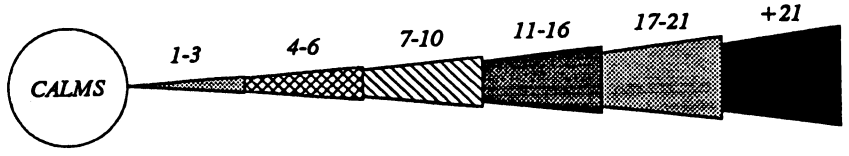


CALM WINDS 8.29%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5-96	MADI	UPDATED WIND ROSE

CHECKED BY:	JKS	DATE: APR.'95
APPROVED BY:	MADI	DATE: APR.'95
APPROVED BY:	JWS	DATE: APR.'95

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FIGURE 3.4-4
WIND ROSE
OCTOBER THROUGH DECEMBER, 1994

Scale:	NOT TO SCALE	Date:	APRIL, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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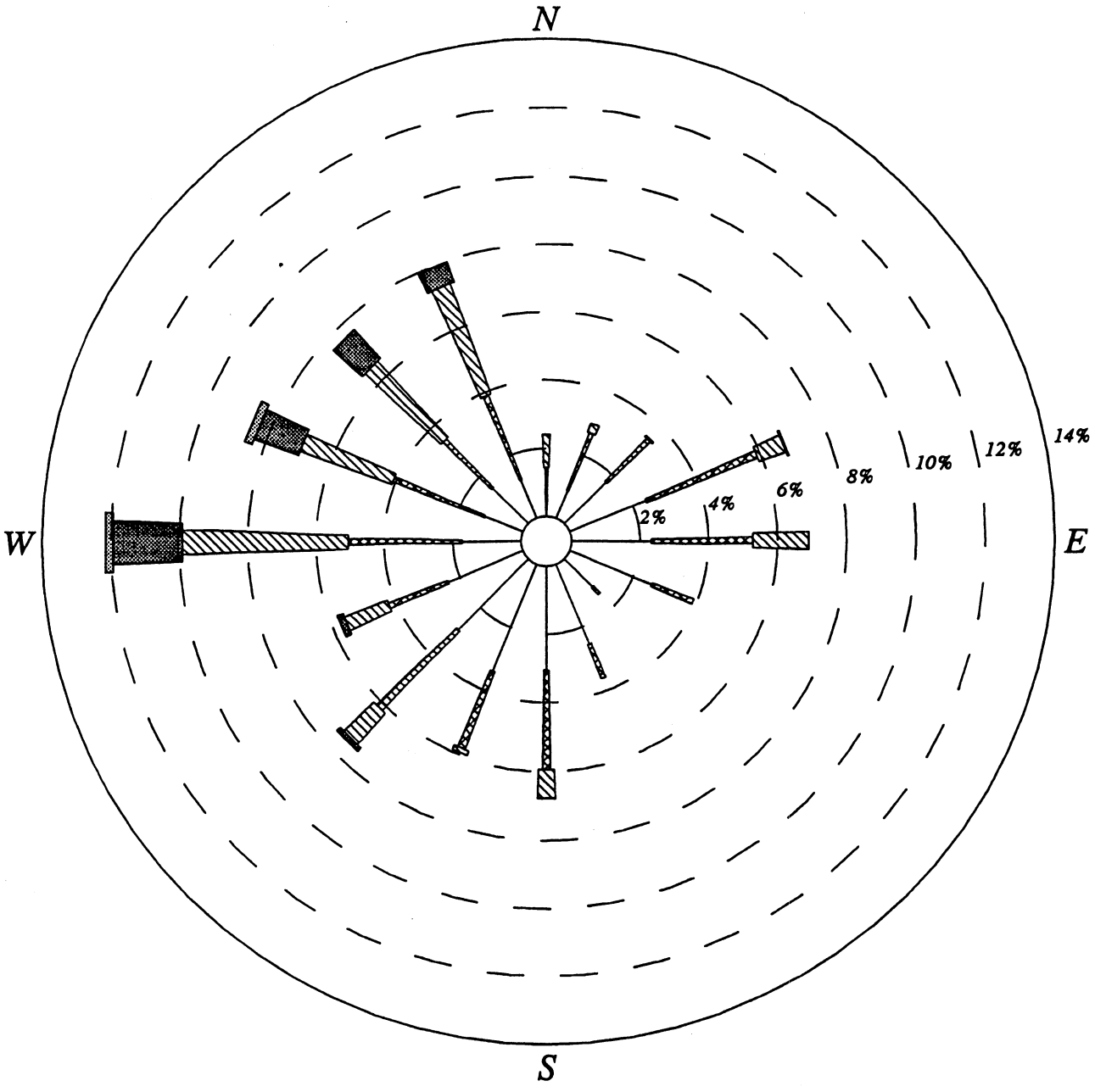
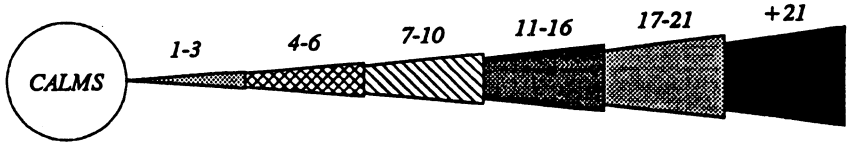


CALM WINDS 6.16%

WIND SPEED (KNOTS)

NOTE: Frequencies indicate direction from which the wind is blowing.



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5-96	MADI	UPDATED WIND ROSE

CHECKED BY:	JKS	DATE:	APR.'95
APPROVED BY:	MADI	DATE:	APR.'95
APPROVED BY:	JWS	DATE:	APR.'95

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FIGURE 3.4-5
WIND ROSE
JANUARY THROUGH MARCH, 1995

Scale:	NOT TO SCALE	Date:	APRIL, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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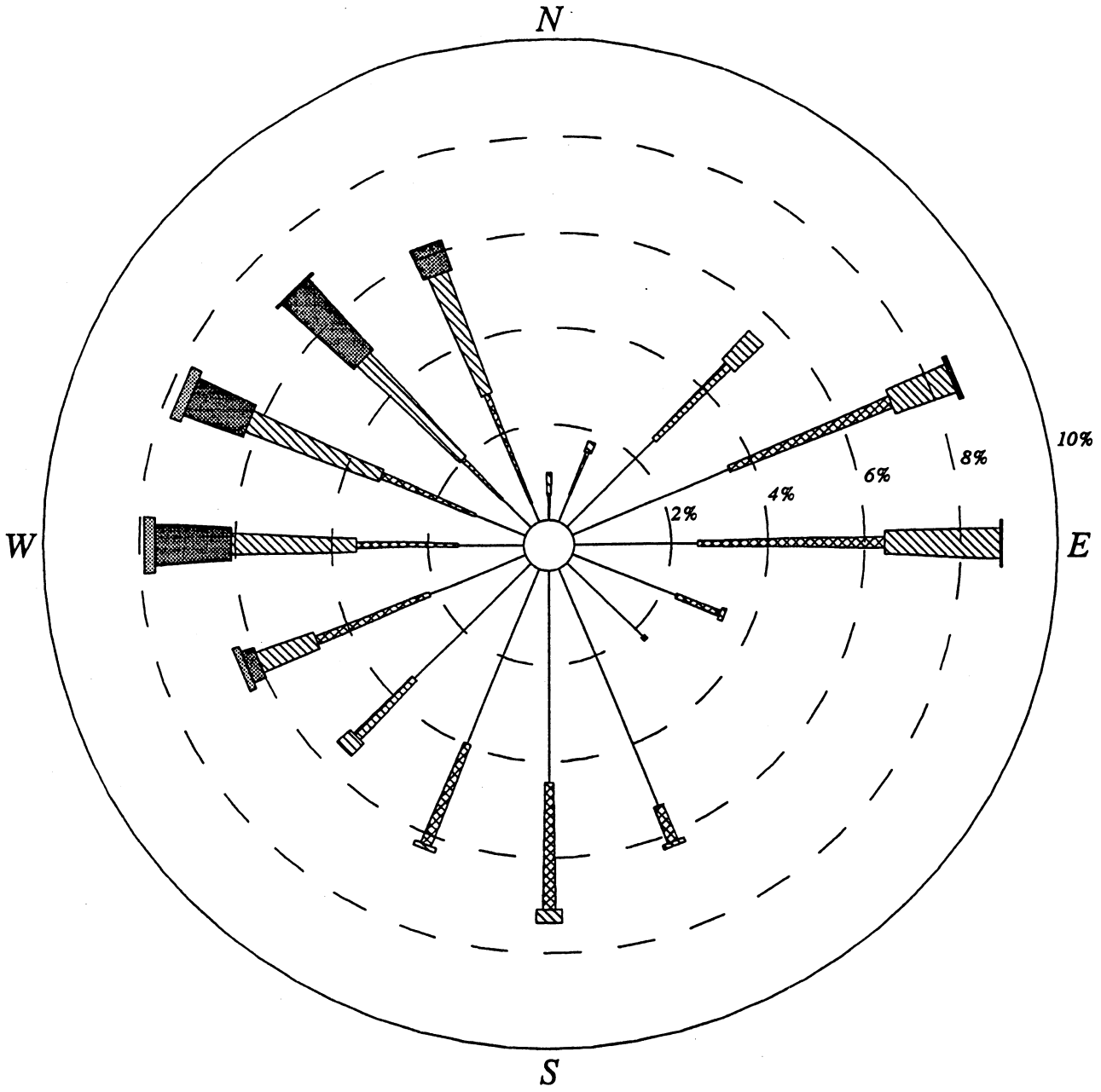
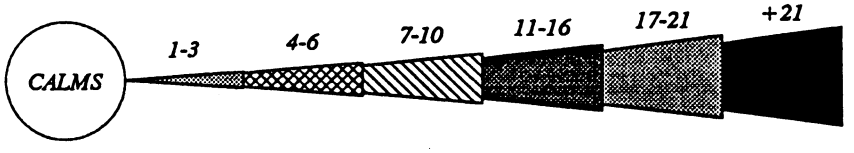


CALM WINDS 7.73%

NOTE: Frequencies indicate direction from which the wind is blowing.

WIND SPEED (KNOTS)



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS	DATE: MAY '96
APPROVED BY:	MADI	DATE: MAY '96
APPROVED BY:	JWS	DATE: MAY '96

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FIGURE 3.4-6
WIND ROSE
APRIL THROUGH JUNE, 1995

Scale:	NOT TO SCALE	Date:	MAY, 1996
Prepared By:	Foth & Van Dyke	By:	JRB

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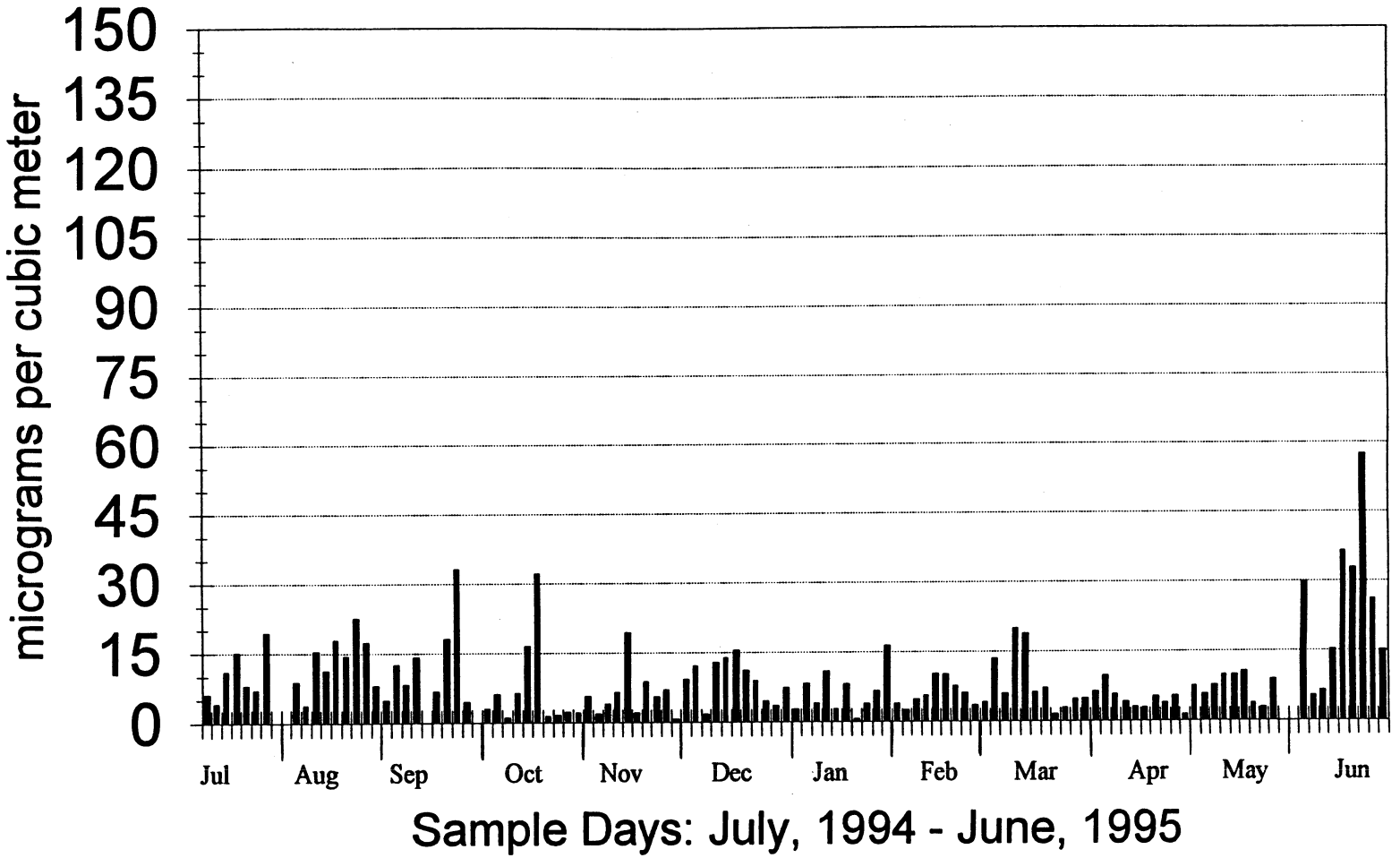
Particulate Matter Less than 10 Micron

Site No. 1, Monitor No. 5



Sample Days: July, 1994 - June, 1995

Note:
Lack of concentration information indicates a lack of data for the sampling day.

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5/96	MADI	UPDATED BAR CHART

CHECKED BY:	JKS	DATE: MAY '95
APPROVED BY:	MADI	DATE: MAY '95
APPROVED BY:	JWS	DATE: MAY '95

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FIGURE 3.4-7

PARTICULATE MATTER LESS THAN 10 MICRON
SITE NO. 1, MONITOR NO. 5

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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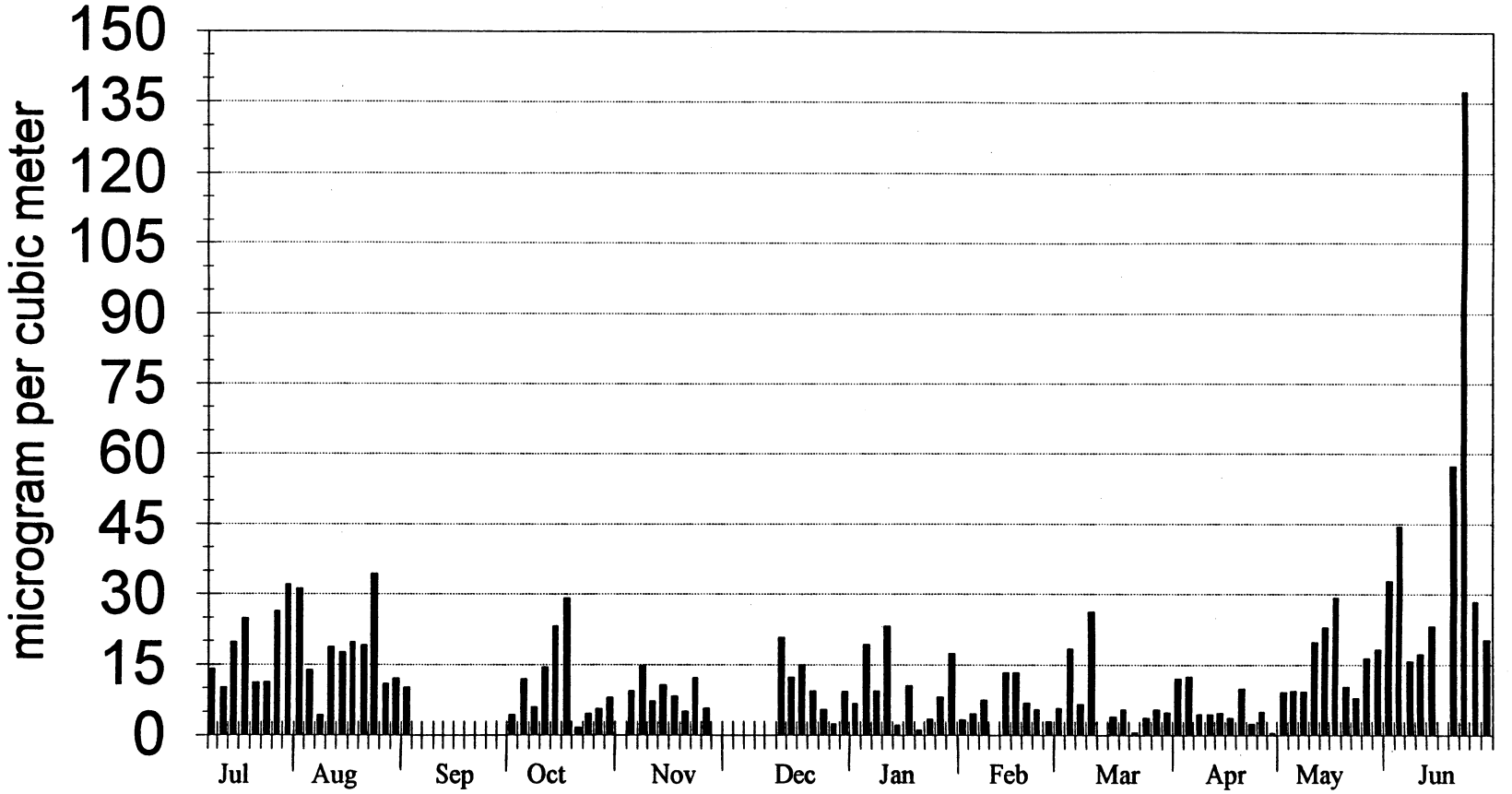
Total Suspended Particulate

Site No. 1, Monitor No. 2



Sample Days: July, 1994 - June, 1995

Note:
Lack of concentration information indicates a lack of data for the sampling day.

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5/96	MADI	UPDATED BAR CHART

CHECKED BY:	JKS	DATE: MAY '95
APPROVED BY:	MADI	DATE: MAY '95
APPROVED BY:	JWS	DATE: MAY '95

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FIGURE 3.4-8
TOTAL SUSPENDED PARTICULATE
SITE NO. 1, MONITOR NO. 2

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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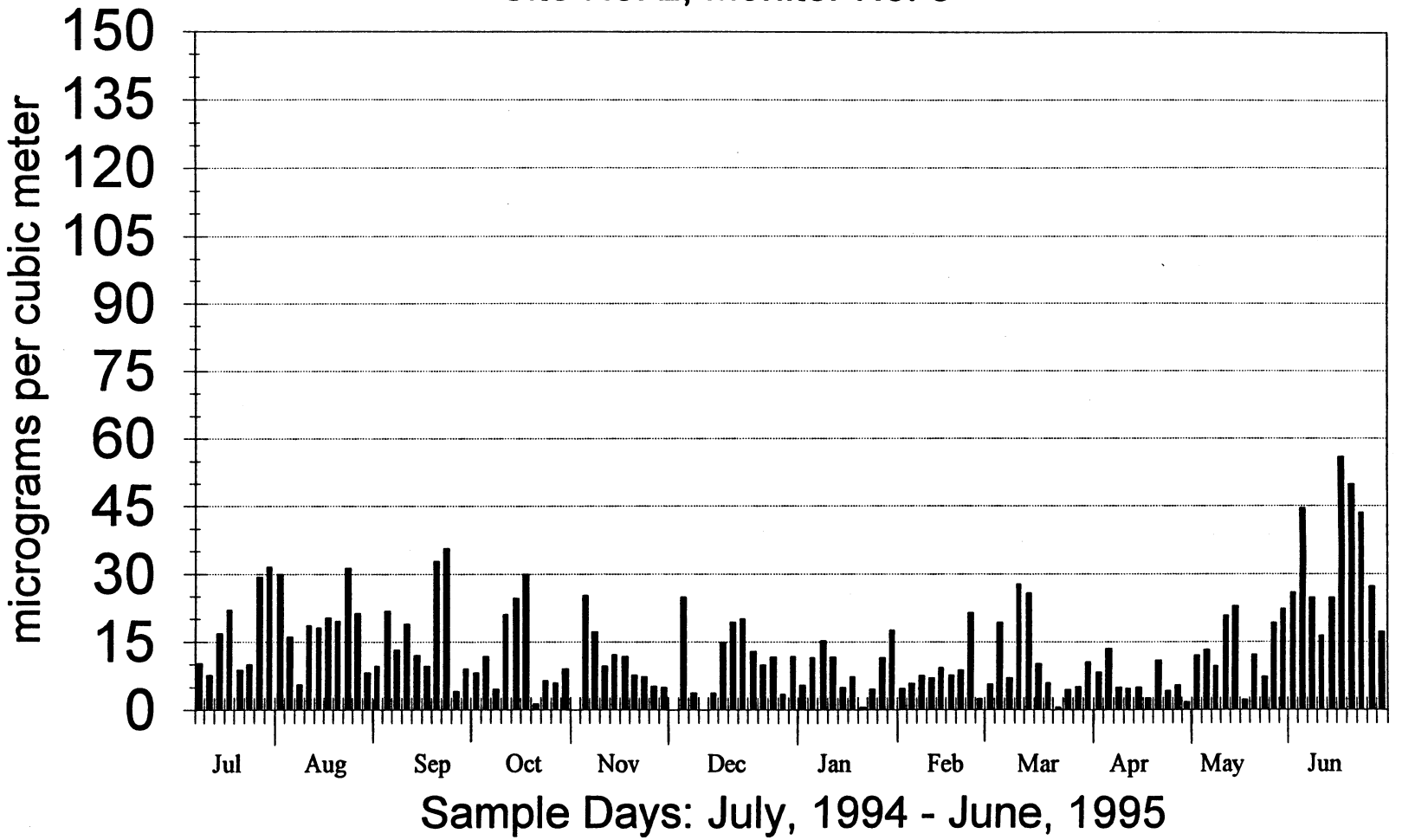
Total Suspended Particulate

Site No. 2, Monitor No. 3



Note:
Lack of concentration information indicates a lack of data for the sampling day.

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REVISED	DATE	BY	DESCRIPTION
1	5/96	MADI	UPDATED BAR CHART

CHECKED BY:	JKS	DATE: MAY '95
APPROVED BY:	MADI	DATE: MAY '95
APPROVED BY:	JWS	DATE: MAY '95

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FIGURE 3.4-9
TOTAL SUSPENDED PARTICULATE
SITE NO. 2, MONITOR NO. 3

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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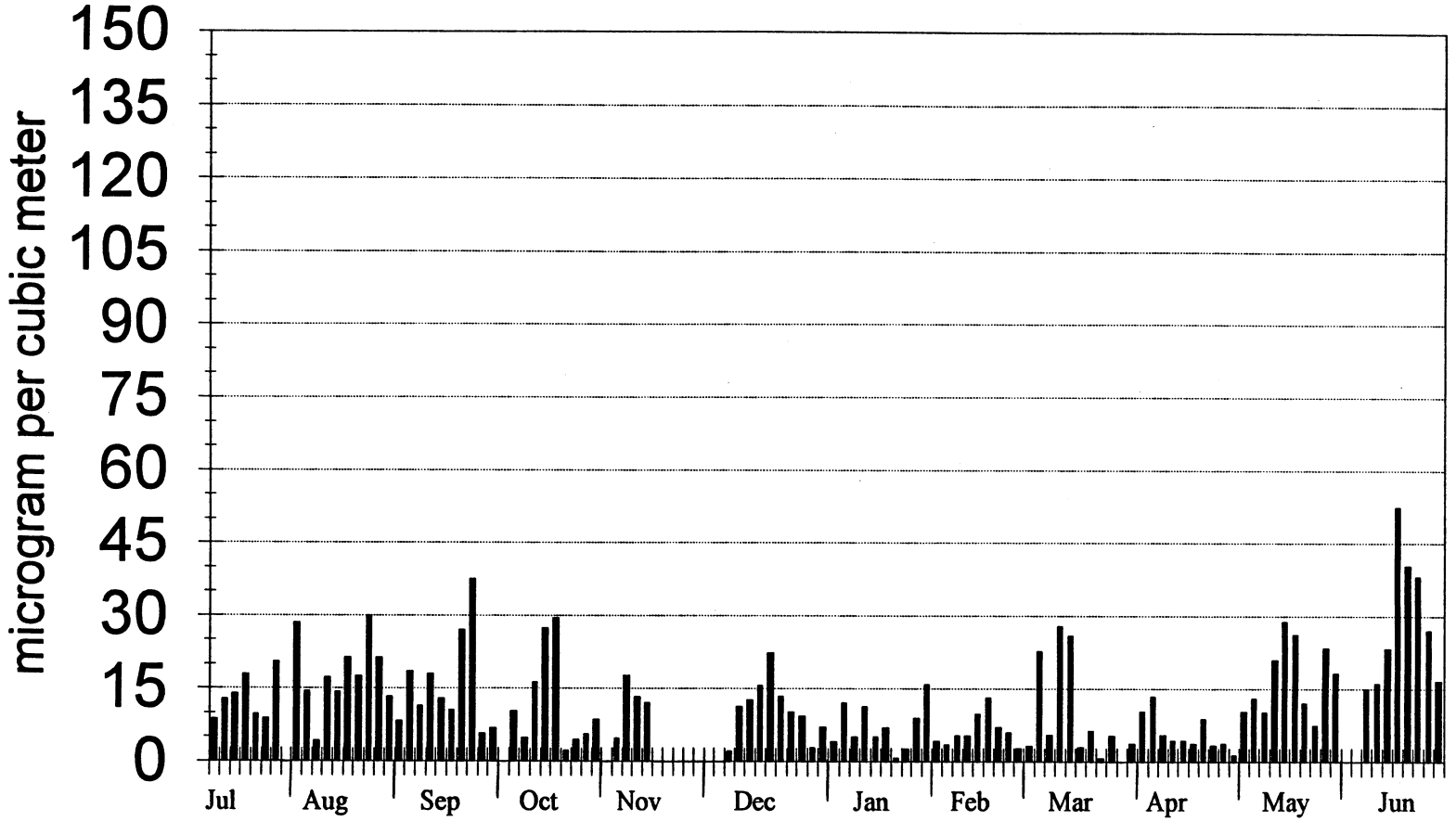
Total Suspended Particulate

Site No. 3, Monitor No. 4



Sample Days: July, 1994 - June, 1995

Note:
Lack of concentration information indicates a lack of data for the sampling day.

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	5/96	MADI	UPDATED BAR CHART
CHECKED BY: JKS			DATE: MAY '95
APPROVED BY: MADI			DATE: MAY '95
APPROVED BY: JWS			DATE: MAY '95

Crandon Mining Company

FIGURE 3.4-10
TOTAL SUSPENDED PARTICULATE
SITE NO. 3, MONITOR NO. 4

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

93C049

Crandon Mining Company

Environmental Impact Report

Section 3.5

Geology and Soils

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3.5 Geology & Soils

The Crandon deposit is situated in Precambrian volcanic and sedimentary rocks of the Rhinelander-Ladysmith greenstone belt that strikes easterly across northern Wisconsin. The deposit is identifiable for a distance of approximately 4,900 feet along strike and to an approximate depth of 2,200 feet. Its thickness varies from less than 10 feet on the western and eastern margins to 250 feet near its center (Schmidt, et al., 1978). In the study region, the Precambrian bedrock is overlain by as much as 300 feet of glacial drift. A saprolite has developed in the upper part of the Precambrian bedrock at the site. Overlaying the saprolite is a series of glacial deposits and landforms. Irregular erosion of this glacial drift results in the rolling topography that characterizes the area.

The geologic study for the Crandon Project was designed to document geologic conditions in the area of the deposit. Specifically, the study had four purposes:

- to document bedrock conditions in the study area;
- to document the stratigraphy of the glacial overburden in the study area;
- to estimate the maximum potential level of earthquake-induced ground motion for the site area; and,
- to characterize the waste materials that will be produced by the project.

Major emphasis was placed on characterizing glacially-derived deposits, that will act as the major source of groundwater inflow into the mine. This was achieved through the use of aerial photographs, field examination of material exposed in road cuts, and the examination of samples collected from test borings drilled in the study area. Laboratory tests were performed on selected samples to aid in the correlation of the various glacial deposits. Tests included analysis of grain size, clay mineral content, pH, moisture content, color, and carbonate pebble content. The methodologies employed in the geologic investigations are described in Section 3.5.1. Allied studies for waste characterization are discussed in Section 3.5.5.

The study area as shown on Figure 3.5-1 encompasses an area roughly bounded to the north by Lake Metonga; to the east by Hemlock Creek, Ground Hemlock, Kimberly, Clark, Walsh and St. Johns Lake; to the south by St. Johns and Rolling Stone Lakes; and the west by Pickerel Creek and Mole Lake. A few borings were completed outside of the study area to provide regional geologic information.

3.5.1 Field and Laboratory Methods - Bedrock and Glacial Overburden Characterization

The geologic studies were designed to characterize geologic conditions of the bedrock and glacial overburden in the study area. Initially, geologic conditions were reviewed based on data available from the U.S. Geological Survey (USGS), topographic maps, glacial deposits exposed at road cuts, and information available from the 1976 Exploratory Drilling Program. Based on this initial review, subsequent detailed field investigations were designed and completed for characterization of geologic conditions in the study area and the location and design of the tailings management area. Sections 3.5.1.2 through 3.5.1.10 contain a description of each

investigation and the methods employed. Section 3.5.1.1 addresses the establishment of the site grid system.

The geologic investigations described in this section, and the groundwater investigations described in Section 3.6 were conducted simultaneously. The reader will therefore notice a degree of overlap between this section and Section 3.6. This section is focused on describing the portions of the geologic and groundwater investigations that consist primarily of soil boring and diamond drilling data which have been used to characterize geologic formations and conditions. Section 3.6 discusses those portions of the geologic and groundwater investigations that have been used to characterize groundwater flow, groundwater surface water interaction, groundwater quality and hydraulic characteristics of specific geologic formations.

3.5.1.1 Site Grid System

A site grid system based on the Wisconsin State Plane Coordinate System (SPCS), North Zone, 1927 adjustment has been established at the site. Mean sea level (MSL) 1929 datum was used to establish site vertical control. In developing the site grid system, coordinates referenced to the Wisconsin SPCS system were established for monuments that were found, or were reestablished to mark the corners of the public land survey system.

Periodically over the years monuments other than those that are part of the public land survey system have been set at the site based on the Wisconsin SPCS. These monuments and their coordinates have been used throughout the project life to determine the positions of core holes, soil borings, monitoring wells, wetlands, etc.

Coordinates and elevations for two monuments and one bench mark near the southern end of the proposed plant site are as follows:

- Monument at SW corner of Section 30, T35N, R13E = 115,876.549N, 2,276,372.499E.
- Monument at South ¼ corner of Section 30, T35N, R13E = 115, 970.459N, 2,279,074.529E.
- Bench marks were established on many of the brass capped monuments including CM-1 @ 116,258.889N, 2,278,177.497E, Elev.= 1643.09 feet MSL.

3.5.1.2 Historical Drilling and Monitoring Well Installation Programs

Crandon Project boring and well installations have been conducted in various stages that date from 1977. The following is a description of the major historical coring and boring programs and the methods employed.

3.5.1.2.1 Ore Body and Bedrock Drilling Programs

Mineral exploration drilling programs were conducted to delineate the ore deposit, to provide samples for metallurgical and rock mechanics testing, to evaluate the site, and to investigate the hydrologic regime of the site. Over 270 bedrock core holes have been drilled in the deposit and proposed TMA vicinity. Core drilling began in 1975 and has continued intermittently through mid-1994.

The ore body was drilled in large part on a 200-foot grid both horizontally and vertically. Closer-spaced drilling has been conducted in a number of areas to provide added data for varied studies. Under the direction of an experienced drill supervisor, the following site-specific techniques were developed to control grid accuracy:

- Three different drill rigs were typically used to complete most holes. Overburden drilling was accomplished using a tophead drive, air rotary rig. An eight-inch hole was mud drilled and cased with six-inch casing. This allowed rapid penetration of the sand and gravel overburden and facilitated a straight hole.

- A second tophead drive, hammer drill was used to advance the hole to the approximate depth of mineralization. A rigid stabilizing system was used to prevent hole drift. By modifying the stabilizing system, rod pressures and direction of rotation, the hole could, in effect, be directionally drilled.

- The remainder of the hole was cored. A combination of stabilizing systems, size and length of core barrels, and varying rod pressures was used to deflect the hole into the plane of the deposit at the desired dip and azimuth. Hammer-and-core drilling progress was monitored by in-hole surveying at 100-foot intervals using a single-shot magnetic camera. Gyroscopic surveying was performed to confirm the applicability of the single-shot method.

Figure 3.5-2 shows the location of core hole collars in the vicinity of the ore body. Figure 3.5-3 shows the horizontal trace of core holes used to delineate the bedrock environment in the vicinity of the ore body. Core hole location and down hole footage data is summarized in Table 3.5-1.

3.5.1.2.2 1977-1979 Investigations

From February 1977 to November 1979, boreholes were drilled in three different phases for geologic characterization of the unconsolidated deposits under programs managed by Dames & Moore (1981). For the first phase, the DMA series of borings, piezometers and groundwater monitoring wells were installed to provide a basic understanding of the geology and groundwater resources within the study area. Information obtained from this phase was then used to select locations for the DMB series of boring and monitoring well installations. The DMB series was installed to gain additional more detailed information on geologic conditions within the study area. The third, or DMC series of borings and wells, were then installed to obtain information on the geologic conditions and groundwater resources along the eastern edge of the study area. Additional borings and wells referenced as the DMI, DMP, DMS, DW, TW-1, TW-2 and WW series, were completed for special studies undertaken to evaluate the feasibility of various mine facility design alternatives. Logs for the Dames & Moore borings are provided in Appendix 3.5-1. No boring logs are available for TW-1, TW-2. The location of the borings and wells are shown on Figures 3.5-4 and 3.5-5. Table 3.5-2 contains a summary of the completion details for each boring.

Table 3.5-1

Summary of Bedrock Exploration Holes and Tests Conducted

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
1	116163	2276609	407.0	X										AB
2	115846	2277821	967.0	X								X		AB
3	116082	2276598	892.0	X						X		X		AB
4	116511	2278169	1060.0	X								X		AB
5	116944	2275380	850.7	X						X		X	X	AB
6	116868	2277783	1316.0	X								X	X	AB
7	117255	2274584	1386.8	X						X		X		AB
8	117202	2274983	1161.0	X						X		X		AB
9	116778	2279000	1262.0	X								X	X	AB
10	116171	2279775	648.0	X								X		AB
11	117139	2276182	1451.0	X						X		X		AB
12	117070	2276982	1407.0	X						X		X		AB
13	117630	2276188	2189.0	X								X	X	AB
14	118080	2276191	3058.0									X		AB
15	117672	2278579	2895.0	X								X	X	AB
16	117772	2277787	3545.0	X						X		X	X	AB
17	117565	2276968	2304.0	X						X		X		AB
18	117236	2275791	1547.0	X						X		X	X	AB
19	117429	2277374	2009.0	X								X		AB
20	116776	2278582	1256.0	X								X	X	AB
21	117296	2278173	2126.0	X									X	AB
22	117008	2277376	1407.0	X								X		AB
23	117261	2278577	1894.0	X						X		X	X	AB
24	117190	2278977	2076.0	X									X	AB
25	117524	2276584	2489.0	X						X				AB
26	116541	2279377	1211.0	X								X		AB
27	117275	2274183	1615.2	X										AB
28	116986	2277582	1785.0	X	X			X		X			X	AB
29	117658	2275787	2244.0	X										AB
30	117690	2275388	2280.0	X										AB
31	117767	2274987	2435.0	X									X	AB
32	117662	2274600	2407.2	X										AB
33	117720	2274190	191.0											AB
34	116983	2279381	661.1	X										AB
35	117667	2276979	2654.0	X						X			X	AB

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
36	117979	2276189	2774.0	X										AB
37	117563	2277786	2824.0	X						X			X	AB
38	117617	2276361	2184.0	X									X	AB
39	117096	2274382	1596.1	X										AB
40	117092	2274182	174.0											AB
41	117514	2277182	2090.0	X										AB
42	117470	2277586	2904.0	X									X	AB
43	118392	2274984	3788.1	X										AB
44	117096	2278182	1554.0	X									X	AB
45	117570	2277373	2397.0	X									X	AB
46	117376	2278983	2774.0	X									X	AB
47	117386	2275379	1774.0	X									X	AB
48	117002	2279381	2214.0	X										AB
49	116798	2279780	1606.0	X									X	AB
50	117154	2279382	950.0	X										AB
51	116875	2280181	1784.0	X										AB
52	117351	2279382	1434.1											AB
53	116577	2274179	1255.0	X										AB
54	117272	2276584	1813.0	X	X			X						AB
55	117219	2280184	2654.0	X										AB
56	117367	2277786	589.0											AB
57	117625	2274980	1975.0	X										AB
58	117489	2274597	1627.0	X										AB
59	116862	2279754	2804.0	X										AB
60	117345	2279571	3575.0	X										AB
61	116878	2276183	1287.1	X										AB
62	116971	2277183	1037.0	X					X					AB
63	116785	2276180	699.0	X										AB
64	117118	2276776	1857.0	X					X				X	AB
65	117263	2275793	1946.0	X					X					AB
66	117010	2275778	1078.0	X				X		X	R			AB
67	116974	2276779	1278.0	X										AB
68	117200	2276777	2624.0	X									X	AB
69	117376	2277787	1940.0	X					X				X	AB
70	116895	2277584	1334.0	X				X		X	R			AB
71	116886	2275382	664.0	X									X	AB
72	116881	2275781	794.0	X										AB

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
73	117009	2278585	2265.0	X									X	AB
74	116893	2278181	1334.0	X									X	AB
75	117008	2274973	856.0	X					X					AB
76	116727	2276580	730.0	X									X	AB
77	117060	2274783	1049.0	X				X		X	R			AB
78	117080	2275179	1164.0	X					X					AB
79	116723	2276982	801.0	X										AB
80	116617	2277375	703.0	X										AB
81	116407	2278578	597.0	X									X	AB
82	116923	2274387	1034.0	X										AB
83	116553	2279378	1794.0	X										AB
84	116601	2279182	944.0	X									X	AB
85	116988	2277985	1319.0	X									X	AB
86	116251	2278976	782.0	X					X					AB
87	116389	2277777	516.0	X										AB
88	116882	2275979	1454.0	X										AB
89	116778	2276379	1424.0	X										AB
90	116890	2274581	786.0	X										AB
91	116827	2278780	1425.0	X				X		X	R		X	AB
92	116758	2278784	1165.0	X									X	AB
93	117296	2274984	1714.0	X										AB
94	116861	2278380	1335.0	X										AB
95	116247	2279176	1073.0	X					X				X	AB
96	117276	2275564	1311.0	X										AB
97	117086	2275383	364.0											AB
98	117240	2278186	1714.0	X									X	AB
99	116749	2274398	857.0	X										AB
100	117577	2275578	1874.0	X										AB
101	116478	2276177	475.0	X										AB
102	116528	2276178	533.0	X										AB
103	116425	2276177	406.0	X										AB
104	116375	2276177	409.0	X										AB
105	116685	2275380	520.0	X										AB
106	116584	2275378	396.0	X										AB
107	116634	2275379	490.0	X										AB
108	116535	2275377	334.0	X										AB
109	116384	2276576	423.0	X										AB

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
110	116335	2276576	355.0	X										AB
111	116437	2276575	535.0	X										AB
112	116531	2275777	444.0	X										AB
113	116581	2275777	577.0	X										AB
114	116482	2275776	426.0	X										AB
115	116485	2275377	305.0	X										AB
116	116486	2276576	520.0	X										AB
117	116372	2276977	410.0	X										AB
118	116165	2277776	300.0	X										AB
119	116109	2278575	325.0	X										AB
120	116051	2278974	251.0	X										AB
121	116423	2276978	400.0	X										AB
122	117702	2276187	3174.0	X						X			X	AB
123	116914	2279380	1974.0	X						X				AB
124	117167	2277783	2254.0	X						X				AB
125	117121	2277184	1534.0	X										AB
126	117378	2275985	1734.0	X										AB
127	117024	2276581	1884.0	X										AB
128	117414	2277185	2664.0	X									X	AB
129	117097	2275383	1454.0	X										AB
130	117006	2279627	2334.0											AB
131	116885	2278981	3053.0	X						X			X	AB
132	116886	2278380	1684.0	X									X	AB
133	116888	2277984	2794.0	X									X	AB
134	119144	2273092	900.0	X										AB
135	124576	2272372	1006.0	X										AB
136	116664	2270060	2000.0	X										AB
137	117127	2276777	3435.0	X									X	AB
138	117065	2277987	2399.0	X									X	AB
139	117374	2276584	3531.0	X									X	AB
140	117709	2278590	3455.0	X									X	AB
141	117414	2277185	1304.0											AB
142	117289	2277990	839.0	X										AB
143	116725	2278996	1899.0	X			X							AB
144	117311	2278382	796.0										X	AB
145	117270	2275199	2105.0	X						X				AB
146	117223	2275983	2425.0	X										AB

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
147	118109	2278189	1164.0	X										AB
148	119100	2278904	338.0											AB
149	117045	2278378	2405.0	X						X			X	AB
150	117160	2277587	2148.0	X									X	AB
151	117568	2277775	3871.0	X			X							AB
152	117058	2279197	2263.1	X						X				AB
153	117057	2279213	2766.0	X										AB
154	117004	2278782	2175.0	X									X	AB
155	117094	2278198	2997.9		X		X		X		R			OP
156	119105	2278598	1370.0											AB
157	119110	2278200	1284.0											AB
158	119094	2278899	1200.0	X										AB
159	117227	2276382	2595.0	X						X			X	AB
160	117355	2277990	3074.0	X			X			X			X	AB
161	117673	2275793	2700.0	X									X	AB
162	117280	2275577	2205.0	X										AB
163	117375	2278970	3815.0	X									X	AB
164	119122	2276477	1304.0										X	AB
165	117384	2277777	2971.0	X					X		R		X	AB
166	117368	2279882	2785.0											AB
167	117356	2279898	1060.0											AB
168	118495	2276622	1180.0	X										AB
169	116792	2277983	1154.0	X			X			X				AB
170	117047	2278372	1865.0	X			X							AB
171	116535	2278729	818.0	X	X									AB
172	117249	2278583	1731.0										X	AB
173	117063	2277797	2044.0	X	X		X							AB
174	116723	2278991	1334.0	X	X		X	X						AB
175	116702	2278389	895.0	X			X							AB
176	116877	2278371	1368.0	X	X		X	X		X			X	AB
177	116784	2277584	1004.0	X			X							AB
178	117066	2275166	738.0	X			X							AB
179	117272	2275195	1364.0	X	X	X	X	X						AB
180	117055	2274775	801.0	X			X							AB
181	117603	2276355	3405.0	X	X		X		X				X	AB
182	117378	2275976	3174.0	X			X							AB
183	117153	2274781	1233.9	X	X		X	X						AB

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
184	116945	2274380	864.0	X	X		X	X						AB
185	117242	2275783	1735.0	X	X		X							AB
186	117280	2275577	1889.0	X										AB
187	117352	2276578	480.0											AB
188	116877	2275972	1012.0	X	X	X	X	X		X				AB
189	116924	2276414	968.0	X	X		X	X						AB
190	117517	2277177	2244.0	X			X							AB
191	117076	2275584	946.0	X	X		X	X						AB
192	117384	2277777	3219.0	X	X		X		X					AB
193	116928	2276764	953.0	X	X		X							AB
194	116984	2277384	1584.0	X			X						X	AB
195	116342	2278974	452.0		X		X							OP
196	116744	2274372	550.0		X		X							OP
197	117114	2276770	1586.0	X	X		X							AB
198	117432	2276585	2154.0	X			X			X			X	AB
199	113412	2286407	1951.0											AB
200	112753	2283365	1991.0											AB
201	115395	2270438	2034.0											AB
202	114083	2270000	380.0											AB
203	110489	2287173	2005.0											AB
204	112717	2286264	2055.0											AB
205	111575	2286710	2004.0											AB
206	113751	2285904	1991.0											AB
207	113742	2290048	281.5											AB
208	114125	2270008	1984.0											AB
209	116815	2278236	1068.0		X		X			X				OP
210	116621	2278907	911.5							X				OP
211	116837	2276377	980.5						X	X	A			OP
212	116880	2276240	704.0				X			X				AB
213	116472	2278542	879.5						X	X	A			OP
214	116808	2278244	1255.0								A			OP
216	116610	2277558	1169.0											OP
217	116430	2278611	834.0											OP
218	117044	2276076	1201.0		X		X							OP
219	116788	2276378	657.0											OP
220	116723	2276316	550.0											OP
221	116522	2278378	700.0											OP

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
222	116476	2278432	674.0											OP
223	116378	2278529	544.0											OP
224	116392	2278676	461.0											OP
225	116800	2276112	224.0											AB
226	116704	2277618	795.0											OP
227	116615	2277686	630.0											OP
228	116679	2277450	755.0											OP
229	116544	2277559	499.0											OP
230	116746	2276432	664.0											OP
231	116749	2276193	487.0											OP
232	116554	2278092	743.0											OP
233	117129	2276335	1282.2	X	X		X	X				X		OP
234	117382	2276595	1752.0	X	X		X	X				X		OP
235	117241	2278195	1478.0	X	X			X				X		OP
236	117142	2276484	1342.0	X			X					X		OP
237	117241	2276604	1607.0	X	X		X	X				X		OP
238	117310	2276379	1682.0	X	X		X	X				X		OP
239	117139	2276454	1455.0	X		X	X	X				X		OP
240	116877	2277749	1152.0	X	X	X	X	X				X		OP
241	117014	2278124	1214.0	X								X		OP
242	116788	2278164	1024.0	X								X	X	OP
243	117415	2275868	1775.0	X	X		X	X				X		OP
244	117146	2276515	1323.0	X	X		X	X				X		OP
245	117213	2277027	1800.0	X	X		X	X				X		OP
246	117159	2277296	1797.0	X	X		X	X				X		OP
247	117154	2277693	1259.0	X		X	X	X				X		OP
248	116981	2278478	1263.0	X	X		X	X				X		OP
249	117070	2278479	1523.0	X	X		X	X				X		OP
250	116781	2279020	1341.0	X	X		X	X				X		OP
251	116908	2278780	1405.0	X			X	X				X		OP
252	117412	2277874	1520.0	X	X	X	X	X				X		OP
253	116695	2275380	375.0								F			OP
254	116435	2276177	435.0								F			OP
255	116581	2277375	423.2								F			OP
256	116624	2275375	394.0								F			OP
257	115660	2276140	396.0											OP
258	116289	2278567	1544.0											OP

Table 3.5-1 *(Continued)*

Hole No	C North	C East	Total Footage	Tests Conducted										Status
				ASY	UCT	TCT	PLT	BT	CA	RT	PT	SG	WC	
259	116742	2277743	1437.0											OP
260	116390	2277534	885.0											OP
261	116220	2278570	887.0											OP
262	116647	2277375	946.0	X								X		AB
263	116565	2278729	1169.0	X								X		AB
264	117033	2277797	1565.0	X										AB
265	117565	2276988	2156.0	X								X		AB
266	116312	2278974	963.0	X								X		AB
267	117327	2276800	1844.0	X								X		AB
268	117184	2277693	1566.0	X								X		AB
269	116923	2278181	1341.0	X								X	X	AB
270	117524	2276564	2446.0	X								X	X	OP
271	117524	2276784	2536.0	X									X	AB
272	117702	2276584	2574.0	X										AB

Bedrock Tests Legend:

ASY	Assay
UCT	Uniaxial Compressive Tests
TCT	Triaxial Compressive Tests
PLT	Point Load Tests
BT	Brazilian Tests
CA	Chemical Analysis
RT	Radiological Tests
PT	Permeability Tests
SG	Specific Gravity
WC	Waste Characterization

Permeability Tests (PT) Legend:

F	Falling Head
R	Rising Head
A	Pump Test

Status Legend:

AB	Abandoned
OP	Open and Welded Shut

Source: Crandon Mining Company

Table 3.5-2

Environmental Boring Construction Data Summary

TAB352.WB2

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
AR-1	1/8/81	122219.204	2276458.105	NR	30.4	NO
AR-1A	2/9-10/81	122226.743	2276468.145	NR	42.8	NO
AR-2	1/9/81	122141.530	2276489.023	NR	21.5	NO
AR-2A	2/6/81	122137.003	2276497.697	NR	31.5	NO
AR-3	1/5/81	NR	NR	NR	30.5	NO
AR-4	1/5-6/81	NR	NR	NR	30.4	NO
BE-211-1	3/3/81	116533.635	2276308.686	1647.53	200.5	YES
BE-211-2L	2/19/81	116451.725	2276560.523	1660.92	188.5	YES
BE-211-2U	2/19/81	116451.725	2276560.523	1660.92	188.5	YES
BE-211-3L	3/19/81	116476.081	2276300.595	1647.89	220.5	YES
BE-211-3U	3/19/81	116476.081	2276300.595	1647.89	220.5	YES
BE-213-1	2/13/81	116025.402	2278436.725	1618.92	92.5	YES
BE-213-2	2/17/81	116063.997	2278664.481	1616.09	95	YES
BE-213-3L	3/24/81	116112.337	2278467.363	1623.74	115	YES
BE-213-3U	3/24/81	116112.337	2278467.363	1623.74	115	YES
BE-216-1	3/10/81	116252.761	2277530.922	1657.45	151.5	YES
BE-216-2	3/18/81	116327.310	2277744.023	1655.18	140.5	YES
BE-216-3L	4/14/81	116338.082	2277555.071	1661.98	178.5	YES
BE-216-3U	4/14/81	116338.082	2277555.071	1661.98	178.5	YES
CDM-1	12/81	116262.640	2274808.450	1657.76	180	NO
CDM-2	12/4/81	116553.280	2274955.100	1661.54	180	NO
CDM-3	11/30/81	116190.920	2275349.520	1639.36	200	NO
CDM-4	11/30/81	116533.290	2275382.320	1641.39	~195	YES
CDM-5	11/30/81	116295.400	2275803.430	1640.01	~220	NO
CDM-6	12/4/81	116510.450	2275773.760	1638.47	~225	NO
CDM-7	12/3/81	116887.540	2275778.210	1648.65	~200	NO
CDM-8	12/2/81	116096.800	2276342.470	1656.93	~225	NO
CDM-9	12/3/81	115984.440	2276977.670	1676.90	~220	NO
CDM-10	11/30/81	116367.270	2276978.190	1683.81	~230	NO
CDM-11	12/1/81	116713.820	2276976.800	1678.67	~190	NO
CDM-12	12/3/81	115627.680	2278064.000	1608.67	~145	NO
CDM-13	12/3/81	116241.850	2277991.320	1648.65	~130	NO
CDM-14	12/2/81	116038.900	2278989.830	1608.42	~105	NO
CDM-15	12/81	119587.670	2276543.210	1645.76	180	YES
CDM-16	12/81	114360.100	2277074.010	1595.56	180	YES
CMC-01	3/31/94	116166.600	2282677.100	1650.20	92.5	YES
CMC-01P	3/25/94	116168.300	2282682.700	1650.15	202	YES
CMC-01R	5/3/94	116156.500	2282675.100	1650.15	68	YES
CMC-02	3/28/94	115308.700	2286070.100	1697.90	95	YES
CMC-02P	3/22/94	115306.800	2286077.300	1697.90	191.1	YES
CMC-02R	9/8/94	115299.210	2286062.480	1697.66	120	YES
CMC-03	3/24/94	113563.600	2286751.700	1705.20	86	YES
CMC-03P	3/22/94	113560.100	2286745.300	1705.20	201	YES
CMC-03R	4/4/94	113563.600	2286751.700	1705.20	98	YES
CMC-03RR	4/27/94	113563.600	2286751.700	1705.20	128	YES
CMC-04	3/10/94	111448.500	2285112.200	1683.90	113	YES
CMC-05	3/10/94	111541.200	2283490.000	1656.90	79	YES
CMC-06P	3/10/94	112380.300	2283011.500	1666.50	152	YES
CMC-07	3/28/94	114389.200	2282896.000	1626.90	51	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
CMC-08	3/1/94	117115.900	2278213.600	1662.50	75	YES
CMC-08P	4/18/94	117107.100	2278200.200	1662.50	113.5	YES
CMC-09	3/30/94	116258.800	2274907.300	1653.50	90	YES
CMC-09P	4/15/94	116258.800	2274914.700	1653.30	168.5	YES
CMC-10	3/30/94	116056.600	2278575.400	1621.10	50	YES
CMC-10P	3/3/94	116046.900	2278514.200	1620.80	101.5	YES
CMC-10PP	10/18/94	116050.240	2278600.210	1619.70	110	YES
CMC-11P	10/15/94	116228.680	2275939.770	1643.50	215	YES
CMC-12P	10/13/94	116478.660	2276322.760	1648.00	205	YES
CMC-13P	10/3/94	116352.220	2276978.090	1684.40	236	YES
CMC-14P	10/7/94	115996.510	2278987.850	1608.90	110	YES
CMC-B0-101A	2/7/94	117361.700	2283366.800	1637.30	16	YES
CMC-BO-101B	2/1/94	117357.700	2283369.500	1637.30	41.5	YES
CMC-B0-102	1/31-2/7/94	117942.100	2283283.500	1636.30	40	NO
CMC-DL-103A	2/11/94	113334.650	2281957.000	1613.60	9	YES
CMC-DL-103B	2/11/94	113333.300	2281954.300	1613.60	36.5	YES
CMC-DL-103C	2/8-9/94	113207.700	2281788.400	1611.85	28	NO
CMC-LSL-101	2/11/94	113246.700	2278416.000	1592.10	31	NO
CMC-LSL-102	2/16/94	114872.500	2278461.800	1592.10	17	NO
CMC-LSL-102	2/15/94	114399.100	2278953.700	1592.10	18.5	YES
CMC-LSL-102	2/14/94	114284.900	2279010.600	1592.10	34	YES
CMC-LSL-103	2/12/94	113851.100	2276753.900	1592.10	48	NO
CMC-LSL-104	2/13/94	112076.200	2275945.000	1592.10	18	YES
CMC-LSL-104	2/13/94	112072.700	2275937.400	1592.10	28	YES
CMC-LSL-105	2/15/94	110284.700	2276504.730	1592.10	20	NO
CMC-O2-SE	7/29-31/96	114671.000	2286626.000	1705.00	115	YES**
CMC-O2-NW	8/1-2/96	116354.000	2284724.000	1709.00	104	YES**
CMC-OWA-1R	10/17/94	116229.250	227761.240	1657.60	205	YES
CMC-OWA-1	10/11/94	116229.000	227761.000	1657.60	32	NO
CMC-OWA-2	10/20/94	116283.020	2277645.760	1658.70	191	YES
CMC-OWA-3	10/18/94	116218.570	2277666.070	1657.80	131	YES
CMC-OWA-4	10/11/94	116367.710	2277607.170	1661.20	126	YES
CMC-OWA-5	10/15/94	115990.280	2277837.120	1648.60	132	YES
CMC-PWA	9/25/94	116169.000	2277699.690	N/A	~230	YES
CMC-PWAR	10/4/94	116183.060	2277679.090	1656.80	~270	YES
CMC-PWB	10/9/94	116040.800	2278646.220	1616.50	400	YES
CMC-SB-05	3/02/94	111541.200	2283490.000	1656.90	4.5	NO
CMC-SB-08A	2/24/94	117115.900	2278213.600	1662.50	15	NO
CMC-SB-08B	2/24/94	117115.900	2278213.600	1662.50	35	NO
CMC-SB-10P	2/24-26/94	116656.600	2278575.400	1621.10	42	NO
CMC-SC-101	2/10/94	121709.700	2274141.300	1540.50	27	NO
CMC-SC-102	2/10/94	121956.500	2274409.300	1540.40	12	NO
CMC-SCC-101	1/31-2/7/94	120369.900	2281221.200	1582.90	24	NO
CMC-SCC-102	2/07/94	120038.800	2280679.900	1583.70	11	YES
CMC-SCC-102	1/31-2/7/94	120042.700	2280678.300	1583.70	22.5	YES
CMC-SL-103A	2/7-8/94	117856.600	2281146.900	1599.20	30	YES
CMC-SL-103B	2/8/94	117848.700	2281133.900	1599.20	50	NO
CMC-SL-103C	2/9/94	117848.700	2281133.900	1599.20	50	YES
CMC-SL-104	2/8/94	117613.200	2280834.500	1598.50	36	NO
CMC-TMA-101	2/6/96	116701.380	2283073.560	1643.64	175	NO
CMC-TMA-102	1/23-2/5/96	118180.570	2283980.350	1646.61	260	NO
CMC-TMA-103	2/9/96	117253.210	2286081.080	1706.99	260	NO
CMC-TMA-104	2/8/96	116551.790	2286501.980	1719.83	278	NO
CMC-TMA-105	1/23-2/9/96	112723.050	2286269.230	1704.01	312	NO
CMC-TMA-106	2/6/96	116662.990	2283777.340	1697.22	140	NO

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
CMC-TMA-107	2/7/96	114674.040	2286757.540	1712.04	302	NO
CMC-TMA-108	2/5/96	114054.810	2283584.730	1660.08	60	NO
CMC-TMA-109	2/10/96	115523.320	2283474.350	1676.41	122	NO
CMC-TMA-110	2/7/96	114154.220	2285066.570	1691.23	122	NO
DMA-1	3/14/77	113660.000	2272030.000	1637.96	55	YES
DMA-3	3/11/77	115494.403	2273938.327	1647.51	45	YES
DMA-4	3/23/77	111424.715	2280846.947	1612.03	30	YES
DMA-5	3/24/77	115380.000	2282390.000	1639.82	50	NO
DMA-6	3/25/77	115450.000	2285290.000	1716.95	30	NO
DMA-7	5/13/77	112880.000	2289900.000	1583.81	44.5	NO
DMA-10	3/15/77	110510.000	2275400.000	1593.58	46	YES
DMA-12	3/24/77	117887.267	2279966.309	1621.18	45	YES
DMA-13	5/14/77	110450.000	2265800.000	1554.66	40.5	YES
DMA-14	3/16/77	128420.000	2276320.000	1601.88	35	NO
DMA-16	3/17/77	123792.874	2271254.081	1589.93	60.3	YES
DMA-17	4/6/77	106565.370	2275547.040	1563.95	36	YES
DMA-18	4/6/77	111757.520	2269883.645	1619.36	70.5	YES
DMA-19	3/21/77	115003.778	2279719.951	1597.24	30	YES
DMA-1N	5/77	113664.490	2272028.860	1637.96	55	YES
DMA-1S	5/77	113661.403	2272029.866	1637.96	55	YES
DMA-20	3/28/77	119200.231	2272622.047	1591.97	54	YES
DMA-22	4/19/77	113800.000	2297350.000	1628.63	35.5	NO
DMA-22B	11/8/79	113800.000	2297350.000	1629.19	100.4	YES
DMA-27	5/11/77	105150.000	2254020.000	1540.05	85.5	NO
DMA-27A	5/4/77	104430.000	2254790.000	1547.11	39.2	NO
DMA-29	3/26/77	101230.000	2251380.000	1537.11	40	YES
DMA-29AL	5/12/77	101250.000	2251380.000	1536.69	53	YES
DMA-29AU	5/12/77	101250.000	2251380.000	1539.69	53	YES
DMA-30	4/16/77	122680.000	2281010.000	1577.58	45.5	NO
DMA-31	4/18/77	120160.000	2281570.000	1592.09	25	YES
DMA-32	4/26/77	112050.000	2290580.000	1592.14	9.5	NO
DMA-32A	4/28/77	112050.000	2290580.000	1592.14	175	YES
DMA-33	4/8/77	109525.000	2251770.000	1537.93	90	NO
DMA-34	4/15/77	114000.000	2248050.000	1535.92	30.5	YES
DMA-35	5/14/77	111180.000	2245820.000	1570.39	29.5	YES
DMA-36	3/30/77	129500.000	2250180.000	1675.46	29	NO
DMA-37	4/7/77	125340.000	2247430.000	1684.09	39	NO
DMA-38	5/3/77	141150.000	2249880.000	1772.00	30	YES
DMA-39	5/3/77	143560.000	2250980.000	1772.31	30	NO
DMA-42	3/29/77	133040.000	2271020.000	1615.85	26	NO
DMA-43	3/25/77	137000.000	2272720.000	1624.70	40	YES
DMA-44	3/25/77	88280.000	2259180.000	1590.84	31	NO
DMA-45	5/1/77	100630.000	2310200.000	1640.61	49.2	YES
DMA-46	5/02/77	117420.000	2319400.000	1714.52	72.5	YES
DMA-47	3/30/77	121392.614	2276057.949	1573.62	31	YES
DMA-48	3/26/77	118981.495	2268708.522	1547.42	29.5	YES
DMB-1	5/11/78	114405.000	2282890.000	1627.30	59.3	YES
DMB-1A	5/16/78	114405.000	2282900.000	1627.94	79.4	YES
DMB-2	5/17/78	114995.000	2285800.000	1706.28	100.3	YES
DMB-3	5/18/78	116895.000	2287465.000	1687.93	61.5	YES
DMB-4	5/22-23/78	118405.000	2283785.000	1644.49	80.3	YES
DMB-5	5/24/78	112135.000	2285540.000	1688.77	98.5	YES
DMB-5A	12/4/78	112130.000	2285545.000	1689.33	120.2	YES
DMB-6	5/26/78	112385.000	2283015.000	1666.47	86	YES
DMB-7	6/6/78	106150.000	2287845.000	1653.67	79.2	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
DMB-8	6/7/78	114595.000	2287840.000	1622.74	50.7	YES
DMB-9	6/5/78	110555.000	2287235.000	1661.61	242	NO
DMB-9A	6/24-26/78	110555.000	2287235.000	1661.61	260.5	YES
DMB-9B	6/24-26/78	110555.000	2287325.000	1661.61	260.5	YES
DMB-9C	6/24-26/78	110555.000	2287235.000	1661.61	260.5	YES
DMB-10	6/23/78	117720.000	2271170.000	1619.11	99.5	YES
DMB-11	6/27/78	109960.000	2273820.000	1656.85	100	YES
DMB-12	6/27/78	107390.000	2275205.000	1586.05	81.9	YES
DMB-13	6/29/78	107110.000	2269980.000	1609.39	60	YES
DMB-14	6/29/78	110075.000	2270985.000	1638.69	100.9	YES
DMB-15	6/7/78	113660.000	2272025.000	1637.52	79.5	YES
DMB-16	6/9/78	111880.000	2273475.000	1674.63	99.2	YES
DMB-17	6/9/78	108960.000	2268755.000	1648.95	80.5	YES
DMB-18	6/10/78	110560.000	2268060.000	1601.40	80.9	YES
DMB-19	6/21/78	110450.000	2265815.000	1554.64	160.7	YES
DMB-20	6/10/78	115725.000	2270530.000	1605.80	40	YES
DMB-20A	11/27-28/78	115720.000	2270545.000	1606.20	84.8	YES
DMB-21	6/12/78	112820.000	2265775.000	1559.32	49.5	YES
DMB-22	6/13/78	113240.000	2269090.000	1616.48	79	YES
DMB-23	6/21/78	115900.000	2268205.000	1563.30	99.2	YES
DMB-24	12/18/78	102060.000	2271375.000	1565.43	49	YES
DMB-25	12/15-18/78	105725.000	2268525.000	1644.66	129.5	YES
DMB-26	12/12-13/78	105520.000	2282250.000	1712.98	134.1	YES
DMB-27	12/6/78	108675.000	2283695.000	1649.04	83.9	YES
DMB-28	12/5/78	106840.000	2285425.000	1642.13	70	YES
DMB-29	11/29/78	104385.000	2288110.000	1629.98	69.3	YES
DMC-1	11/13/79	115120.000	2292330.000	1614.34	47.5	YES
DMC-2	11/12/79	126510.000	2288740.000	1588.60	51.5	YES
DMC-3	11/19/79	106940.000	2291715.000	1610.02	46.5	YES
DMI-1	6/14/77	116746.693	2278815.316	1636.74	109	YES
DMI-2L	6/21/77	116608.916	2278750.054	1629.43	139	YES
DMI-2U	6/21/77	116608.916	2278750.054	1629.43	139	YES
DMI-3	5/24/77	116504.436	2278692.158	1626.34	105	NO
DMI-4	6/8/77	116374.694	2278621.737	1637.06	200.5	NO
DMI-5	6/27/77	116392.018	2278473.556	1641.24	87	NO
DMI-7	5/29/77	116412.929	2278275.264	1647.69	252.8	NO
DMI-8	6/12/77	116430.248	2278125.170	1647.29	264	NO
DMI-9	6/24/77	116908.854	2278902.931	1633.82	104	NO
DMP-1	10/30/79	116675.000	2278480.000	1647.62	70.7	YES
DMP-2	10/31/79	115135.000	2278685.000	1595.58	36.5	YES
DMP-3	11/2/79	113665.000	2275625.000	1623.55	65.6	YES
DMS-1	9/16/77	117104.143	2278219.913	1661.65	128	YES
DMS-2	9/27/77	117926.677	2277889.698	1641.19	184	YES
DW-1A	3/77	116334.871	2276266.441	1648.49	71	YES
DW-1L	3/77	116320.893	2276261.008	1648.32	215	YES
DW-1U	3/77	116320.893	2276261.008	1648.42	215	YES
DW-2L	3/77	116776.783	2279794.404	1600.74	95	YES
DW-2U	3/77	116776.783	2279794.404	1600.74	95	YES
DW-3L	3/77	116254.648	2274840.101	1657.07	169	YES
DW-3U	3/77	116254.648	2274840.101	1657.07	169	YES
EX-1AL	2/29-3/1/84	104151.000	2273714.000	1555.48	132.8	YES
EX-1AU	2/29-3/1/84	104151.000	2273714.000	1555.48	132.8	YES
EX-1BL	3/1/84	104144.000	2273710.000	1555.16	47	YES
EX-1BU	3/1/84	104144.000	2273710.000	1555.16	47	YES
EX-2AL	3/27/84	110340.000	2262240.000	1592.11	192	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
EX-2AU	3/27/84	110340.000	2262240.000	1592.11	192	YES
EX-2BL	3/27/84	110340.000	2262240.000	1591.99	37	YES
EX-2CL	5/17/84	110340.000	2262240.000	1592.11	47	YES
EX-3AL	3/30/84	110285.000	2263941.000	1559.09	162	YES
EX-3AU	3/30/84	110285.000	2263941.000	1559.09	162	YES
EX-3BL	3/30/84	110287.000	2263932.000	1559.38	75	YES
EX-3BU	3/30/84	110287.000	2263932.000	1559.38	75	YES
EX-3CL	3/31/84	110280.000	2263921.000	1560.09	12	YES
EX-4AL	2/6-8/84	119912.000	2274288.000	1573.87	119	YES
EX-4AU	2/6-8/84	119912.000	2274288.000	1573.87	119	YES
EX-4BL	2/6-8/84	119917.000	2274278.000	1573.68	67.95	YES
EX-4BU	2/6/84	119917.000	2274278.000	1573.68	67.95	YES
EX-4CL	2/7/84	119929.000	2274283.000	1573.58	29	YES
EX-5AL	2/7-8/84	119857.000	2276790.000	1632.50	189	YES
EX-5AU	2/7-8/84	119857.000	2276790.000	1632.50	189	YES
EX-5BL	2/15-16/84	119858.000	2276781.000	1632.54	112	YES
EX-5BU	2/15-16/84	119858.000	2276781.000	1632.54	112	YES
EX-5CL	4/3/84	119851.000	2276781.000	1632.78	75.88	YES
EX-6AL	3/6-7/84	120340.000	2289928.000	1606.94	196	YES
EX-6AU	3/6-7/84	120340.000	2289928.000	1606.94	196	YES
EX-6BL	3/7/84	120341.000	2289919.000	1606.80	87	YES
EX-6BU	3/7/84	120341.000	2289919.000	1606.80	87	YES
EX-7AL	3/8/84	117862.000	2286791.000	1580.35	169	YES
EX-7BL	3/9/84	117856.000	2286783.000	1580.67	112	YES
EX-7BU	3/9/84	117856.000	2286783.000	1580.67	112	YES
EX-7CL	3/8/84	117853.000	2286779.000	1581.15	11.5	YES
EX-8AL	3/14/84	116362.000	2287655.000	1586.46	175	YES
EX-8AU	3/14/84	116362.000	2287655.000	1586.46	175	YES
EX-8BL	3/12/84	116371.000	2287651.000	1586.62	77.74	YES
EX-8BU	3/12/84	116371.000	2287651.000	1586.62	77.74	YES
EX-9AL	3/21/84	116461.000	2284725.000	1708.86	280	YES
EX-9AU	3/21/84	116461.000	2284725.000	1708.86	280	YES
EX-9BL	3/30/84	116472.000	2284729.000	1708.64	193.5	YES
EX-9BU	3/30/84	116472.000	2284729.000	1708.64	193.5	YES
EX-10AL	3/16/84	115111.000	2284239.000	1674.93	256	YES
EX-10AU	3/16/84	115111.000	2284239.000	1674.93	256	YES
EX-10BL	3/16/84	115109.000	2284216.000	1673.62	147	YES
EX-10BU	3/16/84	115109.000	2284216.000	1673.62	147	YES
EX-11AL	3/24/84	113254.000	2283698.000	1682.05	285	YES
EX-11AU	3/24/84	113254.000	2283698.000	1682.05	285	YES
EX-11BL	3/25/84	113260.000	2283714.000	1681.75	174	YES
EX-11BU	3/25/84	113260.000	2283714.000	1681.75	174	YES
EX-11CL	3/27/84	113259.000	2283684.000	1681.98	102	YES
EX-12AL	3/2-7/84	113156.000	2284707.000	1687.76	305	YES
EX-12AU	3/2-7/84	113156.000	2284707.000	1687.76	305	YES
EX-12BL	3/7/84	113163.000	2284692.000	1688.02	186.07	YES
EX-12BU	3/7/84	113163.000	2284692.000	1688.02	186.07	YES
EX-13AL	2/20/84	111555.000	2283499.000	1657.32	235	YES
EX-13BL	2/21-22/84	111541.000	2283510.000	1657.71	193.01	YES
EX-13BU	2/21-22/84	111541.000	2283510.000	1657.71	193.01	YES
EX-13CL	2/27/84	111538.000	2283501.000	1657.56	108	YES
EX-13DL	2/29/84	111534.000	2283508.000	1657.88	75	YES
EX-14AL	2/23/84	110251.000	2286304.000	1682.67	283	YES
EX-14AU	2/23/84	110251.000	2286304.000	1682.67	283	YES
EX-14BL	2/25/84	110257.000	2286282.000	1682.78	167	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
EX-14BU	2/25/84	110257.000	2286282.000	1682.78	167	YES
EX-15AL	2/10-12/84	112443.000	2280005.000	1626.64	235	YES
EX-15AU	2/10-12/84	112443.000	2280005.000	1626.64	235	YES
EX-15BL	2/11/84	112447.000	2280010.000	1626.10	52	YES
EX-16AL	2/13-14/84	113316.000	2282043.000	1614.70	145	YES
EX-16AU	2/13-14/84	113316.000	2282043.000	1614.70	145	YES
EX-16BL	3/1/84	113322.000	2282041.000	1614.62	70.57	YES
FVD-AR-1	4/21/81	125891.152	2270867.568	1601.1	5.58	NO
FVD-AR-2	4/22/81	125916.783	2271553.849	1581.4	5.25	NO
FVD-AR-3	4/22/81	125936.513	2272111.220	NR	4.33	NO
FVD-AR-4	4/22/81	125955.647	2272635.804	1597.8	4.92	NO
FVD-AR-5	4/22/81	125969.997	2273029.243	1588.0	3.28	NO
FVD-AR-6	4/22/81	125984.347	2273422.681	1583.1	4.76	NO
FVD-AR-7	4/22/81	126002.285	2273914.479	1592.9	4.92	NO
FVD-AR-8	4/22/81	126014.244	2274242.344	1586.4	4.59	NO
FVD-AR-9	4/22/81	126026.202	2274570.209	1581.4	6.40	NO
FVD-AR-10	4/22/81	126038.161	2274898.074	1578.2	5.41	NO
FVD-AR-11	4/22/81	126025.120	2275552.020	1571.6	3.28	NO
FVD-AR-12	4/22/81	125712.432	2276118.719	1566.7	5.02	NO
FVD-AR-13	4/22/81	125300.123	2276380.421	1578.2	6.40	NO
FVD-AR-14	4/22/81	124980.184	2276447.837	1553.6	4.27	NO
FVD-AR-15	4/22/81	124488.133	2276454.065	1550.3	6.40	NO
FVD-AR-16	4/24/81	123831.970	2276456.050	1553.6	6.40	NO
FVD-AR-17	4/24/81	123503.916	2276460.621	1551.9	4.92	NO
FVD-AR-18	4/24/81	123175.869	2276465.466	1560.1	5.09	NO
FVD-AR-19	4/24/81	122847.822	2276470.311	1574.9	6.40	NO
FVD-AR-20	4/23/81	122519.772	2276468.018	1576.5	6.40	NO
FVD-AR-21	4/23/81	122191.820	2276458.142	1548.6	2.95	NO
FVD-AR-22	4/23/81	121863.912	2276447.421	1551.9	4.10	NO
FVD-AR-23	4/23/81	121536.005	2276436.699	1566.7	3.61	NO
FVD-AR-24	4/23/81	121372.050	2276431.338	1578.2	6.40	NO
FVD-AR-25	4/23/81	120879.947	2276427.617	1586.4	4.43	NO
FVD-AR-26	4/23/81	120060.065	2276450.741	1632.3	3.81	NO
FVD-AR-27	4/23/81	119569.779	2276432.364	1647.1	4.00	NO
FVD-AR-28	4/22/81	118957.134	2276199.873	1653.6	3.44	NO
FVD-AR-29	4/23/81	118313.555	2276131.097	1656.9	3.94	NO
FVD-AR-30	4/22/81	117737.684	2276364.097	1660.2	3.77	NO
FVD-AR-31	4/23/81	117273.704	2276828.077	1660.2	3.94	NO
FVD-RR-1	9/8/81	118996.986	2281317.070	1614.3	3.94	NO
FVD-RR-2	9/8/81	119279.087	2281739.350	1633.9	4.00	NO
FVD-RR-3	9/8/81	119692.465	2282042.251	1630.7	6.89	NO
FVD-RR-4	9/8/81	120316.595	2282324.197	1615.9	2.69	NO
FVD-RR-5	9/8/81	120675.124	2282497.755	1614.3	3.02	NO
FVD-RR-6	9/8/81	120698.753	2282436.540	1609.3	2.62	NO
FVD-RR-7	9/8/81	121054.012	2282591.254	1614.3	3.61	NO
FVD-RR-8	9/8/81	121709.585	2282714.360	1601.1	4.04	NO
FVD-RR-9	9/8/81	122671.136	2282683.593	1607.7	2.79	NO
FVD-RR-10	9/8/81	123665.038	2282558.073	1584.7	3.12	NO
FVD-RR-11	9/8/81	125423.995	2283797.974	1582.8	6.23	NO
FVD-RR-12	9/8/81	125432.967	2283846.714	1582.4	6.40	NO
FVD-RR-13	9/8/81	125845.671	2286088.853	1585.4	6.23	NO
FVD-RR-14	9/8/81	125812.367	2286270.397	1584.7	6.23	NO
FVD-RR-15	9/8/81	125643.747	2284991.819	1583.1	6.23	NO
FVD-RR-16	9/8/81	125650.383	2284590.286	1579.8	5.41	NO
FVD-RR-17	9/8/81	125580.125	2284102.832	1584.7	6.00	NO

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
FVD-RR-18	9/9/81	125539.497	2283609.920	1581.4	6.07	NO
FVD-RR-19	9/9/81	125512.185	2283272.289	1578.2	5.02	NO
FVD-RR-20	9/9/81	125148.938	2282655.465	1584.7	6.00	NO
FVD-RR-21	9/9/81	124912.046	2282488.542	1581.4	6.23	NO
FVD-RR-22	9/9/81	124345.343	2282491.832	1594.6	4.92	NO
FVD-RR-23	9/9/81	124103.525	2282589.580	1571.6	6.23	NO
FVD-RR-24	9/9/81	123972.635	2282580.175	1570.6	3.97	NO
FVD-RR-25	9/9/81	123835.194	2282570.299	1576.5	5.74	NO
FVD-RR-26	9/9/81	123727.204	2282562.540	1579.8	6.07	NO
FVD-RR-27	9/10/81	118883.378	2280784.379	1617.5	4.76	NO
FVD-RR-28	9/10/81	118894.705	2280636.774	1627.4	3.12	NO
FVD-RR-29	9/10/81	118803.667	2280140.677	1632.3	3.12	NO
FVD-RR-30	9/10/81	118683.369	2279936.852	1607.7	3.28	NO
FVD-RR-31	9/10/81	118165.560	2279463.468	1625.7	3.05	NO
FVD-RR-32	9/10/81	117736.964	2279003.801	1640.5	4.76	NO
FVD-RR-33	9/10/81	125857.549	2286153.386	1581.4	6.23	NO
FVD-RR-34	9/10/81	125768.465	2285669.392	1577.5	6.40	NO
FVD-RR-35	9/10/81	125911.000	2286443.783	1584.7	6.23	NO
G40-D24	12/20/79	108060.000	2266940.000	1629.93	188.5	YES
G40-E16	3/13/79	113255.000	2267520.000	1574.40	51.5	NO
G40-E22	1/10/80	109650.000	2267465.000	1594.10	51.5	NO
G40-G19	3/21/79	111340.000	2269350.000	1649.93	65.5	NO
G40-G24	12/11/79	107830.000	2268850.000	1658.70	100.8	NO
G40-G26	12/12/79	106690.000	2268660.000	1678.65	101	NO
G40-G7	1/13/82	118955.000	2268700.000	1548.35	119	NO
G40-H13	3/14-21/79	115275.000	2269330.000	1762.21	195.3	NO
G40-H16	3/28/79	113260.000	2269110.000	1617.10	268	YES
G40-H27	12/20/79	105930.000	2269650.000	1602.12	250	YES
G40-J15	3/02/79	113810.000	2270150.000	1603.60	51.5	YES
G40-J20	11/10-14/80	111140.000	2269905.000	1629.67	76	NO
G40-K13	3/01/79	115130.000	2270885.000	1600.90	50.25	YES
G40-L9	1/5-13/82	117745.000	2271185.000	1621.00	210	NO
G40-L19	3/17-20/79	111060.000	2271025.000	1671.31	120.5	NO
G40-L23	1/15/80	108920.000	2271065.000	1639.30	90.9	YES
G40-M14	3/16/79	114595.000	2271820.000	1649.57	95	NO
G40-M15	4/11/79	113660.000	2271735.000	1637.60	310	YES
G40-P10	12/18/79	117145.000	2273040.000	1634.04	70.8	NO
G40-P10A	1/15/82	116745.000	2272895.000	1651.35	160	YES
G40-P17	12/6/79	112710.000	2273490.000	1707.94	100.5	NO
G40-P20	1/3/80	111070.000	2275515.000	1641.09	81	NO
G40-P20	1/3/80	111070.000	2273515.000	1641.09	81	YES
G40-Q7	1/17/80	119050.000	2274350.000	1608.07	70.5	YES
G40-R23	1/8/80	108770.000	2274805.000	1620.30	81	YES
G40-S11	12/26-27/79	116240.000	2275365.000	1639.88	80.8	NO
G40-S17	12/17/81	112295.000	2275770.000	1595.65	150.7	YES
G40-S17A	12/18/81	112335.000	2275790.000	1595.90	30	YES
G40-T30	2/11/82	105765.000	2278410.000	1590.40	162	YES
G40-X1	1/15/82	121515.000	2277990.000	1616.55	143	YES
G40-X1A	1/14/82	121930.000	2277830.000	1578.90	75	YES
G40-Y15	12/17/81	113655.000	2279180.000	1593.40	175	YES
G40-Y15A	12/17/81	113665.000	2279170.000	1593.70	20	YES
G40-Y21	12/28/81	110730.000	2278040.000	1592.80	20	YES
G40-Y22	1/22/82	108880.000	2278310.000	1609.10	196	YES
G40-Y26	1/20/82	106680.000	2278800.000	1590.70	128	YES
G41-A23	1/18/82	108070.000	2280288.000	1608.00	48	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
G41-A24	6/9/81	107060.000	2280500.000	1614.08	180	YES
G41-B12	12/31/81	116120.000	2280610.000	1610.65	126	YES
G41-C11	2/27/79	116095.000	2281690.000	1634.40	50.9	NO
G41-C13	3/10/79	114775.000	2281895.000	1617.17	50.5	NO
G41-C15	3/7/79	113350.000	2282075.000	1615.60	217.3	YES
G41-C15A	3/9/79	113365.000	2282080.000	1615.60	145	YES
G41-C15B	3/30-31/79	113265.000	2281850.000	1611.60	26.5	YES
G41-C15C	1/18/82	113160.000	2281790.000	1611.35	22	YES
G41-C32	2/9/82	102500.000	2282115.000	1739.80	262	YES
G41-D14	3/2/79	114075.000	2282300.000	1615.10	53	NO
G41-D17	3/6/79	112220.000	2282525.000	1649.15	50.8	NO
G41-D18	3/3-5/79	111300.000	2282140.000	1680.37	65.2	NO
G41-E11	3/3-5/79	115865.000	2282875.000	1651.61	49.5	NO
G41-E13	3/6/79	114395.000	2282889.000	1627.30	250.5	YES
G41-E13A	3/27/79	114395.000	2282890.000	1626.70	191	YES
G41-E15	3/1-2/79	113380.000	2282935.000	1647.25	50	NO
G41-E17	4/2/79	112385.000	2283005.000	1666.40	260	YES
G41-E19	3/8/79	110750.000	2283085.000	1620.94	50.3	NO
G41-E19A	5/15/81	110260.000	2283290.000	1645.59	276	YES
G41-E22	1/04/82	109970.000	2282570.000	1609.75	224	YES
G41-E22A	1/06/82	109955.000	2282590.000	1609.50	42.1	YES
G41-F13	3/12-13/79	114845.000	2283660.000	1670.67	55.8	NO
G41-F24	1/8/80	107255.000	2283465.000	1653.50	243	YES
G41-G11	2/27/79	116095.000	2284345.000	1687.13	81.5	NO
G41-G12	3/31/79	115825.000	2284430.000	1675.70	21	YES
G41-G13	6/4/81	115260.000	2284725.000	1709.58	319	YES
G41-G14	3/13-16/79	113930.000	2284315.000	1705.13	96.5	NO
G41-G14A	11/16/79	114080.000	2284315.000	1706.91	241	YES
G41-G14B	11/30/79	114055.000	2284315.000	1706.80	360.1	YES
G41-G14C	12/4/79	114030.000	2284315.000	1706.33	160	YES
G41-G14D	12/11/79	113855.000	2284315.000	1705.56	257	YES
G41-G14E	12/07/79	113830.000	2284315.000	1705.61	165	YES
G41-G14F	11/6/79	113805.000	2284315.000	1703.50	332	YES
G41-G15	4/9/79	113415.000	2284420.000	1691.50	338	YES
G41-G15A	3/9/79	113480.000	2284390.000	1692.75	113	YES
G41-G15B	3/13/79	113440.000	2284385.000	1692.10	170	YES
G41-G15C	3/28-31/79	113440.000	2284405.000	1692.47	146	NO
G41-G16	2/26/79	112790.000	2284390.000	1685.70	75.4	NO
G41-G19	3/9/79	110880.000	2284280.000	1696.60	90.5	NO
G41-G21	12/5/79	109495.000	2284265.000	1664.83	100.5	YES
G41-H9	5/26/81	117330.000	2285000.000	1702.04	315	YES
G41-H13	3/6-9/79	114700.000	2284975.000	1715.21	104.3	NO
G41-H17	2/28/79	112145.000	2284960.000	1684.50	74.3	YES
G41-H18	3/9/79	111430.000	2285125.000	1684.30	75.3	YES
G41-H18A	3/30/79	111590.000	2285065.000	1680.40	21.5	YES
G41-H18B	6/3/81	110995.000	2285335.000	1683.80	288	YES
G41-J11	3/7-9/79	116010.000	2285580.000	1709.00	99.7	NO
G41-J14	2/27-3/1/79	114110.000	2285890.000	1689.20	80.2	NO
G41-J17	4/5/79	112110.000	2285530.000	1688.85	40	NO
G41-J17A	4/3-4/79	112090.000	2285520.000	1689.24	30	NO
G41-J18	3/13/79	111215.000	2285495.000	1679.70	70.5	YES
G41-J19	3/13-14/79	110780.000	2285680.000	1686.51	75.5	NO
G41-K13	4/9/79	114755.000	2285965.000	1699.70	285	YES
G41-K13A	3/31/79	114770.000	2285955.000	1699.90	122.2	YES
G41-K13B	3/28/79	114850.000	2286070.000	1696.80	20	YES

Table 3.5-2, continued

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
G41-K17	3/9-12/79	112155.000	2286325.000	1688.71	79.3	NO
G41-K21	11/14-15/79	109385.000	2286215.000	1673.66	75.5	NO
G41-K21A	5/18-26/81	109730.000	2285890.000	1680.35	298	NO
G41-K26	5/11/81	106260.000	2286445.000	1686.10	330	YES
G41-L11	3/13-14/79	115895.000	2286690.000	1708.49	90.5	NO
G41-L13	3/12/79	114665.000	2286795.000	1711.54	86.5	NO
G41-L15	3/2-3/79	113575.000	2286755.000	1705.33	74.3	NO
G41-L19	3/1/79	111060.000	2286820.000	1686.36	69.1	NO
G41-L23	11/27-30/79	108275.000	2286580.000	1677.55	80.9	NO
G41-L25	12/3-4/79	106640.000	2286975.000	1693.68	85.5	NO
G41-M11	4/28/81	116270.000	2287725.000	1582.79	160.5	YES
G41-M15	5/8-13/81	113155.000	2287645.000	1653.00	254	NO
G41-M24	12/5/79	107900.000	2287176.000	1653.11	30.8	YES
G41-N21	12/1/79	109170.000	2288410.000	1727.36	150.5	YES
G41-P16	4/27/81	113755.000	2288760.000	1588.72	181	YES
G41-P18	3/27/79	111645.000	2288825.000	1588.90	130	YES
G41-P18B	3/29/79	111390.000	2288820.000	1589.10	44.5	YES
G41-P24	12/20/79	107550.000	2288660.000	1681.95	345	YES
G41-Q22	5/8/81	108460.000	2289190.000	1612.30	316.5	YES
RP-1	2/22/84	115604.000	2280542.000	1634.71	27.5	NO
RP-2	3/8/84	115652.000	228119.000	1642.51	34	NO
RP-3	3/12/84	115712.000	2281620.000	1642.48	33.5	NO
RP-4	3/7/84	115903.000	2282534.000	1659.07	33.7	NO
RP-5	3/9/84	115119.000	2280901.000	1644.62	40	NO
RP-6	3/10/84	115346.000	2281381.000	1644.51	27.5	NO
RP-7	3/12/84	115410.000	2281782.000	1636.08	21.5	NO
RP-8	3/2/84	115562.000	2282668.000	1654.91	30.5	NO
RP-9	3/9/84	114750.000	2280723.000	1654.67	34	NO
RP-10	3/9/84	114892.000	2281336.000	1625.80	11.5	NO
RP-11	3/1/84	115033.000	2282358.000	1630.33	11.5	NO
RP-12	3/1/84	115000.000	2282868.000	1648.79	26.4	NO
RP-13	3/1/84	114509.000	2282328.000	1620.30	7.5	NO
RP-14	2/29/84	115863.000	2281985.000	1645.44	23.8	NO
RP-15	6/7/84	115462.000	2282287.000	1642.23	23.5	NO
RR-1	1/8191	124445.408	2282310.619	NR	41	NO
RR-2	1/6/81	124445.116	2282336.142	NR	41.5	NO
STS-B1	1/25/80	116792.120	2278140.830	1655.70	110.3	YES
STS-B2	1/25-28/80	116642.800	2278170.600	1652.90	40.5	NO
STS-B3	1/18/80	116580.770	2277998.570	1654.82	21	NO
STS-B4	1/18/80	116778.800	2278048.000	1661.10	21	NO
STS-B5	1/29/80	116299.700	2277963.500	1655.50	41	NO
STS-B6	1/30/80	116253.800	2278124.300	1649.60	20.4	NO
STS-B7	1/29/80	116253.800	2278314.500	1642.10	21.5	NO
STS-B8	1/29/80	116437.400	2278124.300	1652.90	20	NO
STS-B9	1/16-18/80	116555.600	2278219.400	1651.90	20.9	NO
STS-B10	1/18/80	116499.900	2278330.900	1647.60	21.5	NO
STS-B11	1/18/80	116516.300	2278413.000	1650.90	21.5	NO
STS-DHL-1	2/13/84	108983.000	2281442.000	1605.40	43	YES
STS-DL-1	2/8/84	112581.000	2281760.000	1611.80	60	YES
STS-DL-2	10/25/85	113175.000	2281778.000	1611.70	~34.5	YES
STS-DL-3	10/25/85	113882.000	2281574.000	1612.50	~19.5	YES
STS-DL-4	10/25/85	113114.000	2281514.000	1612.60	~20	YES
STS-DL-5	10/25/85	112448.000	2280776.000	1612.60	~20	YES
STS-DL-6	10/25/85	111630.000	2280917.000	1615.20	~20	YES
STS-EVS	3/21/78	116340.800	2278955.800	1614.40	83.8	YES

Boring/Well Label	Date(s) Installed	State Plane Coordinates (ft)		Ground Elevation (msl)	Total Depth BGS (ft)	Converted to well (yes/no)
		North	East			
STS-LSL-1	3/18/82	114280.000	2278245.000	1591.90	52	NO
STS-LSL-2	3/22/82	113575.000	2277080.000	1591.90	40.5	NO
STS-LSL-3	3/19/82	113510.000	2277990.000	1591.90	45	NO
STS-LSL-4	3/20-21/82	112345.000	2276430.000	1591.90	47.5	NO
STS-LSL-5	3/21/82	111310.000	2277390.000	1591.90	36	NO
STS-LSL-6	3/20/82	110950.000	2276590.000	1591.90	36	NO
STS-OL-1	2/9-10/84	114464.000	2273195.000	1633.47	53	YES
STS-SL-1	2/9/84	117588.000	2280516.700	1598.00	17.4	YES
STS-SL-2	2/27/84	117588.000	2280522.700	NR	10.5	YES
STS-SL-3	10/25/85	117765.800	2281033.500	1633.50	~6	YES
STS-SL-4	10/25/85	118074.100	2281309.100	1600.30	~7.5	YES
STS-SL-5	10/25/85	117778.900	2281095.900	1598.70	~26	YES
STS-WVS	3/22/78	116744.500	2274385.900	1683.40	189.5	YES
TW-1	3/77	116883.850	2279723.300	1601.19	55	YES
TW-2	3/77	116282.490	2274923.310	1654.40	96	YES
TW-41	1/29/81	114130.000	2284315.000	1707.19	340	YES
WP-1L	3/15/84	110547.000	2265406.000	1553.85	33	YES
WP-1U	3/15/84	110540.000	2265404.000	1553.85	6	YES
WP-2L	3/30/84	119694.000	2267150.000	1536.12	32.6	YES
WP-2U	3/30/84	119698.000	2267150.000	1536.03	6	YES
WP-3L	3/29/84	119269.000	2268045.000	1537.73	33	YES
WP-3U	3/29/84	119246.000	2268023.000	1540.89	11	YES
WP-4L	3/29/84	121799.000	2274240.000	1541.18	32	YES
WP-4U	3/29/84	121825.000	2274236.000	1545.29	10.2	YES
WP-5L	4/2/84	120871.000	2274355.000	1548.02	33	YES
WP-5U	4/2/84	120865.000	2274352.000	1547.98	5	YES
WP-6L	3/30/84	118254.000	2287403.000	1579.60	33	YES
WP-6U	3/30/84	118247.000	2287407.000	1579.51	6.5	YES
WP-7L	3/14/84	116486.000	2287958.000	1580.08	33	YES
WP-7U	3/14/84	116494.000	2287958.000	1580.26	6	YES
WW-1	7/26-8/2/76	116903.198	2277828.575	1671.20	129.6	YES
WW-2	9/20-22/76	116442.007	2276157.379	1645.39	155	YES
WW-3	3/23-30/	NR	NR	NR	60	YES
WW-4	4/4-5/81	116170.970	2278391.910	1623.67	98	YES

LEGEND

BGS = Depth Below Ground Surface
* = Approximate Elevation
** = Multilevel Gas Probes Installed
NR = No Record

Prepared by: MLB\TLM\LLA\MLD2
Checked by: EAS/JJA/JWS

3.5.1.2.3 1979-1982 Investigations

From 1979 to 1982, borings were drilled and monitoring wells were installed as part of the hydrogeologic and geotechnical investigations for the siting and design of the TMA (Golder Associates, 1981). The investigations were completed in several phases and consisted of concurrent detailed characterization studies in two areas. The first evaluation conducted at Area 40, consisted of the G40 series borings and wells, encompassed an area between Little Sand Lake on the east, Mole Lake to the west, Rolling Stone Lake to the south and Swamp Creek to the north. The second evaluation conducted at Area 41, consisted of the G41 series borings and wells, encompassed an area between Ground Hemlock Lake on the east, Little Sand Lake to the west, Swamp Creek to the north and Walsh Lake to the south. The location of the borings and monitoring wells for these two investigations are shown on Figures 3.5-4 and 3.5-5. A summary of the construction details for each boring is contained in Table 3.5-2.

The boreholes were primarily drilled by the mud-rotary method. A biodegradable viscosity increasing agent, Revert, was used to form the drilling fluid. Tri-cone bits were normally used to drill the holes with drilling rods of 2⅜ inch diameter ("N" rods) or larger. Nominal hole diameters ranged between four inches and six inches. A minimum of five feet of casing was used to start each hole. The holes were held open with mud below the bottom of the casing. Upon completion, all holes not used for the installation of an observation well were backfilled with cement grout to the ground surface.

Disturbed and undisturbed samples were obtained from the boreholes. Samples were generally collected every five feet to a depth of 100 feet, and every 10 feet below a depth of 100 feet. The disturbed samples were obtained by driving a split spoon sampler with a drop hammer. At the start of the program, two inch O.D. split spoons were driven with a 140 pound hammer freely falling 30 inches. The number of blows required to drive the sampler the last 12 inches of an 18 inch penetration was recorded on the boring logs. The blow counts, as they are called, provide a rough indication of in situ soil density which is called the Standard Penetration Resistance ("N"). Due to the very high density of the soil at the site, little sample recovery was possible with the 140 pound hammer. In order to increase sample recovery, three inch O.D. split spoons were substituted and driven with 300 pound to 360 pound drop hammers. The number of blows required to drive this larger sampler was also recorded on the boring logs. On drilling rigs with air compressors, the sampler was driven with an air hammer. The air hammer combines a fast vibratory motion with down-pressure to advance the sampler. This method resulted in a very good sample recovery in the very dense soil. All samples were placed in glass jars, which were packed in corrugated cardboard boxes for shipment and storage.

Several undisturbed samples were collected in some of the wetlands, such as boring G41-C15B and G41-C15C in the Duck Lake wetland, where soft material was encountered. Thin-walled sampling tubes, 76mm (three inch) O.D., were pushed into the soil using hydraulic pressure. The tubes were capped and sealed in wax for transport and storage.

Twenty-three of the boreholes were drilled to bedrock. Bedrock samples were obtained by coring in twelve of the borings. The rock was cored with a diamond bit on a double tube core barrel, yielding a minimum core diameter of two inches. Test well TW-41, used for a 24-day pump test described in Section 3.6 was also installed by Golder Associates. Boring logs for all these holes are included in Appendix 3.5-2. Note that well construction information is included on the respective boring log for those borings converted to groundwater monitoring wells.

3.5.1.2.4 1981 Ore Body Pump Test Drilling Program

In 1981 a series of borings and monitoring wells were installed in the vicinity of the ore body to characterize the hydrogeologic characteristics of bedrock overburden contact. These borings and monitoring wells were installed as part of programs managed by Camp, Dresser & McKee (1982) and Braun Engineering, respectively. The location of the borings and monitoring wells are shown on Figure 3.5-5. A summary of boring construction details is provided in Table 3.5-2.

The BE Series borings were completed via direct rotary methods using a circulating biodegradable drilling fluid. Soil samples were generally collected every 10 feet with split spoon sampling techniques. Logs for the BE series borings are contained in Appendix 3.5-3.

The CDM Series borings were completed at 16 locations for geophysical borehole logging and split spoon sampling. The borings were advanced using direct rotary methods. Soil samples were collected via split spoon samplers. The total length of the hole sampled varied with each hole. Several of the holes were sampled from the ground surface to bedrock. In other borings, the sampling interval was generally the 30 feet of soil above the bedrock. The sampling interval was every five feet except in holes which were sampled over their entire length. In these, the upper fifty feet were sampled at ten-foot intervals and the rest of the hole sampled at five-foot intervals.

The borings were advanced ten to twenty feet into the bedrock to allow geophysical logging of the contact between the bedrock and glacial overburden. The geophysical logging was coordinated by Camp, Dresser & McKee. The combined boring and geophysical logs are provided in Appendix 3.5-4.

3.5.1.2.5 1984 Investigation

In 1984, STS Consultants, Ltd. (STS, 1984a and b) completed 16 EX series borings and seven WP series borings that were converted to nested piezometers or well points. This investigation was designed to provide increased resolution of the hydrostratigraphic units within the study area through the placement of nested wells and extensive grain size analysis.

The drilling program included sixteen soil borings for multiple monitoring well installations and seven borings for well point installations. Figures 3.5-4 and 3.5-5 show the location of the borings. Boring construction data is summarized in Table 3.5-2. In general, the EX series boreholes were drilled with a Schramm Model T-64HB rotary drilling rig, using both air and mud rotary techniques. Casing was installed to stabilize the top of the borehole. These techniques produced a borehole with approximately a 6¼ inch diameter. Water used in the drilling process was obtained from an on-site well. A liquid polymer, Drispac and Quik-Trol, was added to the bentonite drilling mud to improve cuttings removal and to increase sample recovery.

The borings ranged in depth from 119 feet at EX-4 to 305 feet at EX-12. In general, the deepest borings were in the vicinity of the proposed TMA (borings EX-9 through EX-16). All of the borings were extended to the bedrock except EX-16, which was located adjacent to an older boring, G41-C15, which penetrated the bedrock.

Split spoon soil samples were collected in each boring. For most of the EX borings, split spoon samples were collected every ten feet, with the exception of borings EX-7, 15 and 16, which had

only three or four control samples collected approximately every 60 feet. The samples were collected using a three inch O.D., 2½ inch I.D. split spoon sampler which was 24 inches long. At the EX locations, the split spoon sampler was driven by an air hammer. The length of penetration and recovery were plotted on the soil boring logs (Appendix 3.5-5). Note that well construction information is included on each boring log. In boring EX-11, the split spoon sampler was increased to 48 inches in length to obtain larger samples of the glacial till.

Each sample from the EX borings was divided into three representative portions. One portion was placed in a small glass jar to be stored at the field office. Another portion was placed in a sealed plastic bag to be used for water content determination. The remaining portion of the sample was placed in a large mason jar and shipped to the STS laboratory in Green Bay, Wisconsin for grain size analyses.

Each of the samples recovered from the boreholes was examined by an experienced geologist to determine the major and minor soil components, degree of saturation, and any conspicuous lenses and seams found in the sample. The soils were then classified according to the Unified Soil Classification System. The capitalized symbol in parentheses on the boring logs is the appropriate group symbol according to this classification system. Upon completion of the sample classification, the geologist grouped the samples by geologic origin as shown on the soil boring logs. The strata contact lines represent approximate boundaries between soil types since changes in the soil types in situ may be gradual in both the horizontal and vertical directions. Core samples of the bedrock were obtained in selected borings with N-size, double-tube core barrels with either diamond or carbide bits.

Six EX borings, EX-4, 5, 7, 13, 15 and 16, were geophysically logged using mechanical, nuclear and sonic devices. The geophysical logging was completed by Snyder Brothers, Inc. of Grayville, Illinois. The logging was conducted in the uncased boreholes which were filled with bentonite drilling mud. Borings EX-4 and 5 were logged first so that the logging results could be compared to the soil boring logs developed by conventional split spoon sampling.

The WP series bore holes used for well point installation were drilled approximately 30 feet deep with flight augers. Since hollow stem augers were not used, split spoon samples were not collected. Rather, soil cuttings were logged as they came up and out of the hole. The soil cuttings encountered at each hole are summarized in Appendix 3.5-5.

3.5.1.2.6 Miscellaneous Borings

In 1978, Soil Testing Services completed two borings (STS-EVS and STS-WVS) for siting the location of the east and west vent shafts. The location of the borings is shown on Figure 3.5-5 with construction information provided in Table 3.5-2. Boring logs are provided in Appendix 3.5-6. As part of the planning and design of plant facilities a series (STS-BI through STS-B11) of shallow geotechnical borings were completed by Soil Testing Services in 1980. These borings were typically completed to a depth of between 20 and 30 feet in the vicinity of the plant site. The location of these borings is shown on Figure 3.5-5 and summarized in Table 3.5-2. The boring logs are provided in Appendix 3.5-6.

In 1981, Soil Testing Service completed the AR and RR series borings for the design of the access road and railroad spur. The FVD-AR and FVD-RR series borings were completed by Foth & Van Dyke in 1981 also for design of the railroad spur and access road. RP series

borings were completed in 1984 by Soil Testing Services for the design of the reclaim ponds. The locations of all of these borings are shown are on Figure 3.5-6. Boring construction details are summarized in Table 3.5-2. Boring logs are provided in Appendix 3.5-6.

3.5.1.3 Lake Bed and Wetland Drilling Studies

A number of investigations have been completed to characterize the hydrogeologic characteristics of lake beds and wetlands within the immediate project area. These investigations were conducted in the early to mid 1980's, and during 1994 and 1995. The investigations consisted of drilling programs to characterize the soil properties that comprise the lake bottoms, to place piezometers within and below the lake bottoms to assess the hydraulic relationship between lakes and the regional groundwater system, and geophysical studies to assess the continuity of low permeability layers that comprise part of the lake bottoms. The following is a summary of the methods employed for each investigation. Figure 3.5-7 shows the locations of lake and wetland borings.

3.5.1.3.1 1982 Little Sand Lake Drilling Program

In 1982, STS Consultants, Ltd. (1982) conducted a drilling program referred to as the STS-LSL series, on Little Sand Lake to characterize lake bed sediments with regard to thickness, physical characteristics and permeability. A total of six borings were completed that covered primarily the central area of the lake.

The borings were completed via rotary wash methods with casing advanced through the lake bed deposits and into the outwash deposits below the lake bed. Undisturbed soil samples were obtained from each boring for grain size analysis and permeability tests. Boring logs are contained in Appendix 3.5-7.

3.5.1.3.2 1984 Deep Hole, Duck, Skunk, and Oak Lake Drilling Program

In 1984, a second lake bed drilling program was completed to characterize thickness, physical characteristics, and hydraulic conductivity of additional lakes within the study area. The drilling program was conducted by STS Consultants, Ltd. (1984). The lakes that were investigated were Oak, Deep Hole, Duck and Skunk Lakes. The borings are referred to as the STS-OL, STS-DHL, STS-DL, and STS-SL series of borings and wells, respectively.

The borings were completed via conventional rotary wash methods with casing advanced through the lake bed into the top of the underlying outwash/till deposits. Undisturbed soil samples were obtained of the lake bed for grain size analysis and permeability testing. After completion of the borings, monitoring wells were installed in the borings. After stabilized water level measurements were obtained from the monitoring wells, they were abandoned with a cement-bentonite grout. Logs for these borings are provided in Appendix 3.5-8.

3.5.1.3.3 1985 Duck and Skunk Lake Wetland Drilling Program

In 1985, a third investigation was conducted related to the lakes in the vicinity of the project site. The focus of this investigation was the wetlands in the vicinity of Duck and Skunk Lakes. This investigation was completed by STS Consultants, Ltd. (1986), and consisted of four well installations in the Skunk Lake wetland and five well installations in the Duck Lake wetland.

The borings and wells are referred to as the STS-DL-2, 3, 4, 5, 6 and STS-SL-3, 4, 5, 6 series. The wells were installed manually with a hand auger, and thus no undisturbed soil samples were obtained for permeability testing. Boring logs are contained in Appendix 3.5-9.

3.5.1.3.4 1994 Little Sand Lake and Wetland Drilling Program

In 1994, Foth & Van Dyke completed a fourth lake bed and wetland drilling program. The areas that were investigated as part of this program were:

- the littoral zone of Little Sand Lake (CMC-LSL series of borings and wells);
- the Skunk and Duck Lake wetlands (CMC-DL and CMC-SL series of borings and wells); and
- Burr Oak Swamp, the Swamp Creek Cedars Wetland and the Swamp Creek Wetland (CMC-BO, CMC-SCC, and CMC-SC series of borings and wells, respectively).

Soil borings and well installations were conducted from January 31, 1994 to February 15, 1994. Two borings were completed in the Swamp Creek wetland to assess soil types beneath the wetland that control the discharge of groundwater to these wetlands. One boring and one piezometer nest were completed in each of the Swamp Creek Cedars, Burr Oak Swamp and Skunk Lake wetlands. One piezometer was installed immediately adjacent to the Duck Lake wetland, since the wetland could not be accessed by any drilling equipment. Previous studies on Little Sand Lake focused on lacustrine clay thickness and hydraulic characteristics in the center of the lake. For the 1994 study, borings were completed at six locations around the perimeter on the littoral zone of Little Sand Lake to assess the thickness and hydraulic characteristics of lacustrine clay in shoreline areas. At two of the boring locations, piezometer nests were installed and designated as CMC-LSL-102 A/B and CMC-LSL-103 A/B.

Drilling was performed with conventional rotary and hollow stem drilling per ASTM D2113 and ASTM D1452. To begin a drill hole in the lake beds, threaded steel casing was driven several feet into the lacustrine deposits forming the lake bed. The steel casing provided a means to recirculate drilling fluids and also contain drilling fluids and cuttings. Drilling was performed with a standard tri-cone bit by inserting the drill rod into the casing and then advancing into the lake bed deposit. Drilling fluids were circulated from a holding tub at the surface down through the drill rod and out the tri-cone bit. The drilling fluids and suspended soil cuttings were then circulated up through the steel casing to the surface where it emptied back into the holding tub. This closed system contained the drilling fluids and cuttings and prevented them from being discharged into the lake. Threaded joints on the casing were sealed with teflon tape to minimize the loss of drilling fluids to the lake through joints in the casing. Wash water and soil cuttings were transported off the frozen lake, and disposed in mud sumps at the proposed plant site.

Wetland drilling was performed with hollow stem augers. To begin a soil boring, a four by eight foot sheet of plywood was placed on the ground. A one foot hole was cut in the center of the plywood through which the augers were advanced into the soil. As soil cuttings came off of the augers, they were collected on the plywood, at which point they were transferred to an all-terrain vehicle. The all-terrain vehicle transported the cuttings out of the wetland to mud sumps at the proposed plant site.

The soils were sampled ahead of the bit/augers and casing by standard thin walled tubes (ASTM 1587) and split spoon sampling techniques. Soils were logged in the field according to the Unified Soil Classification System in accordance with ASTM (D2488). Soil boring logs were prepared on standard WDNR forms. Boring logs are contained in Appendix 3.5-10. Completed abandonment forms are also included in the appendix for those borings not converted to monitoring wells.

For each boring, one or more representative samples of soil were analyzed for particle size distribution (ASTM D422), liquid limit and plastic index (ASTM D4318) and classified according to ASTM D2487. Where cohesive soils were encountered, undisturbed soil samples were collected with a thin walled tube to measure saturated hydraulic conductivity according to ASTM Method D5084, which is the Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter.

3.5.1.3.5 1994 Lake Bed and Wetland Geophysical Study

The lake bed and wetland drilling programs described above provided point estimates of lake characteristics with regard to soil types, thickness, etc. Additional, more detailed data were desired to assess the continuity and variability in the thickness of clay/silt soils that comprise a portion of the lake beds and wetland soils.

To accomplish this goal, a detailed time-domain electromagnetic (TDEM) survey was conducted on the lakes and accessible regions of adjoining wetlands. The study was conducted on a grid spacing of approximately 200 feet, and was described in detail in a technical report issued by Subsurface Detections Investigations, Inc. (SDII, 1994). A copy of this report and related analysis is presented in Appendix 3.5-11.

The TDEM method mapped the thickness of a low resistivity geo-electric unit that is considered to be equivalent to silty clay and silt that forms a portion of the lake beds of lakes within the project study area. The lakes that were studied included Little Sand, Deep Hole, Duck, and Skunk Lakes. Previously completed borings were used as lithologic control points for TDEM data calibration. The control data was used to interpret the low resistivity geo-electric layer and to prepare maps showing the occurrence and thickness of this layer in the entire lake basin.

3.5.1.4 1994 Groundwater Monitoring Well Installation Drilling Program

During 1994, a program was initiated to install additional groundwater monitoring wells at the plant site and the TMA. The focus of this program was to collect additional groundwater quality data, that when compared to data collected previously, would verify the existing groundwater quality database. At the plant site, wells were installed at three locations to intersect the water table, and piezometers were generally installed immediately above the massive saprolite in Pre- to Early Wisconsinan Till. At the TMA site, wells were installed at six locations to intersect the water table, and four piezometers were installed to monitor the coarse outwash below the water table. Existing wells from previous drilling programs were used in the program to the extent possible. In total, the drilling program consisted of the installation of nine water table monitoring wells and seven piezometers at ten locations (Table 3.5-3). Figure 3.5-5 shows the location of the monitoring points. Construction details for these borings are summarized in Table 3.5-2.

Table 3.5-3

Groundwater Monitoring Wells Included in 1994 Sampling Program

Monitoring Well I.D.	Existing Well/ Well Type[1]	Location
CMC-01R	N.W.	TMA
CMC-01P	N.P.	TMA
		TMA
EX-9BL	E.P.	TMA
EX-9BU	E.W.	TMA
CMC-02R	N.W.	TMA
CMC-02P	N.P.	TMA
CMC-03RR	N.W.	TMA
CMC-03P	N.P.	TMA
CMC-04	N.W.	TMA
G41-H18B	E.	TMA
CMC-05	N.W.	TMA
EX-13 BU	E.	TMA
DMB-6	E.	TMA
CMC-06P	N.P.	TMA
CMC-07	N.W.	TMA
DMB-1A	E.W.	TMA
CMC-08	N.W.	Plant Site
CMC-08P	N.P.	Plant Site
CMC-09	N.W.	Plant Site
CMC-09P	N.P.	Plant Site
CMC-10	N.W.	Plant Site
CMC-10P	N.P.	Plant Site

[1] N = New
E = Existing
W = Water Table
P = Piezometer

Prepared by: EAS
Checked by: WJS

In general, wells were drilled with either a Mobile 57 A-T drilling rig or a Canterra C-120 drilling rig using mud rotary techniques. Attempts were made to use hollow-stem augers and air rotary techniques on borings CMC-SB-05, -08A, -08B and 10P, but these were not successful due to the presence of cobbles and boulders. CMC-01R was installed to replace CMC-01 as it was screened below the water table. CMC-02R was installed to replace CMC-02, and CMC-03RR was installed to replace CMC-03 and CMC-03R. These changes were necessitated by the fact that CMC-02, CMC-03, and CMC-03R were screened across a perched zone within the Late Wisconsinan Till and could not maintain sustained water within the wells for groundwater monitoring. CMC-02R was drilled using Rotasonic™ drilling techniques.

Split spoon samples were collected at five foot intervals from one boring at each location. Samples were also collected at the screened interval from each well. Boring logs for each of these bore holes are contained in Appendix 3.5-12. During the drilling program, four holes were not completed due to auger refusal. Boring logs for these holes, SB-05, SB- 08A, SB-08B and SB-10P, are also included in Appendix 3.5-12. Complete abandonment forms are included in Appendix 3.5-12 for those boreholes not converted to monitoring wells and for those monitoring wells that were abandoned. Table 3.5-3 summarizes the wells that were installed and used as part of the 1994 groundwater verification program.

3.5.1.5 1994 Saprolite Investigation and Drilling Program

In 1994, an investigation was completed to characterize the geologic material at the glacial overburden/bedrock interface in the vicinity of the ore body. Specifically, the investigation was conducted to delineate the continuity and thickness of a massive saprolite layer that is developed at the top of the bedrock and ore body. Related studies, described in Section 3.6.1.6.7, were conducted to evaluate hydraulic characteristics of the massive saprolite and adjacent stratigraphic layers. The drilling program is described in extensive detail in a saprolite report prepared by Foth & Van Dyke (1995a). This report was submitted to the WDNR and the USCOE in February 1995 and was the subject of detailed discussions with the reviewers to define how the data generated by the study would be incorporated into the regional groundwater model for the project. The saprolite report can be found in Appendix A of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3. A technical memorandum addressing the comments raised by the reviewers and the discussions held between CMC and the reviewers regarding this topic precedes the saprolite report.

Table 3.5-4 summarizes the borings and piezometers that were completed for the saprolite investigation. Figure 3.5-8 shows the location of these and other 1994 borings and piezometers used for saprolite characterization. Boring logs for the saprolite investigation wells are provided in Appendix 3.5-13. The logs describe the drilling, sampling techniques, and the intervals that soil and rock samples were acquired from. The borings for wells CMC-10PP, -11P, -12P, and -13P were sampled in the Pre- to Early Wisconsinan till, massive saprolite, and structured saprolite. Borings for CMC-14P and CMC-OWA1R and -OWA2 were sampled in the massive saprolite and structured saprolite. Borings for wells CMC-OWA3, -OWA4 and -OWA5 were terminated in the Pre- to Early Wisconsinan till and were sampled at the screened interval. The borings for CMC-PWA, -PWAR, and -PWB were blind drilled in which case the massive saprolite unit was inferred based on collected and preserved drill cuttings.

Table 3.5-4

Saprolite Investigation Well Drilling and Sampling Summary

Well #	Total Depth	Continuous	Geologic Unit	Method(s) of	Purpose
CMC-10PP	110	110	Massive Saprolite	Rotasonic Coring	Evaluate massive saprolite thickness, slug testing, pump test observation well
CMC-11P	215	193	Massive Saprolite	Rotasonic Coring	Evaluate massive saprolite thickness, slug testing, pump test observation well
CMC-12P	205	27	Massive Saprolite	Rotasonic Coring	Evaluate massive saprolite thickness, slug testing, pump test observation well
CMC-13P	236	96	Massive Saprolite	Conventional Coring	Evaluate massive saprolite thickness, slug testing, pump test observation well
CMC-14P	110	25	Massive Saprolite	Split Spoon/ Conventional Coring	Evaluate massive saprolite thickness, slug testing, pump test observation well
CMC-OWA1R	205	55	Structured Saprolite	Conventional Coring	Pump test observation well, slug testing
CMC-OWA2	191	38	Structured Saprolite	Conventional Coring	Pump test observation well, slug testing
CMC-OWA3	131	0	Pre- to Early Wisconsinan Till	Mud Rotary Drilling	Pump test observation well, slug testing
CMC-OWA4	126	0	Pre- to Early Wisconsinan Till	Mud Rotary Drilling	Pump test observation well, slug testing
CMC-OWA5	132	0	Pre- to Early Wisconsinan Till	Mud Rotary Drilling	Pump test observation well, slug testing
CMC-PWA	230	0	Structured Saprolite	Mud Rotary/Air Rotary Drilling	Pump test observation well,
CMC-PWAR	270	0	Structured Saprolite	Mud Rotary/Air Rotary Drilling	Pump test well, specific capacity testing
CMC-PWB	400	0	Structured Saprolite	Mud Rotary/Air Rotary Drilling	Pump test well, specific capacity testing

Prepared by: LLA
Checked by: EAS

3.5.1.6 1996 TMA Soil Boring Installation

In late January and early February 1996, ten soil borings (CMC-TMA-101 through -110) were installed in the vicinity of the proposed TMA using rotary mud and dual tube drilling techniques. Boreholes were abandoned in accordance with NR 141. Table 3.5-4a summarizes the target formation for completion and the actual formation in which each borings was completed. The location of each boring is shown on Figure 3.5-5. Boring construction details are provided in Table 3.5-2. Holes drilled using rotary mud were sampled via split spoon methods at 10-foot intervals. Holes drilled with dual tube drilling techniques were sampled at 5-foot intervals. Boring logs and abandonment forms are provided in Appendix 3.5-13a. The boring logs note the drilling method used and the sample interval. The logs also contain a description of cuttings for CMC-TMA-101, -102, -104, -105, and -107 which penetrated bedrock. The rock cuttings corroborate the absence of significant sulfide mineralization in the vicinity of the TMA.

Table 3.5-4a

1996 TMA Boring Program Summary

Boring	Target	Completed
CMC-TMA-101	Lower Till[1]	Bedrock
CMC-TMA-102	Bedrock	Bedrock
CMC-TMA-103	Lower Till[1]	Lower Till
CMC-TMA-104	Bedrock	Bedrock
CMC-TMA-105	Bedrock	Bedrock
CMC-TMA-106	5' Into Water Table	>5' Below Water Table
CMC-TMA-107	Bedrock	Bedrock
CMC-TMA-108	25' Below TMA Base Grades	>25' Below TMA Base Grades
CMC-TMA-109	5' Below Water Table	>5' Below Water Table
CMC-TMA-110	5' Below Water Table	>5' Below Water Table

[1]Lower Till = Pre- to Early Wisconsinan Till.

Prepared by: SVD1
Checked by: SGL1

3.5.1.7 1996 Soil Gas Probe Installation

Borings were completed during the week of July 29 to August 2, 1996 to facilitate installation of two multi-level soil gas monitoring probes in the vicinity of the proposed TMA facility. The location of the borings are shown on Figure 3.5-5. The first multi-level probe (CMC-O2-SE) borehole was drilled to a total depth of approximately 115 feet. The initial borehole diameter was 8 inches with casing driven to a depth of 75 feet to maintain the integrity of the borehole. The remainder of the boring was advanced as a 6-inch borehole. Adherence to dry drilling conditions was observed when feasible. However, water was used to advance the borehole when resistant materials were encountered such as boulders. No drilling mud or additives were used. The second multi-level probe (CMC-O2-NW) borehole was drilled to a total depth of 104 feet. Casing was driven to a depth of 95 feet to maintain the integrity of the 8-in borehole. The remainder of the borehole was advanced as a 6-inch hole. Water was used to advance the borehole only when resistant materials were encountered. No drilling mud or additives were used. Boring construction details are provided in Table 3.5-2. Logs for these borings are provided in Appendix 3.5-13b.

3.5.1.8 Test Pits

Since the late 1970s, several test pit programs have been completed to aid in the evaluation of design alternatives for various mine related facilities. The location of the test pits are shown of Figures 3.5-9 and 3.5-10. Test pit logs are provided in Appendix 3.5-14. The following is a summary of each test pit program:

1979-1981 - Golder Associates complete test pits TP-1 through TP-22 as part of the preliminary design of the tailings disposal facilities.

1980 - Soil Testing Services completed test pits STS-TP-80-1 through STS-TP-80-13 to aid in the design of various plant facilities.

1983 - Soil Testing Services completed test pits STS-SAF-1 through STS-SAF-16 to aid in the evaluation of soil absorption fields that were previously considered, but are not part of the current permit application.

1984 - Soil Testing Services completed test pits STS-84-1 through STS-84-33 for the evaluation of design alternatives for the TMA.

1985 - Soil Testing Services completed test pits STS-85-1 through STS-85-17 to aid in the design of the previously considered mine refuse disposal facility that is not part of the current permit application.

1994-1995 - Foth & Van Dyke completed the TPA, TPB, TPC, TPD and TPE series test pits to aid in the evaluation of soil absorption fields. The estimated hydraulic loading rates shown on the logs contained in Appendix 3.5-14 were estimated from Table O of ILHR 83: Estimated Linear Loadings Rates Based Upon Soil Texture, Structure & Consistency.

1996 - Thresher & Son, Inc. completed TP-F1 through TP-F7 as part of a fragipan investigation near the Bur Oak Swamp. A technical memorandum relating to the 1996 work is also included in Appendix 3.5-14.

3.5.1.9 Soil and Rock Testing

Soil and/or rock sample testing was conducted at various times during exploration for the ore body in the mid 1970s, during subsequent studies in 1977 to 1980, and during 1993 and 1994 to support project permitting.

Bedrock testing consisted of two categories; geochemical and environmental. The geochemical component consisted of assays, petrographic, mineralogic and specific gravity testing to ascertain economic value and quantity of ore as well as methods for concentrating (i.e. milling) the mined ore. Previously collected core samples and tailings material produced during the 1994 lock cycle metallurgical pilot study were used in the waste characterization geochemical tests. The results of the waste characterization testing, discussed in greater detail in Section 3.5.5, have been used in developing the TMA design, developing management techniques for project generated waste rock and in the solute transport modeling work.

Additional testing to determine the physical characteristics of tailings, including specific gravity, grain size distribution, settling tests and consolidation are discussed in detail within the *Tailings Management Area Feasibility Report/Plan of Operation* (Foth & Van Dyke, 1995c). The findings generally indicate that approximately 90 percent of the whole tailings will pass the 200 sieve. The tailings are non-plastic, and exhibit a hydraulic conductivity on the order of 2×10^{-6} cm/sec (5.7×10^{-3} ft/day).

Environmental testing of the waste rock, ore, backfill tailings and tailings was conducted to characterize the leachate which would potentially be generated if these materials are exposed to weathering for extended periods of time. This testing, described in detail in Section 3.5.5 under the category of waste characterization, was also conducted to determine the chemical reactivity of the materials to determine their leaching and oxidation rates or their ability to remain in a neutral state.

Soil testing consisted of laboratory analyses to define grain size distribution (i.e. particle size analysis) using ASTM Part 19, D422; carbonate pebble content expressed as percentage by weight; tri-axial compressive strength; Atterberg limits using ASTM D 423 and D424; moisture content using ASTM D2216; pH; color using the Munsell Soil Color Chart; and clay mineralogy analyses by x-ray diffraction technique. The soil testing results were used for establishing slope stability design criteria for soil in the vicinity of the TMA and for confirming hydraulic loading capacity of the Late Wisconsinan Till and the glacial outwash. Soil studies were also conducted to determine the ability to attenuate or bind up metals and to form stable compounds.

3.5.1.10 Quality Assurance/Quality Control Procedures

The general procedures for handling core and soil samples which were followed to provide valid field and laboratory data are summarized below.

3.5.1.10.1 Core Drillings, Assaying and Data Analysis

All drilling operations were supervised by qualified field representatives who determined hole locations, orientations and depth and monitored the drilling. Recovered diamond drill core was loaded into boxes in the field which were marked with the drill hole number and footage interval. The core boxes were then transported to the core logging and processing site where the core was logged by a geologist using standard logging procedures. Core recovery measurements were made and recorded. Lithologies, alteration, mineralization and structures, including angle of core to bedding, were noted. Geotechnical data, including fracture frequency and orientation, were noted. All data was recorded on standard logging sheets. Drillers logs were maintained for all holes in addition to the geological logs.

After each hole was logged and the assay intervals designated, the following quality control procedures were followed:

- The core was split in half using a hydraulic splitter or rock saw.
- Half of the core was returned to the core box and returned to storage.
- The other half of the core was then prepared for assaying.
- Core to be assayed was then crushed, split and pulverized to a minus 200 mesh pulp.
- The pulp was then rolled to homogenize the sample prior to separating 100 grams for assaying.

Various laboratories were used to perform assays and to check assay work, including Skyline Assay Laboratory, Hazen Research, Union Assay Laboratory, Bonder-Clagg and Lakefield

Research. Check assays were typically performed by analyzing a duplicate on every tenth sample by the primary lab and by a secondary lab. Laboratory procedures included wet chemistry, atomic absorption, x-ray florescence and fire assay techniques to determine the mineral content of the samples. All results were reported on standard lab assay sheets. For some specialized assay programs, such as waste characterization studies, chain-of-custody forms were used to document movement of samples.

3.5.1.10.2 Surficial Geology and Hydrogeologic Drilling Programs

All drilling operations were supervised by qualified field representatives who classified the soils encountered in the test borings and collected samples for laboratory testing. All groundwater monitoring well installations were monitored, and records of construction details were maintained. In addition, the development of the wells after construction was monitored. Monitoring well construction information and development data were reported on daily memos of field activities or in field books. Recordings of groundwater levels in monitoring wells, groundwater sampling from monitoring wells and in situ permeability tests were conducted. Field investigations were completed by Dames and Moore, Golder Associates, STS Consultants Ltd., Braun Engineering, Camp, Dresser & McKee, and Foth & Van Dyke. The quality control and quality assurance of the groundwater monitoring program is discussed in more detail in Section 3.6.

During the drilling for monitoring well installation, soil samples were collected according to ASTM D-1586. An exception to this standard procedure was made during the saprolite drilling program by Foth & Van Dyke, in which a continuous "core" of soil was retrieved using the Rotasonic™ drilling technique.

During 1994 and 1996 work, each boring was logged in the field by a geologist, hydrogeologist, geological engineer or groundwater hydrologist. The soil and rock samples were described and classified using the Unified Soil Classification System (USCS) according to ASTM Standard D-2488, *Description and Identification of Soils* (ASTM, 1988). Munsell Color notation was used to describe the color of soil and rock samples (Munsell Color, 1975). Soil samples selected for lab analyses were transported from the site to the testing laboratory according to ASTM Standard D-4220, *Preserving and Transporting Soil Samples* (ASTM, 1988). Soil samples were analyzed for grain-size distribution according to ASTM Standard D-422 and Atterberg Limits were determined according to ASTM D-4318 (ASTM, 1988).

3.5.2 Regional Geology

The project area is located, as defined by Olcott (1968), in the Fox-Wolf River Hydrologic Basin. On a regional scale, the geologic conditions around the study area consist of metavolcanic Precambrian bedrock, which hosts the ore body, and is overlain by deposits of glacial till and outwash. These components are described below.

3.5.2.1 Regional Bedrock Geology

The Precambrian bedrock in northern Wisconsin is similar to, and is the southern extension of, a province of the Canadian Shield, referred to as the Southern Province. As shown in Figure 3.5-11, this Province is one of seven Canadian Shield rock provinces consisting of rocks

ranging in age from 960 to 3,200 million years as described in Table 3.5-5 (DNAG, Geology, 1983).

Volcanic rocks are found within the Southern Province as irregularly shaped belts surrounded by granitic and gneissic rock. These belts are comprised of volcanic flows and pyroclastics with interbedded sedimentary rocks such as shale, sandstone and conglomerate. Locally, the volcanic belts are intruded by large masses of granite or granodiorite. It is within these volcanic belts that zinc and copper sulfide deposits in Wisconsin have been found.

These sulfide deposits are generally tabular shaped bodies consisting of more than 50 percent sulfide minerals by volume. The principal sulfide mineral found in these deposits is pyrite (iron sulfide) with lesser amounts of sphalerite (zinc sulfide), chalcopyrite (copper sulfide), galena (lead sulfide), and trace amounts of gold and silver. Some zinc sulfide deposits are underlain by a stockwork of chalcopyrite veinlets that may contain quartz and pyrite.

In Wisconsin, three major ages of Precambrian rocks are exposed. Of these, the Middle Precambrian rocks, which are described below, are of interest in the study area.

- Early Precambrian (Archean, older than 2,500 million years). Rocks in the Early Precambrian are among the oldest in North America. Most of the rock is granitic gneiss, 3,200 million years old, containing minor amounts of volcanic rock that have been folded and intruded by granite (Sims, 1976; Sims and Peterman, 1976).

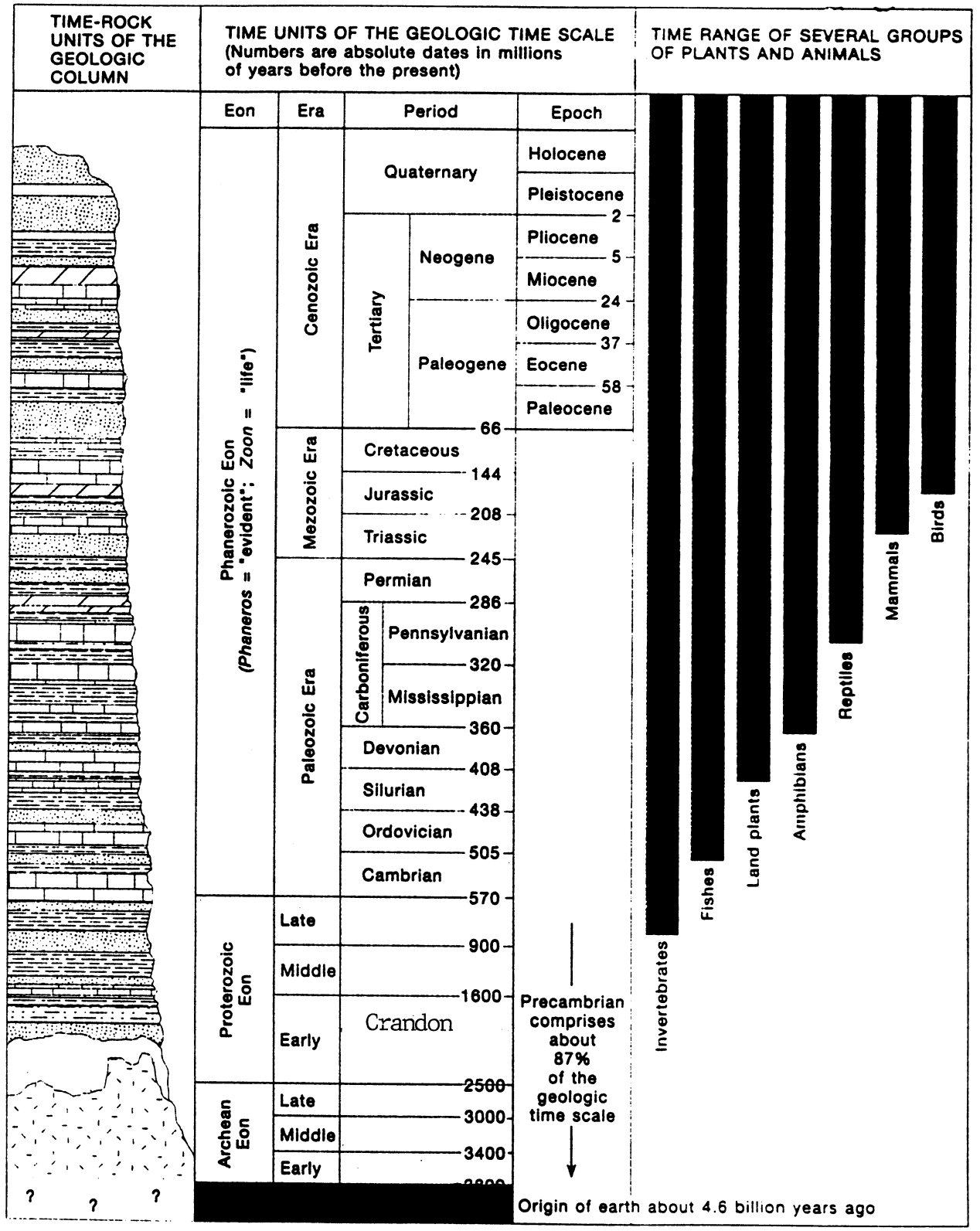
- Middle Precambrian (Early Proterozoic, 1,600 to 2,500 million years). Beginning about 2,100 million years ago, sediments began to accumulate in northeastern Wisconsin. Well-known sediments deposited during this period are the iron formations which host the iron ore of the Gogebic and Florence areas (James, et. al., 1968). To the south, flows and volcanic sediments were deposited in a large trough extending across Wisconsin from Ladysmith to Marinette. It is within this volcanic belt that the massive sulfide ore deposits at Ladysmith (Flambeau and Thornapple), Rhinelander (Lynn and Pelican) and Crandon are found. About 1,800 million years ago, during the Penokean Orogeny, this volcanic belt was faulted and folded and intruded by granite (Goldich, 1972; Maas, et. al., 1977). Erosion followed, and quartz-rich sandstone was deposited to the south and west in the vicinity of Rusk and Barron counties.

- Late Precambrian (600 to 1,600 million years). During this period, quartz-rich sandstone continued to be deposited in western Wisconsin. About 1,500 million years ago, a large body of granite, the Wolf River batholith, was emplaced in east-central Wisconsin (Van Schmus, et. al., 1975). The northernmost area of Precambrian rock in Wisconsin is composed of a sequence of basaltic flows with interbedded sedimentary rocks. These basalt flows accumulated in a large trough or rift, which formed about 1,100 million years ago and extended from Lake Superior into Kansas; a distance of over 1,000 miles (Sims, 1976). Deposits of copper occur in some of these rocks in the Upper Peninsula of Michigan. Near White Pine, Michigan, deposits of copper are also found in a shale.

There has been no major folding, fault, or igneous activity in the Southern Province of the Canadian Shield since the Precambrian era.

Table 3.5-5

Geologic Time Scale



Geologic time scale. *(from A. R. Palmer, The decade of North American geology, geologic time scale, Geology 11:503–504, 1983.)*

3.5.2.2 Regional Pleistocene Geology

The majority of unconsolidated sediments in the study region, and across Northern Wisconsin, consist of glacial drift. Deposits from a number of major glacial advances have been recognized in Wisconsin. In the study region the majority of the unconsolidated sediments were deposited during the Wisconsinan Age. Sediments of pre-Wisconsinan Age are present locally above the bedrock. The pre-Wisconsinan sediments are generally buried by Wisconsinan Age sediments.

The unconsolidated pre-Wisconsinan deposits of the Forest County area include undifferentiated sediments of the Marathon Formation. Pleistocene units younger than the Marathon Formation are early to pre-Wisconsinan undifferentiated sediments of the Lincoln Formation, and the Wisconsinan Mapleview Member of the Horicon Formation. The youngest Pleistocene unit in Forest County is the Nashville Member of the Copper Falls Formation. The Nashville Member, deposited by the Langlade Lobe, is considered the stratigraphic equivalent of the Green Bay Lobe Mapleview Member of the Horicon Formation. In Forest County, the Nashville Member overlies and truncates the Mapleview Member.

The Marathon Formation, a dark brown calcareous till, underlies the Lincoln Formation and the Mapleview Member of the Horicon Formation (Simpkins, et. al., 1987). The Marathon and Lincoln Formations are the oldest glacial units of the region. The Marathon Formation contains till and associated sand and gravel. This unit generally thickens northward. The extent of the formation below the Copper Falls Formation and Horicon Formation is not known (Mickelson, et. al., 1984).

The Marathon Formation typically contains a pebbly loam to clay loam till which is frequently thin (less than 10m) and found directly overlying bedrock, grussified bedrock or saprolitic bedrock-weathering residuum (Mickelson, et.al., 1984). Organic material overlying the youngest member of the younger Lincoln Formation has been radio carbon dated at 40,800 ± 2,000 (beyond reliable radio carbon dating range), making the Marathon Foundation presumably pre- or Early Wisconsinan in age.

Overlying the Marathon Formation are discontinuous deposits of sediments belonging to the Lincoln Formation. In the Forest County region, these sediments are undifferentiated. The pre- or Early Wisconsinan Lincoln Formation includes red-brown sandy loam till and associated sand and gravel (Mickelson, et. al., 1984). This formation also may directly overlie saprolite or bedrock. The Lincoln Formation in the area is generally greater than 40,800 ± 2,000 years BP, making the formation Early - Mid Wisconsinan. The Lincoln Formation probably makes up the majority of sediments found below the Late Wisconsinan deposits.

The Mapleview Member of the Horicon Formation overlies the Marathon and Lincoln Formations. The Mapleview Member of the Horicon Formation was deposited by ice from the Green Bay Lobe in Late Wisconsinan time around 15,000 or 14,000 B.P. (Mickelson, et al., 1984). The Mapleview Member consists mainly of cobbly, pebbly, silty sand till with boulders and associated sand and gravel (Mickelson, et. al., 1984). According to Mickelson, et. al. (1984), the Mapleview Member is at least partly contemporaneous with the Nashville Member of the Copper Falls Formation deposited by the Langlade Lobe. In the vicinity of the site, the Mapleview Member is truncated and overlain by the Nashville Member of the Copper Falls Formation.

The majority of the surficial sediments in the Forest County Region belong to the Nashville Member of the Copper Falls Formation. The Nashville Member consists of a pebbly, cobbly sandy loam till with numerous sand lenses and associated sand and gravel (Mickelson, et al., 1984). Till of the Nashville Member, in Forest County, is generally exposed at the surface in drumlins clustered on upland areas (Simpkins, et. al., 1987). The associated meltwater sands and gravels have filled in low areas around the uplands in pitted and unpitted outwash plains. In the region, the Nashville Member is of Late Wisconsinan Age and stratigraphically equivalent to the Horicon Formation. Locally it is overlain by post-Pleistocene sediments, consisting of wind-blown silts and fine sand, organic deposits of grass-sedge, moss and woody peat, and modern alluvium (Simpkins, et. al., 1987).

3.5.3 Geology of the Study Area

The study area is located within the Northern Highlands physiographic province (Martin, 1965), a region of rolling terrain that reflects its glacial origins. Figure 3.5-12 illustrates the topographic features of the area. Ground surface elevation in the area ranges from less than 1,550 feet MSL near Rolling Stone Lake, approximately three miles south of the ore deposit, to more than 1,750 feet MSL, approximately five miles northwest of the ore body.

The ground surface is variable, from nearly flat in floodplain and basin areas, to a grade of approximately 25 percent. Area topography is characterized by a general southwest trend of ridges and intervening valleys. This trend reflects the southwesterly advance of the most recent Woodfordian glacier, which reshaped the pre-existing topography. Processes associated with the Woodfordian glacier deposited new material on the reshaped uplands and valleys. This southwest trend is especially apparent in the upland areas five to ten miles northwest of the deposit where elongated elliptical ridges, or drumlins, have approximately 100 feet of vertical relief. The southwest trend is also apparent in the Swamp Creek valley and in the orientation of the prominent ridges south of Mole Lake and immediately to the east and west of the ore deposit.

3.5.3.1 Study Area Bedrock Geology

The Crandon deposit, which is composed of two distinct mineralization types, zinc ore and copper ore, is of submarine volcanic origin. The minerals were deposited during the Precambrian era, about 900 to 2,500 million years ago. The deposit was formed at and just below the ocean floor by mineral-bearing fluids of volcanic origin. Some of the materials deposited by this volcanic system were sulfide minerals, which accumulated in low spots on the ocean floor. Continued accumulation of other volcanic materials and sediments buried the sulfide deposit. Deep burial, 33,000 to 50,000 feet, resulted in lithification and metamorphism, which hardened and solidified both the host rock and the sulfide deposit over time. Later, a mountain building phase occurred in the region, tilting the volcanic layers and the deposit to its present near vertical position. The deposit may have been covered by younger sediments, however weathering and erosion have removed these later rocks. The more recent geological process which has affected the deposit is related to Pleistocene glaciation, which left the bedrock deposit buried under unconsolidated glacial till.

The Crandon ore body is long and tabular with an approximate average width of 100 feet, north-south, and a strike length of 4,900 feet, east-west. Based on the current level of drilling, the ore

body extends to an approximate depth of 2,200 feet. The interpreted geologic stratigraphy and ore body configuration are shown on Figures 2-4 and 2-5 of Section 2, respectively.

The bedrock in the hanging wall and in the footwall of the ore body consists of a series of fragmental volcanic rocks, fine tuffs (solidified volcanic ash), debris flow (ocean floor and volcanic-derived sediments), breccia (blocky, angular particles), lapilli tuffs (gravel sized volcanic material) and flows.

The Crandon bedrock was formed during two volcanic cycles that deposited rock locally referred to as the Hemlock Creek and the Swamp Creek groups (Schmidt, et. al., 1978; Lambe & Rowe, 1987). Each group is informally subdivided into formations that are composed of rock of a similar lithologic character and depositional history. Frequently, members of distinct lithologic character have been identified in the formation.

A plan view showing the subcrop geology of the study area is presented on Figure 3.5-13. In the vicinity of the plant site, the geologic formations described in the stratigraphic section are used. Outside the study area, where formational names have not been assigned, descriptive geologic terminology was used. Because of plotting density, all of the nearly 200 holes in the plant site were not plotted. Stratigraphic and lithologic descriptions of the geology of the site area are presented in the following paragraphs. Figures 3.5-14 through 3.5-17 provide supporting documentation for these descriptions.

Diamond core holes 136, 201, 202, and 208 penetrate the bedrock immediately to the southwest of the ore deposit as shown on Figure 3.5-14. The figure represents an approximately north-south stratigraphic cross section through the area west of the ore body. The bedrock is a fairly monotonous sequence of fine and coarse grained tuffs. A gabbro dike is present in this area and has been correlated with the gabbro dike (dg) underlying the ore body because of similar thickness and textural characteristics.

Referring to Figure 3.5-15, the rocks of the first volcanic cycle are referred to as the Hemlock Creek Group. These rocks are not labeled on the figure, but occur south (left) of the Crandon Formation. The lower portion of the cycle is a series of basaltic flows of the Nashville Formation. The base of the flows has not been encountered in drilling. Overlying the flows of the Nashville Formation is the Sand Lake Formation, a thick sequence of tuff with interbedded coarser volcanic debris. Some of the upper portion of this formation consists of a sequence of volcanic breccias composed of angular, dark, chloritic altered fragments and less angular, light-colored siliceous fragments. This sequence of breccias, referred to as the Township Member, formed when hot water and steam from a submarine volcanic system explosively erupted on the sea floor and shattered the preexisting rock. The silicified breccias and tuffs of the Sand Lake Formation were later refractured and locally filled with quartz, chalcopyrite, and pyrite to make up the copper ore.

The breccias are overlain by a sequence of volcano-sedimentary rocks referred to as the Crandon Formation which consists of fine tuff, chert, argillite, and sulfide. The sulfide commonly contains economic amounts of sphalerite with lesser amounts of copper, lead, and silver, and is called the zinc ore. The rock is generally fine grained, thin bedded, and contains no coarse volcanic debris, indicating a period of relative quiescence. All rocks beneath the Crandon Formation are referred to as the stratigraphic footwall and all rocks above the Crandon Formation are referred to as the stratigraphic hanging wall.

The thick chloritic tuff of the Mole Lake Formation, which consists of several lithologic units, overlies the Crandon Formation. Locally, the Prospect Member, a thin unit composed of subrounded siliceous debris, is contained within the Mole Lake Formation near its base. A wedge of cherty tuff, the Oak Lake Formation, interfingers with the chloritic tuff of the Mole Lake Formation at the western end of the deposit. A thick series of volcanic debris and pumice flows, referred to as the Rice Lake Formation, overlies the chloritic tuff of the Mole Lake Formation. Typically, these debris and pumice flows are characterized by angular, somewhat flattened, dark chloritic fragments in a light-colored matrix. Overlying the volcanic debris are the chert, cherty tuff, and tuff of the Skunk Lake Formation, representing the top of the Hemlock Creek Group.

The base of the Swamp Creek Group is marked by flows of the Lincoln Formation, which also contains small amounts of tuff and argillite between the flows. The flows are rhyolitic in composition. Cherty tuff and tuff of the Pine Formation overlie the flows and form a wedge thickening to the west. Interbedded mafic flows are common, especially to the east. Epiclastic sediments of the Forest Formation overlie the Pine Formation on the north. These muddy, sandy sediments contain much terrigenous debris and are highly susceptible to weathering.

The geology between the epiclastic breccia and Swamp Creek Group is not well known. Core from the upper part of holes 164, 156, 157, and 158 indicate intermediate to mafic tuffs and flows. A bedrock core from hole EX-5 consists of relatively felsic fine-grained tuff.

Two holes were drilled for bridge foundation studies at the proposed road crossing at Swamp Creek. Holes AR-1A and AR-2A, Figure 3.5-6, both penetrated bedrock at a relatively shallow depth of 23 feet. Recovered cores consisted of a very siliceous material. A sequence of fine-grained tuff, crystal tuff, lapilli tuff, and intrusive rocks is located north of the siliceous ridge.

Six approximately 1,000-foot bedrock diamond drill core holes were constructed near the proposed area for the TMA. A few meters of bedrock core were also collected from the bottom of six Golder, G series, glacial overburden holes in order to further delineate bedrock geology. A plan view of the geology in the proposed TMA area is shown on Figure 3.5-13. Two north-south bedrock cross sections in the area are presented on Figures 3.5-16 and 3.5-17. The rocks are predominantly a fine-grained tuffaceous sequence, with crystal tuffs predominating. The unit labeled "flows" is a series of 10 to 50-foot thick flows commonly with interflow tuff beds. The laminated tuff sequence to the north of the flows is very fine grained, indicating a distal volcanic source and quiet conditions. A crystal tuff sequence is located north of the laminated tuff.

3.5.3.1.1 Bedrock Morphology

Within the study area, as shown on Figure 3.5-18, the top of bedrock forms an irregular surface. Figure 3.5-18 was constructed using data obtained from project related exploration drilling and environmental drilling. The figure shows that higher bedrock elevations occur over the ore body than in the area surrounding it. Primarily this occurs since the rock in the footwall has been silicified by hydrothermal fluids. Much of the hanging wall rock also consists of siliceous volcanic units. Silica is generally resistant to weathering and erosion. Likewise, an east-west trending bedrock high north of the plant site and south of Swamp Creek is also attributable to siliceous rock, which was encountered in holes AR-1A and AR-2A (Figure 3.5-13).

Higher bedrock elevations may also be emphasized by structural trends, or by previous surface water drainage patterns. For example, the higher east-west trending bedrock elevation south of Swamp Creek is especially prominent because the preglacial surface water drainage eroded an east trending valley to the south, southeast of the high. This valley may have followed a structural trend, causing it to weather more rapidly than surrounding terrain.

Structure alone does not produce lower bedrock elevations. For example, in the area of the proposed TMA, the bedrock is relatively flat. From observation of drill core in holes 199, 206, 200, and G41-C15, it is apparent that an east/west structural zone trends through the sediments and laminated tuff unit, which is the least competent unit in the stratigraphic sequence.

The last major geologic change in the area occurred between 12,500 and 75,000 years ago, when much of northern and central Wisconsin was covered by continental glaciers. The glacial activity deposited from 100 to 230 feet of Pleistocene overburden on top of the Crandon ore deposit.

3.5.3.1.2 Ore Body Geology

The Precambrian bedrock, including the ore body, were deposited during two volcanic cycles, referenced as the Hemlock Creek and the Swamp Creek groups. The formations and members that comprise these two groups are illustrated with descriptions on Figure 3.5-19. The rock formations strike approximately north 80 degrees west and dip 70 to 90 degrees north, as illustrated on Figures 3.5-20, 3.5-21 and 3.5-22.

The Crandon sulfide deposit is identifiable for a distance of approximately 5,000 feet along strike and to a depth of approximately 2,400 feet below the bedrock surface. The economic portion of the deposit or ore body is somewhat smaller, with a strike length of 4,900 feet east-west and extending to a depth of 2,200 feet below the bedrock surface. Its thickness varies from less than one foot on the west to 250 feet near its center (Schmidt, et. al., 1978; Lambe & Rowe, 1987).

Within the Crandon deposit, there are two distinct ore types, designated as zinc ore and copper ore. They occur in nearly equal amounts. The main zinc ore mineral in the deposit is sphalerite, a zinc sulfide. The zinc ore consists of layers of concentrated sphalerite within the sediments of the Crandon Formation. The main copper ore mineral is chalcopyrite, a copper-iron sulfide. Copper ore consists of quartz-chalcopyrite veins in the breccia and tuff of the underlying Sand Lake Formation.

The zinc ore forms a tabular body with a length of 4,260 feet extending to a depth of 2,200 feet, and varying in thickness from 0 to 200 feet. The ore body strikes approximately north 80 degrees west and dips from vertical to 75 degrees northward (Figures 3.5-20 and 3.5-22). The ore consists primarily of bands of sphalerite with minor chalcopyrite and galena interbedded with pyrite. Total sulfide content of the ore averages 70 percent by volume. The remaining 30 percent of the ore generally consists of quartz or chlorite.

The copper ore consists of a network of quartz-chalcopyrite-pyrite veins that crosscut the breccias in the Sand Lake Formation, approximately parallel to and beneath, or to the south of the Crandon Formation zinc ore. The copper ore body is 4,590 feet in length, extends to a depth of 2,200 feet, and ranges from 0 to 160 feet in thickness. Chalcopyrite is the important ore mineral which occurs as stringy or patchy grains in quartz veins. Sphalerite and galena are not common

in this ore. Small, but persistent amounts of carbonate minerals are found in the ores and enclosing rocks (Nimjee, 1979; Rowe, 1980).

Near the surface, the ore body has been partially oxidized and leached. The oxidation of chalcopyrite and subsequent downward percolation of copper bearing water has resulted in the formation of supergene chalcocite, a copper sulfide, which is redeposited as thin films on the pyrite. Chalcocite occurs only in small amounts, generally in the upper 350 feet of bedrock.

The Crandon deposit does not display any major folding or faulting. Minor faulting or shearing exists along the Crandon Formation-hanging wall contact. This minor faulting developed in thin, incompetent beds in response to stress release and prompted the weathering of the Crandon Formation rocks, which is discussed below. Other small fault zones have been observed in drill core, but they can seldom be correlated from drill hole to drill hole.

3.5.3.1.3 Bedrock Weathering

The Crandon deposit has been subjected to weathering since the late Cambrian and perhaps earlier as the area has been one of positive relief since that time. Weathering is the destructive process or group of processes causing the physical disintegration and chemical decomposition of bedrock. The primary agent of destruction is water, commonly containing dissolved oxygen. Over geologic time, the thickness and profile of the weathered bedrock would have varied considerably, depending upon environmental conditions.

In describing the weathered rock at Crandon, drill core was evaluated with respect to the destructive processes of oxidation, leaching, argillization (pervasive clay development), and fracturing (Rowe, 1982). This work was conducted to estimate the mechanical strength of the rocks in relation to developing an underground mine and its attendant facilities. All of the mentioned processes are destructive to the mechanical strength of the rocks. The actual processes are not visible but the byproducts resulting from the processes affecting the rocks are visible. The extent to which each destructive process has affected the material sampled by the drill core was classified by relative intensity as shown on Table 3.5-6.

After each of the effects was evaluated and rated for a specified interval of core, an overall rating of weathering intensity was applied that reflects the severity of the effects of the combined destructive processes. Figure 3.5-23 is a generalized cross section illustrating a typical north-south weathering profile of the Crandon ore deposit rock. The weathering profile and the effects of the destructive processes vary considerably between the stratigraphic footwall, Crandon Formation, and the stratigraphic hanging wall. This is in response to the primary mineralogy and texture of the rocks, and the physical-chemical conditions acting upon them.

The footwall rocks referred to in this discussion are the rocks south of the Crandon Formation, as seen in Figure 3.5-21. The footwall rocks are unique, not only because they contains the copper ore zone, but also because they have been strongly silicified and pyritized by the hydrothermal solutions that created the copper zone ore body. Because of their siliceous character, these rocks are generally more resistant to the destructive weathering processes.

Table 3.5-6

Destructive Processes and Weathering Intensity Ratings

Destructive Processes		
Oxidation	Total:	Total oxidation of all sulfides.
	Partial:	Partial oxidation of all sulfides.
	Trace:	Traces or small quantities of transported and/or indigenous limonite on fractures or bedding planes.
Leaching	Strong:	>5 volume percent secondary porosity.
	Moderate:	2-5 volume percent secondary porosity.
	Weak:	Trace-1 volume percent secondary porosity.
Argillization	Strong:	Pervasive strong development of clay. Rock soft and breaks easily. (Rock easily gouges with nail.)
	Weak:	Weak or partial clay development, but rock does not break easily.
Fracturing	Strong:	>20 fractures/foot.
	Moderate:	5-20 fractures/foot.
	Weak:	1-4 fractures/foot.

Weathering Intensity Rating	
Strong:	Strong development of two or more of the destructive processes. Rocks will have low compressive strengths, and mine workings would likely require support.
Moderate:	Strong development of one of the destructive processes (or moderate development of two) and weak to moderate development of at least one more. Rocks may or may not require ground support, depending upon which destructive processes have been active. Strong development of argillization or fracturing may make the rock weak or unstable, whereas strong development of oxidation or leaching may not seriously affect its ability to permit unsupported mine openings.
Low:	Moderate leaching with only minor other effects. The compressive strength of the rock is not significantly reduced.
Weak:	Weak development of leaching and/or oxidation. Rock strengths are not affected.

Source: Rowe, 1982
Checked by: SVD1

The primary destructive weathering process that affected the footwall rocks is leaching. Leaching is generally in the moderate range for a few tens of meters beneath the subcrop, gradually reducing to the low and weak range (see Figure 3.5-23). The base of the leached zone is somewhat irregular but is not as highly erratic as the Crandon Formation weathering profile discussed below.

The Crandon Formation is more deeply weathered than the footwall rocks because of the presence of thin, interbedded tuffs, high sulfide content, (50 to 90 percent), and minor faulting or shearing. The primary process that affected the Crandon Formation was leaching. Leaching in the ore was enhanced by the past oxidation of the sulfide minerals. The most prominent feature that resulted from the enhanced leaching is a weathering "groove" along the hanging wall side of the Crandon Formation or locally within the Crandon Formation. The groove penetrates to a depth of approximately 1,100 feet in one area. Near surface, the groove actually runs the length of the Crandon Formation and is highly irregular.

The hanging wall rocks are weathered differently from either the Crandon Formation or the footwall rock because the hanging wall rocks are relatively homogeneous, not as silicified, fine-grained chloritic tuff that contain small amounts, generally less than one percent, of sulfides. Argillization is the primary destructive process in the hanging wall rock. Moderate weathering commonly penetrates to a depth of 160 to 245 feet. Chlorite within the rocks can be converted to a kaolinitic clay in the presence of water and low temperature/pressure environments. Relatively strong fracturing is common in the upper 30 to 160 feet, gradually fading in intensity with depth. This type of fracturing is likely to be caused by unloading stress, both weathering and glacial rebound, and near-surface ground movements in the weakened weathered rock.

3.5.3.1.4 Weathering Influences on Rock Permeability

A generalized permeability profile for the bedrock of the mine site area is presented on Figure 3.5-24. The following discussion, and supporting data on bedrock permeability, are based on information presented in the report entitled *Bedrock Permeability* by Exxon Minerals Company (Rowe, 1984).

In the footwall, strong, moderate, and low weathered rocks were all classified by Rowe as moderately permeable. Weakly weathered rock was classified as weakly permeable. No rock was classified as strongly permeable in the footwall.

Per Rowe, high relative permeability in the Crandon Formation is associated with the deeply leached weathering groove. It is also associated with the near-surface siliceous zinc ore, some of which has been oxidized to gossan near the bedrock surface. The weak relative permeability is not only associated with weakly weathered rocks, but more importantly, with oxidized chloritic massive sulfide near the subcrop (Rowe, 1984). The chloritic gangue weathers to kaolinitic clay which results in a significantly reduced permeability. All other strong, moderate, and low-weathered rock was classified as moderately permeable.

Hanging wall permeability was estimated to be consistently in the moderate to weak range in the moderately and weakly weathered rock. This occurs because the kaolinitic clays formed during weathering of chlorite are relatively mobile and have been transported to fill the channelways in the rock thereby reducing the potential for fluid movement. In the strongly weathered rock,

permeabilities are considered to have increased slightly to the upper range of moderate permeability (Rowe, 1984).

The weathering profile is deeper in the vicinity of the ore body when compared to the surrounding rock. The deepening of the strong and moderate weathering in these rocks is a chemical weathering response to the acidic groundwater solutions generated by the leaching of sulfides in the adjacent Crandon Formation. It is also a physiochemical response to the weak movements, shearing and fracturing, along or near the upper contact of the Crandon Formation with the hanging wall rock, which promoted the circulation of groundwater along that contact.

In the TMA area, the bedrock weathering profile has been traced on the geologic cross sections in Figures 3.5-16 and 3.5-17. The intensity of weathering appears to be controlled primarily by rock type. On both cross sections, Figures 3.5-16 and 3.5.17, any core from the flows or from the crystal tuff-tuff breccia are essentially unweathered. This is likely the result of a higher silica content in these rocks compared to the surrounding rocks, and because the original rock porosity in these rocks is lower. The surrounding rocks are more heavily altered to chlorite by regional metamorphism because of their primary texture and mineralogy.

The degree of weathering is related not only to rock type, but is also related to fracture zones, which facilitate water movement and allows for more rapid and deeper penetration of weathering on a geologic timeframe. Fracturing and primary rock type are often related, since earth stresses tend to be released in the least competent stratigraphic units. This phenomenon is illustrated by examining borings 199, 200, 206, and G41-C15, all of which penetrate the sediments and laminated tuff unit (Figures 3.5-16 and 3.5-17), the least competent stratigraphic unit in the TMA area. The rocks in these borings are fractured near the surface. Adjacent competent stratigraphic units, found in borings 203, 205, and G41-E17, contain little to no fracturing. Because prominent fracturing is generally restricted to incompetent stratigraphic units, water movement will be essentially linear, along the trend of the fractures. Should the trend of the fractures not be parallel to the hydraulic gradient, flow will be limited further.

Only one piezometer (EX-9AL) was set in bedrock in the vicinity of the TMA. The boring was drilled to test the glacial aquifer and penetrated ten feet into bedrock without recovering core. Permeability testing in the bedrock resulted in an estimated permeability of 5.1×10^{-5} ft/d (1.8×10^{-8} cm/s) (STS Consultants, Ltd., 1984). This bedrock permeability test in the TMA was located in rock similar to the mine site hanging wall rock where there are results from several permeability tests (Rowe, 1984). Not only is the rock similar in composition, but the active destructive weathering effects are also similar. There is no evidence or reason to believe that permeability values are different.

In addition to the Rowe (1984) work discussed above, a comprehensive February 1995 report titled *Bedrock Hydrogeology at the Crandon Site* prepared by Foth & Van Dyke (Foth & Van Dyke, 1995b) summarized the current level of information and understanding that exists regarding the permeability of bedrock at the Crandon site. Some of the key findings of this report, reproduced in Appendix 3.5-15, include the following:

- The density of bedrock borings, and their associated southwest or southeast trending trajectories, allow for sufficient evaluation regarding the potential existence of significant north-south trending faults and fractures.

- Based on extensive bedrock delineation there is no significant disruption, displacement, offset or folding of key stratigraphic horizons in either the Crandon deposit or host rock.

- Fracture studies for the Crandon Project show that interconnected fractures are limited to the near surface bedrock in the hanging wall and footwall surrounding the Crandon Formation. Within the Crandon Formation, interconnected fracture patterns exist to depths of about 1,000 feet.

- Fracture studies show that fractures are most prominent along east-west trending trajectories that nearly parallel the strike of bedding planes. Fractures are least common along north-south trending trajectories.

- Fracture studies show that at depth, after millions of years, there is little evidence of water movement, in the hanging wall and footwall rocks.

- The weathering intensity is at its maximum extent within the Crandon Formation where it extends to a depth of about 1,100 feet in one area.

- Weathering decreases in depth and intensity as one moves north in the hanging wall away from the deposit. This is a reflection of the proximity to the massive sulfide mineralization and its attendant near surface oxidation. At the 400N projection, weathering is limited to near surface bedrock regions extending to a depth of about 250 feet.

- The depth of the weathering intensity is less along the 200S projection in the footwall of the deposit. This is a reflection of the intensity of silicification in the rocks and also the lack of intense sulfide mineralization as compared to the Crandon deposit. Two hundred feet south of the ore body weathering extends to a depth of about 250 feet.

- A young fresh unweathered, nearly vertical, gabbroic dike, the locally named Duck Lake gabbro dike, is likely to form a low permeability barrier immediately south of the ore body. Lateral flow across this dike would likely be limited to the upper 200 to 300 feet, where there is some evidence of water movement.

- Packer test data from the 1970s and 1980s shows that the bulk hydraulic conductivity of the bedrock outside the area of influence of the Crandon Formation is likely to be in the range of 2.8 x 10-2 ft/d (1 x 10-5 cm/s) to 2.8 x 10-3 ft/d (1 x 10-6 cm/s), and does decrease with depth within the respective formations.

- Down hole temperature surveys indicate a smooth regional thermal gradient and the absence of temperature irregularities suggests limited and infrequent water movement.

- Hydrographs of wells screened in the bedrock, compared to wells screened in the glacial overburden, show little evidence of movement of water to, or from, the bedrock.

- Lateral flow at depth within the Precambrian rock occurs from limited sources of water contained in isolated fractures. Since these fractures are likely discontinuous, and unlikely to extend to the bedrock surface, drainage of these waters will not induce drawdown in the near surface bedrock, and therefore will not induce additional leakage from the glacial overburden.

- Grouting techniques can be an effective method to control point sources of inflow from the Precambrian crystalline rock.

- Practical experience from many mine sites located in Precambrian crystalline rock show that lateral flow of groundwater from the Precambrian rock is minimal and limited to the near surface regions of the bedrock.

- Domestic groundwater use is limited to the glacial overburden. There are no known domestic uses of bedrock groundwater within the immediate vicinity of the mine.

This report was submitted to relevant regulatory agencies and others in February 1995 and was the topic of continuing discussions between the reviewers and CMC at the time the EIR was originally submitted in May of 1995. Since May of 1995 CMC, at the request of the WDNR, completed additional packer tests later in 1995 to verify the permeability of the bedrock surrounding the ore body. The results of the 1995 packer test program in addition to a comprehensive review of bedrock permeability data were described in a report prepared by Hydro-Geo Consultants, Inc. (1995). The Hydro-Geo Consultants, Inc. report is contained as Appendix F of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is contained in Appendix 4.2-3 of this EIR. A summary of the Hydro-Geo Consultants, Inc. (1995) report is provided in Section 3.6.

3.5.3.1.5 Saprolite

Previous investigations in the 1980s described a layer of low permeability materials, termed the resistive layer, over the ore body which would control the seepage of water from the overburden into the mine. A preliminary review of existing samples stored from the 1980s investigations, and new samples collected during the groundwater quality drilling validation program in 1994, potentially identified this resistive layer as massive saprolite. Massive saprolite is a "typically clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous, sedimentary and metamorphic rocks." Below the massive saprolite is structured saprolite, rock which has been weathered to mostly clays, iron oxides and quartz, but still retains the original rock structure. Below the structured saprolite is progressively less weathered bedrock. The massive saprolite at the Crandon Project site is overlain by a thick sequence of glacial deposits. Material now recognized to be massive saprolite was previously described in the geologic logs from pre-1994 investigations as bedrock, weathered bedrock, residuum, lacustrine deposit, and, in some instances, as saprolite.

The identification of the massive saprolite at the Crandon Project site lead to the development of additional investigations conducted in 1994 to confirm its presence, and to determine its physical nature and hydraulic characteristics. Since the reason for conducting these investigations was to provide data for the regional groundwater modeling work, the saprolite and associated materials were classified with regards to their potential for the transmission of groundwater. For example, it was assumed that the structured saprolite would generally be more permeable than the massive saprolite. Therefore some materials that geologically might be classified as being part of the massive saprolite, such as the gossan, were classified as structured saprolite due to the apparent permeable nature of the material. The materials for which this classification was initially used were the existing materials stored since the 1970s and 1980s, many of which were dehydrated. The potential of the materials to transmit water was estimated from morphologic features. The recovery of fresh geologic samples during the 1994 investigations lead to the basic verification of, and to some modification of, the classification.

The 1994 saprolite investigation included the installation of monitoring wells screened above, within and below the massive saprolite; slug tests within these wells; physical analyses of collected soil samples; and a pump test in which the screened interval of the pumping well was installed within a more permeable part of the structured saprolite. The results of the investigation indicate that:

1. The massive saprolite ranges from a silty sand to clay sized material that is generally dark, reddish brown to purple in color over the ore body, and generally lighter in color away from the ore body.

2. Portions of the massive saprolite have limited inclusions of till material within them, suggesting that portions have been slightly reworked by glacial activity at the site. In addition, portions of the till that are in contact with the massive saprolite contain small fragments of massive saprolite-like material, suggesting that part of the massive saprolite was extensively reworked by glacial actions. No intermediate mixtures of the two units were found.

3. Massive saprolite was found within every boring over the ore body with one exception. In that boring till possibly containing fragments of massive saprolite appears to be in direct contact with structured saprolite/weathered bedrock. The thickest parts of the massive saprolite have been developed in the upper part of the Crandon Formation.

4. There are no borings in which outwash sands were found to be in direct contact with weathered bedrock or structured saprolite.

5. The hydraulic conductivity of the massive saprolite as measured by the pump test was 0.04 ft/day (1.4E - 5 cm/s). This hydraulic conductivity is slightly lower than that determined for the till which overlies the massive saprolite. Therefore, the massive saprolite and lower till can be considered to be approximately hydraulically equivalent. The massive saprolite hydraulic conductivity values are similar to those calculated for related materials found at the Flambeau Mine near Ladysmith, Wisconsin (Foth & Van Dyke, 1989).

   The lower till is continuous over the ore body and over the nearby footwall and hanging wall rocks, where it ranges in thickness from about 30-100 feet. The massive saprolite varies in thickness from less than one foot to 80 feet over the ore body. These two units vary in combined thickness from 30 to about 180 feet. The average thickness over the ore body is about 70-100 feet.

6. Due to the approximate hydraulic equivalence of the massive saprolite and lower till, it can be stated that there are no known occurrences where highly permeable sediments are in contact with the structured saprolite/weathered bedrock.

The saprolite and pump test program completed in 1994 is described in extensive detail in a saprolite report prepared by Foth & Van Dyke (1995a). The report was submitted to the WDNR and the USCOE in February 1995 and was the subject of detailed discussions with the reviewers to define how the data generated by the study would be incorporated into the regional groundwater model for the project. The saprolite report can be found in Appendix A of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3. A technical memorandum addressing the comments

raised by the reviewers and the discussions held between CMC and the reviewers regarding this topic precedes the saprolite report.

3.5.3.2 Study Area Local Pleistocene Geology

The bedrock in the study area is covered by approximately 75 to 250 feet of Pleistocene glacial silt, sand, and gravel. These unconsolidated glacial deposits consist of undifferentiated sediments of the Marathon Formation, undifferentiated sediments of the Lincoln Formation, the Mapleview Member of the Horicon Formation, and the Nashville Member of the Copper Falls Formation. Each of these units consists of till and associated meltwater sand and gravels. The Horicon Formation is probably at least partly discontinuous across the site. The surficial sediments on the site belong mainly to the Copper Falls Formation. These are buried locally by wind blown silts, alluvium, peat, and lacustrine sediments.

A series of cross sections depicting the surficial geology through the study area are shown on Figures 3.5-26 through 3.5-32. Figure 3.5-25 is a plan view of the area showing the borings used in developing the cross sections and the location of each cross section. The glacial deposits were interpreted using the data obtained from the numerous borings and geophysical borehole logs, generated for the project and the laboratory soil tests. The results of the various field and laboratory tests used to develop the logs are presented on the logs. The boring logs are included in Appendices 3.5-1 through 3.5-10, 3.5-12, 3.5-13, and 3.5-13a and 3.5-13b. Appendices 3.5-16 through 3.5-28 contain grain size distribution data for all soils tested for the project. Note that regional cross sections E-E' (Figure 3.5-28) and J-J' (Figure 3.5-30) have been updated in accordance with discussions with the WDNR in March and April of 1996. Similarly, cross sections through the TMA have been updated in accordance with the 1996 TMA drilling program.

The oldest Pleistocene deposits in the Crandon region belong to Pre-Wisconsinan Marathon Formation and the Pre- to Early Wisconsinan Lincoln Formation. These units generally overlie saprolite or bedrock. The Marathon Formation is a brown loam to clay loam till and the Lincoln Formation is a red brown to brown cobbly sandy loam till. At the plant site there is a higher percentage of "fines" in the tills near their base due to the incorporation of small amounts massive saprolite into the till. This causes the color of the till in the vicinity of the mine site to be deep red-brown. For the purposes of groundwater modeling, the Marathon and Lincoln Formation tills have been combined on the regional geologic cross-sections discussed below. The complex is referred to as Pre- to Early Wisconsinan till throughout the rest of this report. In the TMA area, the Pre- to Early Wisconsinan unit may also include some massive saprolite. In the 1984 STS report titled *Hydrogeologic Study Update for the Crandon Project* (STS, 1984), this unit was termed the basal till. This unit generally is classified as SM, ML, or GM-GP. The percent passing the #200 sieve for this material is generally less than 50 percent. A representative summary of grain size distributions is shown on Figure 3.5-33. The Pre- to Early Wisconsinan till is continuous across the mine site area.

Outwash associated with Pre- to Early Wisconsinan till and the overlying Horicon Formation till has not been differentiated nor has outwash associated with the Horicon Formation been differentiated from outwash associated with the Copper Falls Formation. This was due to the fact that these deposits have similar physical characteristics and grain size distributions, and that these units are adjacent to one another and are interfingered. For modeling and cross-section purposes, outwash deposits were separated into fine-grained and coarse-grained deposits.

The coarse outwash is fairly continuous across the site and generally occurs between the younger Horicon and Copper Falls Formation tills referred to as the Late Wisconsinan tills, and the older Pre- to Early Wisconsinan tills. The coarse outwash is generally classified as SP, SW, SM-SP,

SM, GP-GM, GP, GW, or GM. A representative summary of grain size distributions for this material is shown on Figure 3.5-34. Generally less than 20 percent of the samples passed the #200 sieve.

Isolated deposits of fine grained outwash occur across the site adjacent to coarse grained outwash deposits. The most continuous of these deposits lies between the Late Wisconsinan till and Pre- to Early Wisconsinan till. The fine outwash is classified as SP, SM-SP, SM or ML. A representative summary of grain size distributions for this material is shown on Figure 3.5-35. Generally less than 40 percent of the sample passed the #200 sieve.

The Mapleview Member of the Horicon Formation and the Nashville Member of the Copper Falls Formation were both deposited during Late Wisconsinan time and are collectively referred to as the Late Wisconsinan till. In the vicinity of the plant site, till of the Nashville Member overlies till of the Mapleview Member. The Mapleview Member consists of a cobbly, gravelly, silty sand till with boulders. Till of the Nashville Member is a gravelly, cobbly, sandy loam. These Late Wisconsinan tills can be differentiated from the Pre- to Early Wisconsinan tills on the basis of the higher fines content and higher degree of consolidation in the older tills.

The Green Bay lobe of the Wisconsin glaciation deposited a sandy, calcareous unit containing approximately two to 56 percent carbonate fragments in the gravel (Michelson et.al., 1974). The color of the suspended silt-clay fraction is generally brown (7.5YR4/6). The last advance of Woodfordian ice to affect the regional study area came from the north and northeast and is termed the Langlade Lobe (Mickelson, et. al., 1974). Deposits from the Langlade Lobe generally overlie the Green Bay Lobe sediments in the vicinity of the site and generally are reddish brown-brown, noncalcareous, nonbedded sand with gravel and some silt and boulders. The Nashville Member is difficult to distinguish from the Mapleview Member; however, it is noncalcareous, generally contains no carbonate gravel, and is reddish brown to brown (5-7.5YR4/6) (Mickelson, et. al., 1974; Mickelson, et.al., 1984).

Sediments from the two lobes are mixed where the ice sheets merged, or were in close proximity to one another. The formations stratigraphically truncate and interfinger one another from continued readvance and retreat of the ice fronts at a given location during Woodfordian time. In some areas, these deposits were overlain and/or separated by bedded sand and gravel and/or sand and silt deposits, termed outwash (Simpkins, 1987).

Differentiation between the Mapleview Member and Nashville Member tills in the study area was made on the basis of the color of the matrix, and the calcareous composition and presence of carbonate pebbles in the Mapleview Member. The initial differentiation in earlier investigations was made during a laboratory examination of the samples based on their reaction to dilute hydrochloric acid. The calcareous Mapleview Member yielded a reaction, but the Nashville Member did not. Particle size analyses and color determination of the suspended silt/clay fraction were performed concurrently. The results of the particle size analyses enabled the samples to be characterized as either ice-laid or water-deposited sediments. The particle size analyses were also used to obtain quantitative estimates of the amount of carbonate fragments in the gravel fraction. Samples with gravel-size fractions were treated with acid by Golder Associates (1981) and Dames & Moore (1981) to identify carbonate pebble content, which was a criterion for indicating Mapleview Member tills. Samples from the Mapleview member had carbonate pebble contents between 0.8 and 35.7 percent, whereas samples with no carbonate pebbles were indicative of Nashville Member tills. The results of the particle size analyses and

carbonate tests are shown in Table 3.5-7. Variations in carbonate content were also used to distinguish till sheets in northeastern Wisconsin by McCartney (1979).

In addition, selected samples were analyzed by X-ray diffraction in earlier investigations to determine their clay mineralogy. The clay minerals montmorillonite and illite were consistently present in all samples. In addition, chlorite was also found in the clay-size fraction in all samples. Kaolinite was present in most samples but in small quantities. The most dominant non-clay mineral was quartz, which was abundant in all samples. The results of these tests are summarized in Table 3.5-8 and contained in Appendix 3.5-29. According to Simpkins, et. al. (1987), the Late Wisconsinan tills contain more illite than the older tills. No differentiation could be made between the Mapleview and Nashville Member based on clay mineralology. However, the results of pH, carbonate content, and color tests were useful in distinguishing between tills.

Due to their similar physical characteristics and contemporaneous stratigraphic position, the Mapleview and Nashville Member tills have been combined for the purposes of modeling and constructing cross-sections. They are referred to as the Late Wisconsinan till. These tills are classified as SM-SP, SC, or SM. A representative summary of grain size distributions for this material is shown on Figure 3.5-36. Usually no more than 50 percent of the sample passed the #200 sieve.

In the vicinity of the plant site, glacio-lacustrine deposits occur locally in the Copper Falls Formation tills and on Pre- to Early Wisconsinan till. These deposits are generally fine grained and varved. The lacustrine deposits are classified as SM-SP, SM, ML, and CL. A representative summary of the grain size distribution of these deposits is shown on Figure 3.5-37. Near the lacustrine deposits occurring above the Copper Falls Formation, ice-marginal facies may also be present.

3.5.3.2.1 Lakebed and Wetland Deposits

Over the past 12 years, five separate studies have been performed to assess the geologic and hydrologic characteristics of the wetlands and lake bed deposits in the vicinity of the plant site. These investigations were conducted to aid in the assessment of potential lake level and wetland water level reductions that might be caused by future mine dewatering. The four characteristics that are key to assessing the potential for drawdown related impacts to these lakes and wetlands are the continuity, thickness and hydraulic conductivity of the soils that underlie the lakes and wetlands, and whether or not the surface water feature is hydraulically connected vertically or laterally to the groundwater system. This section deals with the thickness and continuity of the soils that form the lake beds and wetlands in the vicinity of the plant site. Section 3.6.4.3 addresses the hydraulic characteristics of the lake beds and wetlands in the vicinity of the plant site.

Table 3.5-7

Results of Carbonate Pebble Content Analyses

Boring	Sample No.	Total Pebble Count[1]	Carbonate Pebble Count[2]	% Carbonate Pebbles
DMA-1	4	0	0	0
	5	0	0	0
	8	0	0	0
DMA-4	3	0	0	0
	4	0	0	0
	5	0	0	0
DMA-6	2	0	0	0
	4	0	0	0
	6	63	3	4.8
DMA-10	4	0	0	0
	6	0	0	0
	8	152	26	17.1
DMA-19	2	0	0	0
	3	59	8	13.6
	5	25	2	8.0
DMA-20	4	0	0	0
	5	59	2	3.4
	6	97	6	6.2
DMA-30	1	0	0	0
	9	162	18	11.1
DMB-2	2	0	0	0
	7	118	5	4.2
	12	0	0	0
	15	0	0	0
DMB-3	4	69	1	1.4
DMB-4	5	0	0	0
	7	0	0	0
	8	19	1	5.3
	11	28	3	10.7
	14	0	0	0

Table 3.5-7 *(Continued)*

Boring	Sample No.	Total Pebble Count[1]	Carbonate Pebble Count[2]	% Carbonate Pebbles
DMB-5	6	0	0	0
	11	0	0	0
DMB-6	2	0	0	0
DMB-7	3	0	0	0
	5	0	0	0
	8	0	0	0
	12	0	0	0
	15	49	2	4.1
DMB-9	3	0	0	0
	9	180	8	4.4
	23	0	0	0
DMB-10	3	0	0	0
	4	108	12	11.1
	5	0	0	0
	6	84	8	9.5
	15	120	1	0.8
DMB-11	15	82	4	4.9
	16	105	5	4.8
	19	56	2	3.6
DMB-12	5	28	10	35.7
DMB-13	5	81	8	9.9
DMB-14	6	0	0	0
DMB-15	1	0	0	0
DMB-16	10	0	0	0
DMB-17	4	0	0	0
	5	85	5	5.9
	6	0	0	0
DMB-18	9	0	0	0
DMB-19	7	45	2	4.4
DMB-20	2	0	0	0
	6	0	0	0

Table 3.5-7 *(Continued)*

Boring	Sample No.	Total Pebble Count[1]	Carbonate Pebble Count[2]	% Carbonate Pebbles
DMB-22	9	28	2	7.1
G41-G15	2	NR	NR	2.0
G41-G15	5B	NR	NR	2.7
	6	NR	NR	1.4
	11	NR	NR	1.6
	14	NR	NR	1.2
	18	NR	NR	1.5
	21	NR	NR	1.8
	25	NR	NR	1.0
	29	NR	NR	6.2
	33	NR	NR	4.3
G41-G15A	2	NR	NR	3.3
G41-G15A	5	NR	NR	3.0
	6	NR	NR	2.7

Note: Samples from DMA- and DMB-series borings tested for particles retained on the No. 4 U.S. standard sieve. Samples from G-borings tested for the entire particle size range of each sample.

1 Total number of pebbles collected on a No. 4 sieve.

2 Number of carbonate pebbles counted in the sample.

NR = Not reported.

Source: *Dames & Moore, 1981; Golder Associates, 1981.*

Prepared by: EAS
Checked by: SVD1

Table 3.5-8

Results of Clay Mineralogy Analyses

Boring	Sample	Depth (ft)	Minerals							
			Montmorillonite	Illite	Chlorite	Kaolinite	Quartz	Feldspar	Dolomite	Calcite
DMA-1	3	9.1	9	43	39	9	V	MO	--	--
DMA-4	1	4.0	74	4	14	8	V	MI	--	--
DMA-18	1	3.5	62	22	12	4	V	MI	--	MI
DMB-1	5	19.0	28	32	34	6	V	MI	MO	--
DMB-1	10	44.0	44	26	22	8	V	MI	A	--
DMB-2	4	15.5	13	29	58	--	V	MO	--	--
DMB-5	2	5.5	45	40	12	3	V	A	--	--
DMB-5	19	88.5	36	28	27	9	V	MO	--	--
DMB-6	1	2.0	71	6	18	5	V	MO	--	--
DMB-9	3	6.0	30	47	17	6	A	MI	--	--
DMB-10	7	29.0	15	40	39	6	V	MI	MO	--
DMB-11	7	29.0	15	36	40	9	V	MO	MI	--
DMB-14	12	55.0	83	17	TR	--	V	MI	--	--
DMB-16	11	48.7	43	24	28	5	V	A	--	--
DMB-18	6	25.5	37	37	21	5	V	MO	MO	--
DMB-19	4	55.5	51	21	24	4	V	MO	MI	--
DMB-20	6	24.0	71	13	10	6	V	A	--	--
DMB-22	3	9.0	16	48	36	--	V	A	MI	--

Note: Clay mineral content expressed as percentage of all clay minerals.

Key:
V = Very abundant
A = Abundant
MO = Moderate
MI = Minor
TR = Trace
-- = None Observed

Source: Dames & Moore, 1981.

Prepared by: EAS
Checked by: SVD1

Soils data from the four separate lake bed and wetland drilling programs are summarized in Table 3.5-9. Raw data is provided on the boring logs and in the laboratory reports contained in Appendices 3.5-7, 3.5-8, 3.5-9, 3.5-10, 3.5-26, 3.5-27 and 3.5-28.

Soil boring data show that the lake beds of Little Sand, Deep Hole, Oak, Duck, and Skunk Lakes are very similar. They consist of loose organic silt or fine sand underlain by a soft grey, slightly organic silty clay, or in the case of Deep Hole Lake a soft gray silt. The silty clay and silt deposits were encountered at all borings conducted on the lakes. Given the proximity of Little Sand Lake to the ore body, a total of twelve sites were drilled on this lake. The borings encountered silty clay deposits in the middle of the lake and near the lake edge.

The similarity in grain size, soil color, and consistency of the lake bed soils between lakes and within Little Sand Lake indicate that the lake beds formed in a depositional environment that would give rise to a relatively uniform silt clay/silt layer.

Surficial deposits in the vicinity of the study area generally consist of coarse-grained tills of the Nashville Member of the Copper Falls Formation (Simpkins, et. al., 1987) that, based on grain size analyses discussed above, contain a significant percentage of fines. These sediments typically occur in drumlinoid forms. The result is a very irregular, undulating, hummock surface marked by ice block depressions. Regions of this nature were marked by the development of still water bodies such as lakes and wetlands. These still water bodies characteristically contain fine-grained sediments derived from suspended materials in melt water and eolian sources (Reineck and Singh, 1980).

Little Sand, Deep Hole, Duck, Oak, and Skunk Lakes generally lie in ice block depressions and pitted outwash plains in proximity to deposits of till. These lakes likely formed near the Langlade ice margin in depressions of collapsed and slumped sediments created by the melting of large ice blocks. The water in these lakes contained enough fine grained sediment from the ice blocks and melt water sources to allow for the deposition of the silty clay and silt deposits that form the existing lake beds. The sediments appear, based on boring data, to be continuous across the lake bottoms, thinner in near shore areas, and when investigated, tend to extend beyond the shoreline (e.g., borings DMA-10 and G40-Y15A near Little Sand Lake). Thus the original depositional basins were larger than the current lake basins, and as a result, lake bed sediments of silty clay and silt extend beyond the shoreline. The laminae of thin sand lenses in the silty clay and silt are rythmites or varves formed as a result of coarser sedimentation during glacier retreat.

Skunk Lake is differentiated, slightly, from the other lakes in the vicinity of the plant site by slightly thinner glacio-lacustrine clays marked by more discontinuous sand lenses. Both features are attributed to the ice block that formed Skunk Lake, which likely was smaller than the other three lakes. The features are also attributed to Skunk Lake having formed closer to the ice margin. This would make pulses of coarser sediment loads more likely, with the deposition of fine-grained material during relatively quiet periods. Then, as the ice margin retreated, more normal lacustrine depositional processes resulted in the formation of the characteristic gray silts and clays. In any case, it would be expected that fine-grained sediments would dominate the lacustrine deposits of small glacial lakes, such as Skunk Lake (Reineck and Singh, 1980).

Many of the upland wetland areas formed in a depositional environment similar to that of the lakes and also contain lacustrine silts and clays beneath the wetland that retain the water in these localized environments. Wetlands in lowland areas near streams were formed in till or glacial outwash deposits of sand and gravel.

Table 3.5-9

Lake Bed and Wetland Soil Testing Data

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200
Little Sand Lake	1982	STS-LSL-1	Dark gray silty clay (CL)	30 - 32	---	---	---	14	99.2
			Dark gray silty clay (CL)	44.5 - 47	---	---	---	19	94.4
	1982	STS-LSL-2	Dark gray silty clay (CL)	24.5 - 26.5	---	---	---	11.5	97.7
			Brown medium sand (SP)[a]	39 - 40.5	---	---	---		4.6
	1982	STS-LSL-3	Dark gray silty clay (CL)	28 - 30	---	---	---	19	99
			Dark gray silty clay (CL)	37 - 39	---	---	---	15	99.5
			Brown to medium sand (SP)[a]	43.5 - 45	---	---	---	---	4.2
	1982	STS-LSL-4	Dark gray silty clay (CL)	30.5 - 32.5	---	---	---	15	96.8
			Brown to medium sand (SP)[a]	45.5 - 47	---	---	---	---	18.7
	1982	STS-LSL-5	Dark gray silty clay (CL)	20 - 22	---	---	---	17	98.4
			Dark gray silty clay (CL)	28 - 30	---	---	---	19	96.8
Little Sand Lake	1982	STS-LSL-6	Dark gray silty clay (CL)	16 - 18	---	---	---	8	93.3
			Dark gray silty clay (CL)	28 - 30	---	---	---	9	98.3
	1994	CMC-LSL-101	Dark gray silty clay (CL)	14 - 16	0	4	70.6	25.4	96
			Dark gray silty clay (CL)	20 - 22	0	4.9	75.3	19.8	95.1
	1994	CMC-LSL-102	Dark gray silty clay (CL)	11 - 13	0	18.5	57.1	24.4	81.5
	1994	CMC-LSL-102A	Dark gray silty clay (CL-ML)	16 - 18	0	12.8	67.6	19.6	87.2
	1994	CMC-LSL-102B	Dark gray silty clay (CL)	12 - 14	0	10.9	63.1	26	89.1
			Dark gray silty clay (CL)	16 - 18	0	5.8	67.0	27.2	94.2
			Dark gray silty clay (CL)	24 - 26	0	17.7	56.1	26.2	82.3
			Brown silty clay (CL)	28 - 30	0	2.2	58.0	39.8	97.8
			Brown clayey sand (SC)[a]	32 - 34	17.7	58.8	11.6	11.9	23.5

Table 3.5-9 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200
	1994	CMC-LSL-103	Dark gray silty clay (CL-ML)	30 - 33	0	10.4	72.8	16.8	89.6
			Dark gray silty clay (CL)	33 - 35	0	6.6	72.3	21.1	93.4
			Dark gray silty clay (CL)	18 - 19.6	0	27.6	55.8	16.6	72.4
	1994	CMC-LSL-104A	Dark gray silty clay (CL)	15.4 - 17.4	0	6.6	70.4	23.0	93.4
	1994	CMC-LSL-104B	Dark gray silty clay (CL)	17 - 19	0	7.7	65.2	27.1	92.3
			Dark gray silty clay (CL)	12 - 14	0	2.5	70.0	27.5	97.5
			Brown sand (SP-SM)[a]	24 - 26	29.1	62.0	8.9		8.9
	1994	CMC-LSL-105	Dark gray silty clay (CL)	6 - 8	0	10.2	65.2	24.6	89.8
			Dark gray silty clay (CL)	8 - 10	0	4.9	64.7	30.4	95.1
			Dark gray silty clay (CL)	12 - 14	0	19.7	55.2	25.1	80.3
Duck Lake	1984	STS-DL-1	Dark gray silty clay (CL)	25.5 - 28	---	---	---	--	78
			Dark gray silty clay (CL)	38 - 40	---	---	---	--	93
Skunk Lake	1984	STS-SL-½	Dark gray silty clay (CL)	9.1 - 10	---	---	---	--	93
Oak Lake	1984	STS-OL-1	Dark gray silty clay (CL)	37.5 - 39.5	---	---	---	--	88
			Dark gray silty clay (CL)	42.5 - 44.5	---	---	---	--	93
Deep Hole Lake	1984	STS-DHL-1	Dark gray silt (ML)	21 - 23	---	---	---	--	95
			Dark gray silt (ML)	33.5 - 35.2	---	---	---	--	88
Burr Oak Swamp	1994	CMC-BO-101B	Sand (SC-SM)	4 - 6	0	53.7	32.5 Brown	13.8 Silty Clayey	
			Brown Clay (CL)	12 - 14	0	4.4	73.3	22.3	
			Brown Coarse Sand (SP)	36 - 38	1.8	95.6	2.6		
		CMC-BO-101A	Brown Clay (CL)	14 - 16	0.4	23.3	53.6	22.7	
		CMC-BO-102	Brown Clayey Sand (SC)	16 - 18	17.6	62.4	20		
			Brown Silty Sand (SM)	35 - 37	0	82.9	17.1		

Table 3.5-9 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200
Skunk Lake Wetland	1994	CMC-SL-103A	Gray Silty Clayey Sand (SC-SM)	6 - 8.5	0.1	57.4	19.6	22.9	
		CMC-SL-103B	Gray Clay (CL)	26 - 28	0	14.8	61.1	24.1	
			Brown Sand (SP)	38 - 40	25.5	70.1	4.4		
		CMC-SL-104	Brown Silty Clayey Sand (SC-SM)	4 - 6	0	69.7	15.6	14.7	
			Gray Sandy Silty Clay (CL-ML)	16 - 19	0	30.5	56.0	13.5	
			Brown Sand (SW-SM)	34 - 36	16.3	74.7	9		
Duck Lake Wetland	1994	[b]CMC-DL-103A	Brown Silty Clayey Sand (SC-SM)	4 - 6	11.8	53.5	21.0	13.7	
		[b]CMC-DL-103B	Brown Sand (SM)	20 - 22	0	67.4	27.6	5	
Swamp Creek Cedars Wetland	1994	CMC-SCC-101	Brown Clayey Sand (SC)	6 - 8	21.2	58.7	8.9	11.2	
		CMC-SCC-102A	Brown Silty Clayey Sand (SC-SM)	2 - 4	5.9	53.3	24.4	16.4	
			Gray Clayey Sand (SC)	8 - 10	14.6	57.7	27.7		
		CMC-SCC-102B	Brown Silty Fine Sand (SM)	16 - 18	13.2	67.9	11.6	7.3	
Swamp Creek Wetland	1994	CMC-SC-101	Gray Coarse Sand (SP)	12.5 - 14.5	0	98.6	1.4		
		CMC-SC-102	Gray Coarse Sand (SP)	10 - 12	6.5	90.5	3.0		

[a] Outwash/till soil sample from beneath lake bed.

[b] Located adjacent to wetland.

--- Not tested

Prepared by: JCP
Checked by: SVD1

The TDEM survey discussed in Section 3.5.1.3.5 was conducted to provide a detailed assessment of the thickness and continuity of the silty clay and silt lake bed deposits beneath Little Sand, Deep Hole, Duck, and Skunk Lakes. Oak Lake was not investigated since, as described in Section 3.6.4.3, it is a perched lake that will not be subject to potential drawdown related impacts caused by mine dewatering. The report on the TDEM survey is contained in Appendix 3.5-11, and provides a detailed description of the methodology, field data collection procedures, and data processing and evaluation procedures.

The TDEM survey was conducted on a grid spacing of approximately 200 feet. Figures 3.5-38 through 3.5-40 show the location of each TDEM sounding collected on the investigated lakes. The TDEM method mapped the thickness of a low resistivity geo-electric layer that is equivalent to the silty clay and silt that form the beds of the investigated lakes. Previously completed borings were used as lithologic control points to calibrate the TDEM data. All the TDEM data was then used to generate isopachs of the silty clay/silt equivalent low resistivity geo-electric layer.

In general, the TDEM soundings tended to underestimate the clay/silt layer thickness, as determined from logs of soil borings. For the entire data set of all 19 lake and wetland soil boring stations where direct comparison of clay/silt layer thicknesses to TDEM data is possible (Table 3.5-10), the mean error of lithologic thickness minus TDEM layer 2 thickness is +2.9 feet, with a standard deviation of 5.4 feet. The data set consisting of the differences between the lithologic and TDEM thicknesses was tested for normality using the Shapiro-Wilkes W test and by plotting the data on log probability plots (Figure 1, Donohue and Stewart, 1994). This analysis indicates that the TDEM thickness errors are normally distributed, and that the mean and standard deviation of the data set are reasonable measures of the variation in error.

Eleven of the control points are within Little Sand Lake. These 11 data points provide a measure of the TDEM error within a lake basin. The mean error for the Little Sand Lake data is +5.6 feet (TDEM data underestimate lithologic thickness), and the standard deviation is 4.9 feet. Again, the data plot as a straight line on a log-probability plot (Figure 1, Donohue and Stewart, 1994).

For the entire data set except DL-2 and DL-4, which are discussed below, 81 percent of the TDEM layer 2 thicknesses underestimate the thickness of the clay/silt layer. For the 17 TDEM soundings the mean error between TDEM layer 2 thicknesses and the thickness of the clay/silt layer is 31.5 percent, expressed as the TDEM error divided by the lithologic thickness, times 100. On average, at the soil borings, the TDEM data underestimate the clay/silt layer thickness by about 30 percent. This corresponds to an error of about 4 feet, compared to an average clay/silt layer thickness of 12.9 feet. The average TDEM thickness is 8.9 feet.

It is not clear from the data why the TDEM method underestimates the clay/silt layer thickness in most cases. A likely reason is that geoelectric layer 2, which is defined on electrical properties, and the clay/silt layer are not exactly equivalent, with the lithologic definition producing a greater thickness than the definition based on electrical properties. When introduced into the calibration process this difference in definitions would produce an error with a consistent sign, as seen in the data presented in Table 3.5-10.

Two TDEM/soil boring comparisons, DL-2 and DL-4 wetland soundings, produce results where the TDEM significantly overestimated the apparent thickness of the clay/silt layer. Neither of these borings were used as calibration points and the TDEM thicknesses for these two points in Table 3.5-10 are derived from the adjacent TDEM sounding sites or the TDEM isopach. The

lithologic thickness of the clay/silt layer at these sites is 1 to 1.5 feet, while the estimated TDEM thickness is 6 to 7 feet. The percent error at these two sites is anomalous when compared to other sites. While it might be expected that the percent error in the TDEM estimate of the clay/silt layer thickness would increase as the clay/silt layer thickness decreases, there is no such trend in the data until the clay/silt layer thickness reaches 1 to 1.5 feet, as at DL-2 and DL-4. Satisfactory estimates of the clay/silt layer thicknesses are obtained at SL 1/2 and SL 3/5, where the clay silt thicknesses are 2 feet and 3.5 feet, respectively. It appears that the lower limit of resolution of the TDEM method is 1 to 2 feet for this application.

An independent estimate of the ability of the TDEM to determine lake bed thickness and continuity is provided by an analysis of the response of lake and groundwater levels to the 1987-1990 drought. Lake level declines divided by water-table declines provide a measure of the relative degree of hydraulic connection between each lake basin and the water-table system. For Skunk Lake the ratio is 0.3. For Duck Lake it is 0.1, and the hydrographs for Little Sand and Deep Hole Lakes show no discernible response to the drought. The average TDEM-determined clay/silt layer thickness is 2 feet at Skunk Lake, and about 10 feet at Duck, Deep Hole, and Little Sand Lakes. The TDEM data would predict that Skunk Lake would be much more responsive to changes in water-table levels than the other lakes, an observation supported by the field data.

Figures 3.5-41 through 3.5-44 show the TDEM derived isopachs of the low resistivity geo-electric layer, comprised of silt clay and silt, for Little Sand, Deep Hole, Duck and Skunk Lakes respectively. Note that the isopachs for Deep Hole and Skunk Lakes are slightly different than the original figures presented in the TDEM report provided in Appendix 3.5-11. The isopachs for Deep Hole and Skunk Lakes were revised based on recalibration of the data as a result of review discussions with the WDNR.

Results of the TDEM survey identified a low resistivity geo-electric layer of varying thickness across the entirety of each lake and surveyed area of adjacent wetlands. Table 3.5-10 provides a comparison of the TDEM estimated thickness to the lithologic thickness obtained from the boring logs. As compared to soil borings, the TDEM survey on average underestimated the true thickness of the silty clay deposit that forms Little Sand Lake. The mean error is 5.6 feet. To compensate for underestimation, five feet was added to the Little Sand Lake isopach as shown in Figure 3.5-45.

Skunk Lake has only two calibration points. Thus a statistically reasonable error cannot be calculated to adjust the isopach, as was done with Little Sand Lake. If a mean error were calculated for Skunk Lake it would be a positive 0.65 feet based on a positive error of 0.8 feet at calibration point STS-SL-1/2, and a positive error of 0.5 feet at calibration point STS-SL-3/5. The positive error indicates that the TDEM survey slightly underestimated the silt clay thickness on Skunk Lake. For Deep Hole Lake, one calibration point exists and thus there is no mean error. Since the TDEM data is calibrated to one point on Deep Hole Lake, no adjustment to the isopach, based on a mean error, is possible.

Duck Lake contains five soil borings that can be compared to the TDEM derived isopach, although only two, STS-DL-1 and STS-DL-5 were used as calibration points. The mean error associated with the five data points is minus 1.12 feet. This means that on average, the TDEM data for Duck lake overestimated the true thickness of the silty clay layer by about one foot. Accounting for this error by subtracting one foot from the isopach shown in Figure 3.5-43 results in the adjusted isopach for Duck Lake shown in Figure 3.5-46.

Table 3.5-10

Comparison of Lithologic and TDEM Results for Geo-Electric Layer 2

Boring Station	TDEM Station	Lithologic Thickness (feet)	CMC TDEM Thickness (feet)	Difference (feet) Lithologic Minus TDEM
LSL-1	1.4.4	21	14.6	6.4
LSL-2	1.10.6	15.5	19.7	-4.2
LSL-3	1.7.7	12	10.1	1.9
LSL-4	1.17.5	12.5	11	1.5
LSL-5	1.18.4	11	5.3	5.7
LSL-6	1.22.4	14	4.3	9.7
LSL-101	1.7.8	18	7.8	10.2
LSL-102A/B	1.2.7	20	11.8	8.2
LSL-103	1.10.8	24.5	11.7	12.8
LSL-104A/B	1.20.12	12.2	9.8	2.4
LSL-105	1.26.1	7.4	0.4	7
DHL-1	2.7.2	10	10	0
DL-1	3.6.2	23	16.5	6.5
DL-2	WET[b] 3.5	1.5[a]	6.4	-4.9
DL-4	WET[b] 3.4	1[a]	7	-6
DL-5	WET[b] 3.3	6	5.7	0.3
DL-6	3.2.1	7.5[a]	9	-1.5
SL-1/2	4.1.2	2	1.2	0.8
SL-3/5	WET[b] 4.3.2	3.5	3.0	0.5

CMC-Little Sand Lake Data Set Mean Error of lithologic minus TDEM = 5.6, Standard Deviation = 4.9.
CMC-Entire Data Set Mean Error of lithologic minus TDEM = 2.9, Standard Deviation = 5.4.

[a] Comparison of lithologic to TDEM data is inferred based on isopach of geo-electric layer 2. Boring station was not close enough to a TDEM station to be used in calibration of the resistivity.

[b] Wetland TDEM station.

Prepared by: SVD1
Checked by: SGL

Overall, the data obtained on soil characteristics from four different investigations and the TDEM survey provide strong evidence that the silty clay and silt lake beds are continuous. This data is also consistent with the depositional environment that formed the lake beds that would give rise to continuous lake bed strata.

3.5.3.3 Study Area Soils

A soil map for the proposed study area is provided as Figure 3.5-47. Brief descriptions of the soil units encountered on site are presented in Table 3.5-11. Individual soil data sheets are included in Appendix 3.5-30.

The soils in the vicinity of the proposed Crandon Project site have been mapped and described by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS). Information used to prepared this section of the EIR was obtained from the USDA-SCS-WI Section IIA Technical Guide dated June 13, 1994 (USDA, 1994). The document is unpublished and in draft form. Soil mapping for the area is complete, but nomenclature is not finalized. As such, some of the soil series names have changed or are new, and do not match specific soil interpretation data sheets. As a result, soil types, properties, and extents on the soil map should be correlated by map unit soil number.

Soils at the site belong to the Wabeno-Goodman-Padus Soil Association. These soils are generally moderately deep to very deep, nearly level to sloping, moderately well drained to somewhat poorly drained silty soils on drumlins and moraines. In upland areas on the site, soils that have formed over loamy or sandy glacial till are dominant. These areas are characterized by loams such as the Wabeno-Goodman silt loams, Wabeno-Mud Lake silt loams, Argonne-Sarwet sandy loams, and the Laona-Sarona sandy loams. Low, poorly drained areas on these glacial uplands are covered by Capitola Muck.

In lower areas on the site, soils formed over loamy deposits, and sand and/or gravel glacial outwash are common. These soils are typically silt loams to loamy sands such as Stambaugh silt loam, Whisk Lake silt loam, Padus sandy loam, Padus-Pence complex, Pence-Vilas complex, Pence sandy loam, Vilas loamy sand and the Croswell loamy sand. Low, poorly drained areas over outwash are dominated by Kinross Mucks. Low, moderately well drained to somewhat poorly drained areas underlain by loamy and sandy lacustrine deposits are characterized by Fence and Gaastra silt loams.

The histosols common in bog and wetland settings on site are the Lupton, Cathro, and Markey Mucks and the Loxley, Beseman and Dawson Peats. These soils are typically sapric and generally occur over loamy glacial till or lacustrine deposits in topographic depressions under wetland or marsh vegetation. The Lupton, Cathro and Markey Mucks are common along Swamp Creek and in low wetland areas in the upland surfaces. The Loxley, Beseman and Dawson peats are common around Duck Lake.

The Wabeno-Goodman silt loams with one percent to six percent, and six percent to 13 percent slopes, is the most common soil map unit at the site. These silt loams cover approximately 65 percent of the site. The Mud Lake silt loam and the Argonne-Sarwet sandy loams cover approximately 20 percent of the site and the Lupton, Cathro and Markey mucks and the Loxley,

Table 3.5-11

Description of Soil Mapping Units in the Vicinity of the Proposed Crandon Project Site

Mud Unit Soil No.	Soil Type	Description	Slope	Taxonomic Classification
17:	Capitola Muck	Nearly level, poorly to very poorly drained soil formed in silty deposits and in underlying loamy or sandy glacial till.	0-2%	Typic Haplaquepts
18B:	Mud Lake Silt Loam	Nearly level to gently sloping, somewhat poorly drained soil formed in silty deposits and in underlying loamy or sandy glacial till.	1-6%	Entic Haplaquods
19B:	Wabeno-Mud Lake Silt Loams	Nearly level to gently sloping, moderately well drained soil formed in silty deposits and in underlying loamy or sandy till; and nearly level and gently sloping, somewhat poorly drained soil formed in silty deposits and in underlying loamy or sandy glacial till.	1-15%	Wabeno: Alfic Fragiorthods Mud Lake: Entic Haplaquods
20B: C: D:	Wabeno-Goodman Silt Loams	Nearly level and gently sloping (B) to sloping (C) and to moderately steep and steep (D), moderately well drained to well drained soils formed in silty deposits and in underlying loamy or sandy glacial till.	B: 1-6% C: 6-15% D: 15-35%	Wabeno: Alfic Fragiorthods Goodman: Alfic Haplorthods
22B: 22C: 22D:	Argonne-Sarwet Sandy Loams Laona-Sarona Sandy Loams Laona-Sarona Sandy Loams	Nearly level and gently sloping (B) sloping (C) to moderately steep and steep (D), moderately well drained to well drained soils formed in loamy deposits and in loamy or sandy glacial till.	B: 1-6% C: 6-15% D: 15-35%	Argonne: Alfic Fragiorthods Laona: Alfic Fragiorthods Sarwet: Alfic Haplorthod Sorona: Alfic Haplorthod
100B: C:	Stambaugh Silt Loam	Nearly level and gently sloping (B) to sloping (C), well drained soil formed in silty deposits overlying stratified sand and gravelly coarse sand outwash.	B: 1-6% C: 6-15%	Alfic Haplorthods
103A:	Whisk Lake Silt Loam	Nearly level and gently sloping, somewhat poorly draining soils formed in silty and loamy deposits underlain by sand and gravelly coarse sand outwash.	0-3%	Aqualfic Haplorthods
105B: C: D:	Padus Sandy Loam	Nearly level and gently (B) , sloping (C), to moderately steep and steep (D), well drained soil formed in loamy deposits and in the underlying stratified sand and gravelly sand outwash.	B: 0-6% C: 6-15% D: 15-35%	Alfic Haplorthods

Table 3.5-11 *(Continued)*

Mud Unit Soil No.	Soil Type	Description	Slope	Taxonomic Classification
106B: C: D:	Padus-Pence Complex	Nearly level and gently sloping (B), sloping (C) to moderately steep and steep (D) well drained soil formed in loamy deposits and in underlying stratified sand and gravelly sand outwash.	B: 0-6% C: 6-15% D: 15-35%	Padus: Alfic Haplorthods Pence: Entic Haplorthods
107B: C: D:	Pence-Vilas Complex	Nearly level and gently sloping (B), sloping (C), to moderately steep and steep (D) well drained soil formed in loamy deposits and in underlying stratified sand and in gravelly coarse sand outwash; and excessively drained soil formed in sandy glacial outwash.	B: 0-6% C: 6-15% D: 15-35%	Pence: Entic Haplorthods Vilas: Entic Haplorthods
109B:	Vanzile Silt Loam	Nearly level to gently sloping, moderately well drained soil formed in silty deposits overlying stratified sand and gravelly coarse sand outwash	0-6%	Alfic Haplorthods
111B: C: D:	Pence Sandy Loam	Nearly level and gently sloping (B), sloping (C), to moderately steep and steep (D), well drained soil formed in loamy deposits and in the underlying stratified sand and gravelly coarse sand outwash.	B: 0-6% C: 6-15% D: 15%-35%	Entic Haplorthods
115B: C:	Vilas Loamy Sand	Nearly level and gently sloping (B) to sloping (C), excessively drained soil formed in sandy outwash.	B: 0-6% C: 6-15%	Entic Haplorthods
124	Kinross Muck	Nearly level, poorly drained soil formed in mucky and sandy deposits overlying sandy glacial outwash	0-2%	Typic Haplaquods
127B:	Croswell Loamy Sand	Nearly level and gently sloping, moderately well drained soil formed in sandy glacial outwash.	0-3%	Entic Haplorthods
150B:	Fence Silt Loam	Nearly level and gently sloping, moderately well drained soil formed in silty and loamy deposits underlain by stratified, silty, loamy and sandy lacustrine deposits.	0-6%	Alfic Haplorthods
151A:	Gaastra Silt Loam	Nearly level, somewhat poorly drained soil formed in silty deposits underlain by stratified silty, loamy and sandy lacustrine deposits.	0-3%	Alfic Haplaquods
707	Lupton, Cathro, and Markey Mucks	Nearly level, very poorly drained soils formed in organic material more than 51 inches thick or underlain by loamy glacial till or lacustrine deposits at depths of 16 to 51 inches.	0-1%	Seelyeville: Typic Borosaprists Cathro: Terric Borosaprists

Table 3.5-11 *(Continued)*

Mud Unit Soil No.	Soil Type	Description	Slope	Taxonomic Classification
714	Loxley, Beseman and Dawson Peats	Nearly level, very poorly drained soils formed in acid organic material more than 51 inches thick or underlain by loamy glacial till or lacustrine deposits at depths of 16 to 51 inches.	0-1%	Loxley: Typic Borosaprists Beseman: Terric Borosaprists

Source: USDA-SCS-WI Section II-A Technical Guide Draft 06/13/94.

Prepared by: EAS
Checked by: PRB

Beseman and Dawson peats cover approximately 10 percent of the site. The remaining five percent is covered by a variety of silt loams to loamy sands formed over stratified sand and gravel outwash deposits.

Since full soil descriptions for Forest County have not been completed, the full descriptions for the identical soil mapping units in adjacent Oneida County which have been published (USDA, 1993) can be used to provide additional detail regarding the major soil units on site. In Oneida County, the Goodman silt loams, which should be comparable to the Forest County Wabeno-Goodman Complex, typically have a mat of partially decomposed forest litter about two inches thick at the surface. The surface soil consists of a layer of brown silt loam about three inches thick. The upper 12 inches of the subsoil generally consists of dark brown or dark reddish brown silt loam. In addition, the Oneida County Monico loam, which should be comparable to the Mud Lake silt loam, also tends to have a two inch thick mat of partially decomposed forest litter at the soil surface. The Monico loam surface soil is a one inch thick layer of black loam, below which is a two inch thick subsurface soil layer of brown loam. The upper 11 inches of the Monico loam subsoil consists of a dark brown to dark reddish brown silt loam. Both soils tend to be mottled within 20 inches below the surface due to the incomplete drainage of percolating precipitative water.

3.5.3.4 Topsoil

During construction activities at the site, the upper 9 inches of soil will typically be removed as topsoil. The exception to this will be areas where greater thicknesses of organic rich soil are present. In these areas the stripping thickness will be greater than 9 inches. Generally, the construction topsoil will consist of partially decomposed forest litter, the top surface soil layers and part of the subsoil. During the stripping of the topsoil, these layers will become mixed and will form a single soil unit. Some of the stripped topsoil will be used to dress berms and other project features during construction. The remaining topsoil will be stored in topsoil stockpiles for use during site reclamation. CMC plans to mitigate the loss of wetlands at the site through the establishment of off-site wetlands. Therefore, hydric soils collected from disturbed areas will be mixed and stored with the topsoil from the rest of the developed mine site.

The following discussion presents information on the expected characteristics of the various materials that will make up the stripped topsoil. The characteristics relate to thickness and physical properties. For the purposes of this discussion, construction topsoil will pertain to those planned areas of disturbance relating to the access road and railroad spur corridors, plant site, TMA (including borrow area, reclaim pond, and runoff basins) and the TMA access roads. Other areas of disturbance relating to installation of the potable and TMA water transmission lines are not included since the area of disturbance is small and the topsoil will be immediately replaced and seeded following pipeline installation.

3.5.3.4.1 Data Sources

The stripped topsoil will typically consist of the following major horizons as defined by the SCS (USDA, 1993):

- O horizon. - An organic layer of fresh and decaying plant residue.

- A horizon. - The mineral horizon at or near the surface in which an accumulation of humidified organic matter is mixed with the mineral material. Also, any plowed or disturbed surface layer.

- E horizon. - The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.

In some areas where the O, A, and E horizons are less than 9 inches in total thickness, stripped topsoil will include some subsoil. This subsoil would primarily consist of the B horizon which is in part a layer of transition from the overlying horizon to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) granular, prismatic, or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these (USDA, 1993).

In other areas where the O and/or A horizons are greater than 9 inches, the stripped topsoil will typically only include these two horizons. In these areas, which will primarily consist of low density hydric soils (peat and mucks), stripping or excavation will typically continue until suitable subbase soils are encountered. This will result in a stripping depth greater than 9 inches.

Information regarding the thickness of the combined O and A horizon is provided by the numerous soil investigations that have been conducted in the area around the mine site over the last two decades by CMC and others. These have included both borings and test pits installed to delineate the soils and surficial geology for plant site, access road and railroad spur construction and TMA siting. In addition, a soil gas survey was completed by another company over the ore body in 1995 that involved soil sampling during probe installation. Each of these investigations have provided information regarding the combined O and A horizon thicknesses in the mine site area. The data from these investigations has been compiled and reviewed and relevant information is included as part of the discussion that follows.

A listing of the soil borings and test pits used in defining the combined O and A horizon thicknesses is included in Table 3.5-11a. Only those data points where the combined O and A horizon thickness (on the logs referred to as topsoil) was described are shown. The SCS soil series, and the actual combined O and A horizon thickness encountered at each boring or test pit location, is also shown in Table 3.5-11a. The locations of these borings and test pits are shown on Figure 3.5-47a. Coordinate information for the borings is contained in Table 3.5-2. A discussion of the various boring and test pit installation programs was presented earlier in this section of the EIR. The logs for these borings and test pits are provided in the appendices to this section of the EIR.

Figure 3.5-47b shows the location where soil gas survey probes were installed in the vicinity of the area of disturbance for the plant site and access road. As part of the probe installation process, soil samples were collected from holes 10 to 26 inches deep, averaging 17 inches. Observations of the O and A horizons were recorded along the soil profile to the sampling horizon. The observations showed that the soil profile is variable but poorly developed. Significant A horizon leaching was rarely observed. However, on a number of occasions a developed E horizon was observed. Table 3.5-11b provides information on the thickness of the O and A horizons encountered at each probe location shown on Figure 3.5-47b.

Table 3.5-11a

Soil Boring and Test Pit Data Used to Define the Combined O and A Horizon Thickness

Soil Boring or Test Pit	Field Description[1]	SCS Soil Series No.[2]	Combined O and A Horizon Thickness (in)
Access Road			
FVD-AR-1	Dark brown silt loam (OL)	100	9.1
FVD-AR-2	Black silt loam (OL)	100	11.8
FVD-AR-3	Black silt loam (OL)	100	9.4
FVD-AR-4	Black silt loam (OL)	109	11.8
FVD-AR-5	Black silt loam (OL)	18	11.4
FVD-AR-6	Black silt loam (OL)	109	11.8
FVD-AR-7	Black sandy loam (OL)	100	9.4
FVD-AR-8	Black sandy loam (OL)	100	9.8
FVD-AR-9	Black silt loam (OL)	100	6.7
FVD-AR-10	Black, organic silt loam (OL)	100	5.9
FVD-AR-11	Black sandy loam (OL)	100	2.8
FVD-AR-12	Black silt loam (OL)	100	5.9
FVD-AR-13	Black sandy humus (OL)	100	3.5
FVD-AR-14	Black peat (PT)	707	23.6[3]
FVD-AR-15	Black peat (PT)	707	72.8[3]
FVD-AR-16	Black peat (PT)	707	65.0[3]
FVD-AR-17	Black peat (PT)	707	29.1[3]
FVD-AR-18	Black sandy loam with humus (OL)	107	2.4
FVD-AR-19	Black silt loam (OL)	107	3.9
FVD-AR-20	Black silt loam with humus (OL)	107	0.7
FVD-AR-21	Black organic sand (SP-PT)	707	9.8[3]
FVD-AR-22	Black Peat (PT)	707	9.8[3]
FVD-AR-23	Sandy loam with humus (OL)	106	3.5
FVD-AR-24	Black sandy loam with humus (OL)	106	0.8
FVD-AR-25	Black silt loam with humus (OL)	20	2.0
FVD-AR-26	Black sandy loam with humus (OL)	20	1.8
FVD-AR-27	Black silty loam with humus (OL)	20	2.4

Table 3.5-11a *(Continued)*

Soil Boring or Test Pit	Field Description[1]	SCS Soil Series No.[2]	Combined O and A Horizon Thickness (in)
FVD-AR-28	Black silt loam with humus (OL)	20	2.4
FVD-AR-29	Black silt loam with humus (OL)	20	2.4
FVD-AR-30	Black silt loam (OL)	20	3.9
FVD-AR-31	Dark brown clay loam (OL)	20	3.9
AR-1	Black sandy peat (PT)	707	18[3]
AR-2	Black sandy peat (PT)	707	18[3]
Railroad Spur			
FVD-RR-1	Black silt loam with cobbles (OL)	106	7.9
FVD-RR-2	Black fine sandy loam with cobbles/boulders (OL)	20	4.3
FVD-RR-3	Black sandy loam with boulders/cobbles (OL)	20	2.4
FVD-RR-4	Black loamy sand (OL)	20	4.7
FVD-RR-5	Black sandy loam with humus (OL)	20	3.5
FVD-RR-6	Black sandy loam with humus (OL)	20	3.5
FVD-RR-7	Black sandy loam with humus/boulders (OL)	20	2.4
FVD-RR-8	Black sandy loam with humus (OL)	20	4.3
FVD-RR-9	Black sandy loam with humus (OL)	20	5.9
FVD-RR-10	Black sandy loam (OL)	20	2.4
FVD-RR-11	Black peat (PT)	707	9.8
FVD-RR-12	Black peat (PT)	707	62.2
FVD-RR-13	Dark brown sandy loam (OL)	111	9.1
FVD-RR-14	Black sandy loam with humus (OL)	111	2.0
FVD-RR-15	Black sandy loam with humus (OL)	111	7.0
FVD-RR-16	Black fibrous peat (PT)	111	13.8[4]
FVD-RR-17	Black fibrous peat (PT)	707	36.6[3]
FVD-RR-18	Dark brown sandy loam (OL)	111	9.8
FVD-RR-19	Black fibrous peat (PT)	707	39.4
FVD-RR-20	Black sandy loam (OL)	106	19.7
FVD-RR-21	Black sandy loam (OL)	106	7.1

Table 3.5-11a *(Continued)*

Soil Boring or Test Pit	Field Description[1]	SCS Soil Series No.[2]	Combined O and A Horizon Thickness (in)
FVD-RR-22	Black sandy loam with humus (OL)	106	5.9
FVD-RR-23	Black fibrous peat with coarse gravel (PT)	707	13.8[3]
FVD-RR-24	Creek bottom	707	0
FVD-RR-25	Black fibrous peat (PT)	707	39.4[3]
FVD-RR-26	Black sandy peat (PT)	707	3.9[3]
FVD-RR-27	Black silty loam with humus (OL)	106	2.0
FVD-RR-28	Black sandy loam with humus (OL)	106	2.0
FVD-RR-29	Black sandy loam with gravel & cobbles (OL)	20	5.9
FVD-RR-30	Black sandy loam with humus (OL)	20	5.5
FVD-RR-31	Black sandy loam with humus (OL)	106	2.8
FVD-RR-32	Black sandy loam with humus (OL)	106	2.8
FVD-RR-33	Brown loamy sand (OL)	111	1.6
FVD-RR-34	Black fibrous peat (PT)	111	65.7[4]
FVD-RR-35	Dark brown loamy sand (OL)	111	7.1
RR-1	Black fibrous peat (PT)	707	36[3]
RR-2	Black silty peat (PT)	707	30[3]
Plant Site			
STS-TP-80-1	Black sandy silty topsoil (OL)	20	6
STS-TP-80-2	Black silty sandy topsoil (OL)	20	7
STS-TP-80-3	Brown silty sandy topsoil (OL)	20	5
STS-TP-80-4	Black silty sandy topsoil (OL)	20	8
STS-TP-80-5	Black silty topsoil (OL)	20	5
STS-TP-80-6	Black silty sandy topsoil (OL)	20	5
STS-TP-80-7	Black silty sandy topsoil (OL)	20	5
STS-TP-80-8	Black silty topsoil (OL)	20	6
STS-TP-80-9	Black silty topsoil (OL)	20	4
STS-TP-80-10	Black silty topsoil (OL)	18	6
STS-TP-80-13	Black silty sandy topsoil (OL)	20	6

Table 3.5-11a *(Continued)*

Soil Boring or Test Pit	Field Description[1]	SCS Soil Series No.[2]	Combined O and A Horizon Thickness (in)
STS-SAF-6	Black loam/grey brown loam	18	4.8
STS-SAF-7	Black loam/grey brown loam	20	3.6
STS-SAF-8	Black silt loam	20	4.8
STS-SAF-16	Black loam/grey brown loam	20	4.8
CMC-SB-08A	Dark brown organic topsoil (OL)	20	3.6
CMC-SB-10P	Dark brown organic topsoil (OL)	20	4.8
CMC-10PP	Dark brown organic topsoil (OL)	20	9.6
STS-EVS	Topsoil	20	9.6
DMI-1	Brown sandy silt	20	8
DMI-2	Black fibrous silt	20	6
DMI-8	Grey brown silt (topsoil)	18	12
DMS-1	Light brown sandy silt	20	6
DMS-2	Light brown sandy silt	20	10
TMA and Access Road			
G41-C11	Brown clayey silt	20	12
G41-E11	Topsoil	18	6
G41-E13	Topsoil	18	12
G41-G11	Organic matter	20	6
G41-H13	Topsoil	20	3.6
G41-J11	Topsoil	20	6
G41-K13	Topsoil	20	6
G41-J14	Topsoil	20	6
CMC-01P	Brown topsoil (OL)	18	6
CMC-02P	Brown topsoil (OL)	18	6
CMC-07	Dark brown organic topsoil (OL)	18	14.4

Table 3.5-11a *(Continued)*

Soil Boring or Test Pit	Field Description[1]	SCS Soil Series No.[2]	Combined O and A Horizon Thickness (in)
TP-2	Topsoil	20	12
TP-3	Topsoil	20	18
TP-7	Topsoil	20	6
TP-84-20	Black organic silty topsoil	20	6
TP-84-21	Black organic silty topsoil	20	6
TP-85-2	Topsoil	18	6
TP-85-4	Topsoil & boulders	20	9
TP-85-5	Topsoil	18	6
TP-85-6	Topsoil	20	2.4
TP-85-7	Topsoil	20	2.4
TP-85-8	Topsoil	20	3.6
TP-85-9	Topsoil	20	3.6
TP-85-10	Topsoil	20	2.4
TP-85-14	Topsoil	20	6
TP-85-15	Topsoil	20	6
TP-85-16	Topsoil	18	6
TP-85-17	Topsoil	20	6

[1] OL - Lean Organic Topsoil
PT - Peat
SP-PT - Poorly Graded Sand with Peat

[2] 18 - Mud Lake Silt Loam
20 - Wabeno-Goodman Complex
100 - Stambaugh Silt Loam
106 - Padus-Pence Complex
107 - Padus-Vilas Complex
109 - Vanzile Silt Loam
111 - Pence Sandy Loam
707 - Lupton, Cathro, and Markey Muck

[3] Organic rich hydric soil.

[4] Soil encountered in test pit or boring is likely a hydric soil inclusion within a larger mapped soils series. In these cases the data from that test pit or boring was not used to calculate the average O and A horizon thicknesses addressed in Table 3.5-11c.

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Table 3.5-11b

Soil Gas Survey Data Used to Define the Combined O and A Horizon Thickness

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
117150	2276240	18	3.5
117200	2276180	18	3
117250	2276190	18	3
117300	2276240	18	3
117350	2276240	18	3
117375	2276240	18	3
117400	2276240	18	3.5
117500	2276240	18	3.5
117550	2276225	18	3.5
117650	2276210	20	3.5
117700	2276240	20	3
117750	2276200	20	3.5
117800	2276208	20	3
117850	2276240	20	4
117900	2276220	20	2
117950	2276240	20	3
118000	2276220	20	3
118050	2276240	20	3.5
118100	2276240	20	4
118150	2276240	20	3.5
118200	2276240	20	5
118250	2276240	20	5
118300	2276220	20	4
118350	2276240	20	4
118400	2276240	20	3
118450	2276240	20	3.5

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
118500	2276240	20	3.5
118600	2276240	20	3
118700	2276265	20	3
118815	2276240	20	4.5
118900	2276240	20	4
119000	2276240	20	4.5
119100	2276240	20	4.5
119200	2276240	20	4.5
119300	2276240	20	5
119400	2276240	20	3.5
119500	2276240	20	2
119600	2276240	20	2.5
119700	2276240	20	4
119900	2276240	20	6
120100	2276240	20	2
120300	2276240	20	3
120500	2276240	20	5
120600	2276240	20	7
120700	2276240	20	6
120800	2276240	20	8
120900	2276240	106	3.5
121000	2276240	106	5
116750	2276540	18	4
116800	2276540	18	2.5
116850	2276540	18	3.5
116900	2276540	18	2.5
116950	2276540	18	2.5
117000	2276540	18	2.5

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
117050	2276540	18	3
117100	2276540	18	3
117150	2276540	18	3
117200	2276540	18	2.5
117250	2276540	20	1.5
117300	2276540	20	4
117400	2276540	20	3
117450	2276540	20	3.5
117500	2276540	20	3.5
117550	2276540	20	3.5
117600	2276590	20	4.5
117650	2276590	20	2.5
117700	2276590	20	2.5
117750	2276590	20	4.5
117800	2276590	20	4
117850	2276605	20	3.5
117900	2276580	20	4
118000	2276565	20	4
118050	2276590	20	3.5
118100	2276590	20	4.5
118150	2276590	20	3.5
118200	2276540	20	1.5
118250	2276540	20	1.5
118300	2276560	20	3.5
118350	2276540	20	3.5
118400	2276540	20	3.5
118450	2276540	20	2
118500	2276540	20	2

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
118550	2276540	20	2
118600	2276540	20	2
118650	2276540	20	2
118700	2276540	20	2
118800	2276540	20	2
118900	2276540	20	2
119000	2276540	20	2
119100	2276540	20	2
119200	2276540	20	3
119300	2276540	20	2
119400	2276540	20	2
119500	2276515	20	3.5
119600	2276540	20	2
119700	2276540	20	3
119800	2276540	20	2
120000	2276540	20	3.5
120200	2276540	20	2
120400	2276540	20	3
120700	2276540	20	2
121000	2276540	20	2
116200	2278790	20	2.5
116300	2278790	20	3.5
116350	2278790	20	2.5
116400	2278790	20	3
116450	2278790	20	2
116500	2278790	20	2
116550	2278790	20	2.5
116610	2278780	20	2

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
116650	2278760	20	4
116700	2278790	20	4
116750	2278790	20	4
116800	2278760	20	2.5
116850	2278790	20	3.5
116900	2278830	20	3.5
116950	2278820	20	3
117000	2278805	20	3
117050	2278790	20	3
117100	2278790	20	3
117150	2278790	20	2.5
117200	2278790	20	3
117250	2278770	20	3
117300	2278790	20	2.5
117350	2278710	20	3.5
117400	2278720	20	3
117450	2278730	20	2.5
117500	2278720	20	3.5
117600	2278840	20	2.5
117650	2278790	20	3
117700	2278790	20	3.5
117750	2278790	20	3.5
117800	2278790	20	2.5
117850	2278840	20	2
117915	2278790	20	2
117950	2278790	18	2.5
118000	2278790	18	2.5
118050	2278790	18	3

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
118100	2278790	20	2.5
118200	2278790	20	2
118400	2278790	20	3.5
118500	2278790	18	3.5
118600	2278790	18	3
118700	2278790	18	3
118800	2278790	18	3
116200	2278490	20	3
116300	2278490	20	3
116350	2278410	20	3.5
116400	2278375	20	3
116450	2278390	20	3
116500	2278390	20	3
116550	2278370	20	3
116600	2278285	18	3
116650	2278315	18	2
116700	2278315	18	2
116750	2278315	18	2
116800	2278265	20	2
116850	2278370	20	3
116900	2278440	20	3.5
116950	2278490	20	2
117000	2278490	20	3.5
117050	2278490	20	3.5
117100	2278510	20	3
117150	2278440	20	3
117200	2278540	20	3.5
117250	2278440	20	2

Table 3.5-11b *(Continued)*

Location (State Plane Coordinates)		SCS Soil Series No.[1]	Combined O and A Horizon Thickness (in)
Northing (ft)	Easting (ft)		
117300	2278440	20	2
117350	2278440	20	1
117400	2278490	20	3
117450	2278490	20	3
117500	2278490	20	3
117600	2278440	20	3
117650	2278475	20	2
117700	2278465	20	3
117750	2278475	20	3
117800	2278490	20	3
117850	2278490	20	2
117900	2278490	20	2
117950	2278490	20	3
118000	2278450	20	3
118100	2278450	20	3
118300	2278490	20	2
118500	2278490	20	2
118700	2278490	20	2

[1] 18 - Mud Lake Silt Loam
20 - Wabeno-Goodman Complex
106 - Padus-Pence Complex

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As can be seen from Figures 3.5-47a and 3.5-47b data points are evenly distributed along the access road and railroad spur corridors. Data points are more locally concentrated in the plant site and TMA areas. The plant site and TMA are primarily upland locations and, as discussed below, the on-site data and the recently completed SCS mapping work (see Section 3.5.3.3) provide a good understanding of the thickness of the combined O and A horizons in those areas. Note that only data from those borings, test pits, and soil gas probes located within or immediately adjacent to areas of disturbance was used to estimate the relative O and A horizon thicknesses discussed below.

3.5.3.4.2 Characteristics

Table 3.5-11c contains a summary of SCS thickness data for the soil series expected to be encountered within the planned mine site and a summary of the combined O and A horizon thicknesses encountered during the various investigations on the mine site. The largest areas of disturbance within the mine site relate to the plant site and the TMA. As shown in Table 3.5-11a and on Figure 3.5-47c, both of these areas are dominated by the Wabeno-Goodman Complex, mainly on slopes of 1 to 6 percent. The second most abundant soil type in this area is the Mud Lake (Monico) silt loam. Minor amounts of Padus-Pence Complex soils will be stripped at the plant site; with minor amounts of Lupton, Cathro and Markey muck soils (mainly peat) to be stripped at the plant site and TMA, and Capitola (Cable) silty mucks excavated to some extent at the TMA.

As shown in Table 3.5-11a and on Figure 3.5-47c, soils along both the access road and railroad spur south of Swamp Creek are similar to those at the plant site and the TMA, consisting of predominantly Wabeno-Goodman Complex with Mud Lake silt loams, Padus-Pence Complex soils, and small amounts of Pence-Vilas Complex soils. As both corridors approach Swamp Creek; Lupton, Cathro and Markey mucks (peat) are encountered. North of Swamp Creek, the access road corridor is dominated by Stambaugh and Vanzile silt loams, which have relatively thick O and A horizons compared to the upland soils at the plant site and the TMA. The railroad spur corridor north of Swamp Creek contains Padus-Pence Complex soils; Lupton, Cathro and Markey muck (peat); and Pence sandy loams.

Average combined O and A horizon thicknesses were calculated, using site data, for each soil series encountered within the area of disturbance on the mine site. Average soil thicknesses were calculated rather than producing a soil thickness isopach map due to varying densities of useable data in the differing areas of disturbance. A summary of the calculations is included on Table 3.5-11c. The table shows the mean combined O and A horizon thickness for the SCS soil series encountered in the planned area of disturbance derived using the on-site data contained in Tables 3.5-11a and 3.5-11b. The range of thickness based on the same data is also shown. For illustrative purposes, the typical SCS A horizon thickness in the case of upland soils and O or O plus A horizon thickness for peat and muck soils are shown. Finally, the table also contains an estimate of the percent of the disturbed area represented by each soil series.

Figure 3.5-47d shows the relationship of soil series type and vegetation type within the mine site area of disturbance. As shown by the figure, the plant site and TMA areas are dominated by upland soils and contain mainly northern hardwood vegetation with minor inclusions of deciduous wetlands, conifer swamps, upland opening, etc. Lowland areas are dominated by

Table 3.5-11c

Combined O and A Horizon Thicknesses

SCS Soil Series	SCS Soil Series No.	SCS Typical Thickness[1] (in)	Site Data Points (#)	Mean Thickness from Site Data[2] (in)	Range[2] (in)	Approximate Disturbed Area %
Capitola Muck	17	3	0	NA	NA	2.2
Mud Lake	18	6	42	4.6	2-14.4	26.3
Wabeno-Goodman[3]	20	3-6	211	3.7	1-18	61.9
Minocqua Muck	27	28	0	NA	NA	<0.1
Stambaugh	100	14	10	7.4	2.8-11.8	2.9
Padus-Pence[3]	106	2-4	12	5.3	0.8-19.7	1.8
Pence-Vilas[3]	107	2-7	3	2.3	0.7-3.9	0.6
Vanzile	109	14	2	11.8	NA	0.5
Pence	111	2	6	7.7	1.6-9.8	0.8
Lupton, Cathro and Markey[3]	707	19-60	18	28.7	0-72.8	3.0

[1]For upland soils thickness typically represents A horizon. For peat and muck soils, thickness typically represents the O or the O and A horizons.
[2]O and A horizons. Based on data from Tables 3.5-11a and 3.5-11b exclusive of data for hydric soil inclusions (see Note 4, Table 3.5-11a).
[3]SCS range of thickness due to two soil components in the same series.
NA = No data or insufficient data to calculate mean thickness or range.

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hydric soils and generally contain conifer swamps. Similar characteristics apply to the access road and railroad spur corridors. Table 3.5-11d contains a listing of the soil series, accompanying vegetation type and acreage, and percent vegetation type within each soil series for the areas of planned disturbance within the mine site.

The E horizon thickness on the upland soils, as described in the Oneida County Soil Survey (USDA, 1993) ranges from 1 to 8 inches. For the two soil series in Oneida County that are similar to the two series comprising approximately 90 percent of the disturbed site, the Mud Lake silt loam and the Wabeno-Goodman Complex, the E horizon is generally 2 to 3 inches thick and has a silt loam to loam texture.

The B horizon for soils in the planned area of disturbance is generally greater than 10 inches thick and consists of silt loams. In some very limited areas where these upper horizons are thin or absent, minor amounts of C horizon material may be included in the stripped soil.

Approximately 90 percent of the planned disturbed area across the entire site will consist of the Mud Lake silt loam and the Wabeno-Goodman Complex. Over 95 percent of the stockpiled soils in the TMA and plant site areas will be comprised of the Mud Lake silt loam and Wabeno-Goodman Complex. The physical properties of each of these soil associations are shown in Table 3.5-11e. The table includes properties of both the shallow organic rich horizons as well as the deeper horizons which may be encountered, according to the SCS draft Forest County Soil Survey (USDA, 1994).

Review of the table indicates the properties of the upland soils regardless of the type are very similar. The pH, CEC (cation exchange capacity), and organic matter content for the upland soils generally overlap for both the upper and lower horizons as defined by the SCS. The lowland hydric soils typically have a much higher organic content than upland soils. Other than their percent organic matter and bulk density, the lowland soil properties generally overlap the properties of the upland soils.

Table 3.5-11d

Relationship of Soil Series and Vegetation in the Mine Site Area

SCS Soil Series No.[1]	Approximate Area of Soil Series (ac)	Vegetation Type[2]	Approximate Area of Vegetation Type (ac)	% of Vegetation Type Within a Given Soil Type
Access Road				
18	1.5	N	1.5	100
20	7.9	N	7.9	100
27	<0.01	F	<0.01	100
100	15.7	A	4.5	28
		C	0.4	3
		DW	0.6	4
		F	4.0	25
		N	3.9	25
		P	2.3	15
106	1.7	C	0.3	18
		N	1.4	82
107	2.6	C	0.6	23
		N	1.8	69
		S	0.2	8
109	2.5	N	2.5	100
707	6.1	C	1.5	25
		N	4.6	75[3]
Railroad Spur				
18	0.3	N	0.3	100
20	7.5	N	7.5	100
106	3.5	N	3.5	100
107	0.4	N	0.4	100
111	4.5	A	3.2	71
		C	0.5	11
		N	0.7	16
		B	0.1	2

Table 3.5-11d *(Continued)*

SCS Soil Series No.[1]	Approximate Area of Soil Series (ac)	Vegetation Type[2]	Approximate Area of Vegetation Type (ac)	% of Vegetation Type Within a Given Soil Type
707	2.9	A	0.3	10
		C	1.0	34
		N	0.8	28
		S	0.8	28
Plant Site				
18	22.5	N	22.5	99
		M	<0.1	<1
20	100.6	N	100.6	100
106	4.4	N	4.4	100
707	0.2	N	0.2	100[3]
TMA, etc.[4]				
17	11.6	C	3.4	30
		DW	3.3	28
		N	4.9	42
18	113.4	C	0.4	<1
		S	2.4	2
		DW	3.5	3
		M	0.2	<1
		F	2.5	2
		N	104.4	92
20	213.1	DW	2.6	1
		S	0.1	<1
		F	3.2	1
		M	0.1	<1
		N	207.1	97
707	6.7	C	6.7	100

Table 3.5-11d *(Continued)*

SCS Soil Series No.[1]	Approximate Area of Soil Series (ac)	Vegetation Type[2]	Approximate Area of Vegetation Type (ac)	% of Vegetation Type Within a Given Soil Type
TMA Access Road				
18	3.6	C	0.4	11
		N	3.2	89
20	3.2	N	3.2	100
707	0.1	C	0.1	100

[1] 17 - Capitola Muck
18 - Mud Lake Silt Loam
20 - Wabeno-Goodman Complex
27 - Minocqua Muck
100 - Stambaugh Silt Loam
106 - Padus-Pence Complex
107 - Pence-Vilas Complex
109 - Vanzile Silt Loam
111 - Pence Sandy Loam
707 - Lupton, Cathro, and Markey Muck

[2] A - Agricultural Lands
C - Swamp Conifers
DW - Deciduous Forested Wetlands
F - Fields and Upland Openings
P - Pine Plantations
N - Northern Hardwood Forests
S - Shrub Wetlands
M - Marsh
B - Bog

[3] Likely overlap between percent northern hardwood forests (N) versus percent swamp conifers (C).

[4] Includes TMA, TMA borrow area, reclaim pond, perimeter road, exterior drainage system, and runoff basins.

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Table 3.5-11e

Soil Physical Properties

SCS Soil Series No.	SCS Soil Series	Horizon Thickness (inches)	SCS Texture[1]	Clast %>3 in	Moist Bulk Density (g/cc)	% Organic Matter	Soil Reaction (pH)	Erosion Factor (K)	WEI[2]	CEC[3] (me/100g)
17	Capitola Muck	0-3	SIL	25-50	1.1-1.4	3-7	4.5-7.3	0.37	0	—
		3-37	SIL, L, FSL	0-25	1.4-1.5	—	4.5-7.3	0.37	—	—
18	Mud Lake Silt Loam	0-6	SIL	40-90	1.1-1.4	1-4	4.5-6.5	0.37	0	0-1
		6-32	FSL, GR-L, SIL	0-40	1.6-1.8	0.5-1	4.5-6.5	0.24	—	0-1
20[4]	Wabeno-Goodman Complex (Stony)	0-6	SIL	6-25	1.2-1.5	1-2	3.6-6	0.37	48	0-1
		6-27	SIL, L, FSL	0-25	1.3-1.5	0.5-1	3.6-6	0.43	—	0-1
20[4]	Wabeno-Goodman Complex (Stony)	0-3	SIL	1-13	1.4-1.5	2-4	3.6-6.5	0.37	0	0-1
		3-5	SIL, SI	1-13	1.5-1.6	0.5-1	3.6-6.5	0.43	—	0-1
		5-19	SIL	1-15	1.5-1.6	0-0.5	3.6-6.5	0.43	—	0-1
27	Minocqua Muck	0-4	Muck (PT)	0	0.2-0.4	60-90	4.5-7.8	0.1	134	2-2[5]
		4-28	SIL, L, SL	0-8	1.5-1.6	0-2	4.5-7.8	0.37	—	0-1
100	Stambaugh Silt Loam	0-14	SIL	0-8	1.1-1.6	1-3	4.5-6.0	0.37	56	0-1
		14-35	SL SIL, VFSL	0-8	1.3-1.7	—	4.5-6	0.32	—	0-1
106[4]	Padus-Pence Complex	0-4	FSL	0-9	1.4-1.7	0.5-2	4.5-6.5	0.24	86	0-1
		4-25	FSL, SL, L	0-9	1.4-1.6	0-0.5	4.5-6.5	0.24	—	0-1
106[4]	Padus-Pence Complex	0-2	SL	0-15	1.2-1.6	1-3	4.5-6.5	0.24	86	0-1
		2-14	SL, L, GR-SL	0-19	1.4-1.5	0-0.5	4.5-6.5	0.24	—	0-1
107[4]	Pence-Vilas Complex	0-7	LS	0	1.4-1.6	0.5-1	4.5-6.5	0.17	134	—
		7-15	LS	0	1.5-1.6	—	4.6-6.5	0.17	—	—
107[4]	Pence-Vilas Complex	0-2	SL	0-15	1.2-1.6	1-3	4.5-6.5	0.24	86	0-1
		2-14	SL, L, GR-SL	0-19	1.4-1.5	0-0.5	4.5-6.5	0.24	—	0-1

Table 3.5-11e *(Continued)*

SCS Soil Series No.	SCS Soil Series	Horizon Thickness (inches)	SCS Texture[1]	Clast %>3 in	Moist Bulk Density (g/cc)	% Organic Matter	Soil Reaction (pH)	Erosion Factor (K)	WEI[2]	CEC[3] (me/100g)
109	Vanzile Silt Loam	0-14	SIL	0-8	1.1-1.7	1-3	4.5-6.0	0.37	56	0-1
		14-30	SI, SIL, VFSL	0-8	1.2-1.7	—	4.5-6.0	0.32	—	0-1
111	Pence Sandy Loam	0-2	SL	0-15	1.2-1.6	1-3	4.5-6.5	0.24	86	0-1
		2-14	SL, L, GR-SL	0-19	1.4-1.5	0-0.5	4.5-6.5	0.24	—	0-1
707[4]	Lupton, Cathro and Markey	0-10	Muck (PT)	0	0.1-0.3	25-99	4.5-7.3	0.1	134	2-2[5]
		10-60	Muck (PT)	0	0.1-0.3	25-99	4.5-7.3	—	—	2-2[5]
707[4]	Lupton, Cathro and Markey	0-14	Muck (PT)	0	0.3-0.4	60-85	4.5-7.8	0.1	134	2-2[5]
		14-19	Muck (PT)	0	0.2-0.3	60-85	4.5-7.8	—	—	2-2[5]

[1]SIL = silt loam; FSL = fine sandy loam; GR-L = gravelly loam; SL = sandy loam; SI = silt; PT = peat; L = loam; VFSL = very fine sandy loam; GR-SL = gravelly silt loam; LS = loamy sand; S = sand.
[2]Wind Erodibility Index.
[3]Cation Exchange Capacity.
[4]Map unit has two components and two interpretation sheets.
[5]Draft soil survey reports this value as 2-2. This is likely a typographical error on the survey forms and the actual value is either 0-2 or 0.2-2.

Prepared by: EAS
Checked by: JWS

Source: Draft version of USDA Forest County Soil Survey dated June 13, 1994.

The immediate reuse of some of the stripped topsoil in addressed in the project's MPA. The stockpiled topsoil will not be used for a period of 20 to 30 years. During the time that the soil is stockpiled, it is expected that nutrients will be leached from parts of the soil and that the soil will become compressed. Due to these anticipated changes, no additional current testing of the topsoil at the site is warranted. Instead, it would be more appropriate to conduct nutrient and physical testing of the stockpiled topsoil during site reclamation to determine the need for the addition of amendments to the topsoil for use in revegetating the reclaimed site.

3.5.4 Seismology/Earthquakes

3.5.4.1 Historic Seismicity

Northern Wisconsin and the upper peninsula of Michigan are two of the more seismologically stable areas in the United States. Figure 3.5-11 shows the locations of the few historical seismic events and their relation to the site area and regional structural features. Table 3.5-12 lists the major historical seismic events (Modified Mercalli intensities at the epicenter greater than II) within a 200 mile radius of the study area. This intensity is described by the Modified Mercalli Intensity Scale, described in Table 3.5-13.

The largest seismic events within 200 miles of the site area occurred on the Kewaunee Peninsula (Figure 3.5-11), approximately 130 miles to the north. The largest seismic event occurred on May 26, 1906. The Modified Mercalli epicentral Intensity of this event was reported as an VIII (Docekal, 1970; Coffman and Von Hake, 1973). According to the regional attenuation characteristics reported by Gupta and Nuttli (1976), the intensity felt at the site area from any of the events on the Kewaunee Peninsula would have been an Intensity IV or lower. The localized nature of some of the "felt" areas and calculation of the average radii of the reported "felt" area indicate that these events were probably not even felt at the study area. Major seismic activity may be restricted to the Kewaunee Peninsula and should not be expected in the seismically stable region of the Crandon Project.

The largest seismic events reported in the mid-continent of the United States occurred during the 1811-1812 New Madrid earthquake series located over 800 miles south of the Crandon area. During this period, events with Modified Mercalli Intensities as high as XI-XII were reported in the New Madrid, Missouri area. An isoseismal map of the December 16, 1811 event, prepared by Nuttli (1973), indicates a Modified Mercalli Intensity of IV felt in the Crandon, Wisconsin area. However, an isoseismal map prepared by Stearns and Wilson (1972) for the same event shows the Crandon area experienced a Modified Mercalli Intensity of less than II.

Algermissen, et. al. (1982) presented a map showing seismic source zones in the contiguous United States. These zones were defined on the basis of the historic seismicity and the distribution and activity of faults. According to this map the Crandon site is located in seismic source zone 069 for which the number of intensity V earthquakes per year is listed as 0.00588 and maximum magnitude (M_L) was listed as 6.1. On the basis of the above, it is concluded that seismic activity at the Crandon Project site and its vicinity is very low.

Table 3.5-12

Historical Seismicity Within 200 Miles of the Crandon Project Area[a]

Date	Location	Modified Mercalli Intensity at Epicenter
1905 March 13	Menominee, MI	V
1905 July 26	Calumet, MI	VII
1906 May 26	Kewaunee Peninsula, MI	VIII
1909 January 22	Houghton, MI	V
1931 October 18	Madison, WI	III[b]
1933 December 6	Stoughton, WI	III
1935 October	Negaunee, MI	II-III[b]
1943 February 9	Marinette County, WI	II-III[b]
1944 November 16	Escanaba, MI	II-III[b]
1945 May 18	Escanaba, MI	II[b]
1947 May 6	Southeastern Wisconsin	IV
1955 January 5	Calumet, MI	IV
1955 January 6	Hancock, MI	V
1956 July 18	Oostburg, WI	IV
1956 October 13	Milwaukee, WI	IV

[a]Docekal, 1970; Coffman and VonHake, 1973.
[b]Reported as felt by several people (Docekal, 1970).

Prepared by: JCP
Checked by: SVD1

Table 3.5-13

Modified Mercalli Intensity Scale of 1931 (Abridged)

Intensity	Description
I.	Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel Scale)
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale)
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale)
V.	Felt by nearly everyone; many broken windows; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)
VI.	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale)
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. (IX+ Rossi-Forel Scale)
X.	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale)
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII.	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

Source: Crandon Mining Company.

Checked by: SVD1

3.5.4.2 Site Area Seismic Design

The results of regional and site area geology studies were used to estimate the maximum probable horizontal ground acceleration that might be expected at the site area. Considering the regional geology and seismic history, it is conservatively concluded that the site should not have experienced a Modified Mercalli Intensity greater than III to IV from any historical seismic event. Considering the tectonic stability of the study region, it is improbable that future seismic events will be larger than the historical events. Therefore, a ground horizontal acceleration of four percent of gravity at bedrock is recommended for engineering design. This level is derived conservatively from consideration of an intensity of IV to V felt at the site area as a result of the recurrence of any historical event. The acceleration/intensity conversion employed is derived from Trifunac and Brady (1975) wherein a "mean" acceleration in competent rock expected from an Intensity V event is less than four percent gravity. The design ground motion is conservative, considering the local seismicity, but allows for the possible consequences of large, distant events and their extended duration of motion from long-period seismic waves.

Algermissen (1982) and Algermissen, et. al. (1990) have presented maps showing probabilistic earthquake accelerations and velocities for the United States and Puerto Rico. From these maps it is estimated that for the Crandon Project site, maximum seismic-induced horizontal acceleration in rock with a 90 percent probability of not being exceeded in 250 years (corresponding to a return period of 2371.9 years), is less than four percent of the acceleration due to gravity. These maps represent the result of a very thorough and exhaustive analysis of historic data resulting in the development of seismic source zones and distribution of earthquakes likely to occur in each zone and calibration of extreme cumulative probability of ground acceleration for 250 years using a probabilistic model and ground motion attenuation curves. This design value is conservative compared with some other reports. For example, Milne and Davenport (1969) showed an acceleration value of one percent gravity with a 100-year return period. Perkins (1974) displayed a map wherein the study region lies within a zone where the earthquake risk is described as minor damage, and where distant earthquakes may cause damage to structures with fundamental periods greater than one second, corresponding to Modified Mercalli Intensities of V and VI. The range of expected intensity values in the above analyses is primarily from the various assumptions used by the authors as input to their respective statistical procedure. However, all studies corroborate the low seismicity of the study region.

In reviewing all aspects of the various analyses, an acceleration in rock of no higher than four percent gravity is considered reasonable for design. It is emphasized, however, that this design parameter was developed for the response of firm, competent foundation material.

Since competent bedrock in the site area is overlain by approximately 200 feet of unconsolidated glacial material, some amplification could occur so that structures at the site area might be subjected to somewhat higher levels of acceleration, particularly in certain frequency ranges. An approximation of the amplification can be made based on the responses identified for areas of similar geologic conditions. Seismic acceleration data developed for Illinois Power Company's Clinton Power Station in central Illinois (Illinois Power Company, 1974) indicate an amplification factor of 1.5 for a site underlain by more than 200 feet of unconsolidated glacial material. This factor is in agreement with an empirical approach used by Nuttli (1973), which states that unconsolidated soils can increase ground accelerations by a factor of 1.0 to 1.5. However, for this site an amplification factor of two is recommended, especially in view of the fact that the fundamental natural period of the site soils is likely to be in the range of 0.5 to 1.0 seconds or

more and that the expected peak vibrations are small with (both aspects leading to larger amplification (Hayes, 1980). Applying a factor of two to the assumed four percent gravity acceleration of bedrock indicates an expected ground motion of eight percent gravity at foundation level.

3.5.5 Waste Characterization

Four major categories of wastes will be generated during the development of the mine, its operation, and concentration of ore. These wastes will include: 1) waste rock; 2) tailings; 3) wastewater treatment and reclaim pond solids; and, 4) overburden. Small quantities of laboratory wastes will also be generated during the operation of the mine. In addition, demolition wastes will be generated during the reclamation of the site following the completion of mining operations. The project's waste characterization program was established to evaluate existing data and studies related to the major waste categories, and to conduct additional testing where warranted. Details of the proposed waste characterization program were submitted to WDNR in a letter dated May 23, 1994 for review (Collison, 1994a). Upon departmental approval the program commenced in June of 1994.

Due to the evolutionary nature of the reactions that occur, and the consequent length of time required for these reactions to be completed for some of the materials tested, some of the tests were not completed at the time the project's EIR was prepared. Additional test results were presented in the *Waste Characterization Update Report* (Foth & Van Dyke, 1995d). Modifications to the proposed program were made with departmental approval during the course of the program. These modifications are documented in Appendix 3.5-33. The originally proposed tests have been completed and the final results and interpretations are contained in the following sections.

In the spring of 1996, the WDNR commented on the waste characterization work completed by CMC and requested that a series of additional tests be performed. A work plan for this supplementary program was submitted to the WDNR in June 1996 (Foth & Van Dyke, et al., 1996) and amended in October 1996 (CMC, 1996). The results of the supplementary waste characterization work are discussed in a May 1997 report titled *Crandon Project TMA Supplementary Waste Characterization Program - Interim Report* (SRK, 1997a) that can be found in Appendix 4.2-12 of the EIR.

Waste rock will be generated during the preproduction and operational phases of the mine. The waste rock that will be generated during the preproduction phase will be brought to the surface where it will either be used for construction purposes or placed in the TMA. The segregation of waste products is described in the *Tailings Management Area Feasibility Report/Plan of Operation* (Foth & Van Dyke, 1995c) and in the *Mine Permit Application for the Crandon Project* (MPA) (Foth & Van Dyke, 1995f). Approximately one-half of the waste rock generated during the operational phase of the mine will remain underground and will be used to backfill a portion of the depleted mine stopes.

Preproduction waste rock will be mined from the hanging wall rocks north of the ore body. These rocks are part of the locally named Skunk Lake, Rice Lake and Mole Lake Formations. The preproduction waste rock that will be mined from the lower part of the Mole Lake Formation within 100 feet of the zinc ore (known as the Crandon Formation). Waste rock mined from the development headings during the operating period will be derived from the

Lower Mole Lake Formation. The preproduction waste rock that will be mined from the upper part of the Mole Lake, Rice Lake and Skunk Lake Formations will be generated within the small region defined on the north and west by the location of the main production shaft, on the east by the east ventilation shaft, and on the south by the lower part of the Mole Lake Formation. Based upon an examination of the mineralogy of the rock core obtained from each formation, and the results of the ABA and kinetic testing in the areas from which waste rock will be generated, approximately one-half of the preproduction waste rock will not produce acidic leachate and will leach only minute quantities of substances. These rocks are referred to as Type I wastes throughout the remainder of this report.

Some of the waste rock is expected to have the potential to produce acidic leachate and/or leach greater than minute quantities of substances. These rocks will be referred to as Type II wastes. In general, materials will be either Type I or Type II depending upon the type, abundance and relative proportions of sulfide minerals to acid neutralizing minerals within the rocks.

Most of the waste rock expected to be generated during the development of the production shaft, ventilation shafts and raises, crosscut development drifts connecting the hanging wall drifts to the production shaft, internal access ramps, and equipment and storage facilities is expected to be Type I waste rock. One of the objectives of the waste characterization program is to determine if the potential Type I waste rock generated during the preproduction phase of the project can be used in surface construction, such as road construction, where this material would be in direct contact with soils at the site.

Most of the Type II waste rock is expected to be generated during the development of the stope accesses and hanging wall drifts that parallel the ore body. Type II waste rock generated during mine development will be transported to the surface and stored in a lined facility. During operations a portion of the Type II waste rock will be used to backfill depleted stopes. The Type II waste rock brought to the surface may be used in construction inside the containment area of TMA facilities where the waste rock can be isolated from the surficial environment via liners and covers. Type II waste rock not used in this construction process will be placed in the TMA.

Tailings will be generated as a result of the primary beneficiation of ore at the site. Permanent disposal of tailings, considered to be a Type II waste, will occur both in the mine and in the TMA, both of which are engineered facilities. Current mine plans call for backfilling of depleted mine stopes with a coarse tailings fraction consisting of material larger than 10 to 15 microns in diameter, and the placement of a fine tailings fraction typically smaller than 10 to 15 microns in diameter in the TMA. A future alternative that may be considered during operations will be the use of whole tailings for backfill. Under this option, only whole tailings would be placed in the TMA.

Normally during mining operations, coarse tailings, which will be free draining, will be pumped into mined-out stopes. When required, normal Portland cement (NPC) will be added to the coarse tailings before they are placed in the depleted stopes. It is estimated that about 60 percent of the backfilled stopes will contain cemented tailings, and the remaining 40 percent will contain uncemented tailings. Coarse tailings will be pumped to the mined-out stopes in the form of a slurry consisting of 60 to 70 percent solids. The liquid portion of all tailings slurries will primarily be process water.

Backfilling of the depleted stopes will occur normally on a daily basis. During these times, fine tailings will be pumped to the TMA. When backfilling is not required underground, whole tailings will be pumped to the TMA. It is expected that about 80 percent of the tailings placed in the TMA will consist of fine tailings and that the remaining 20 percent will consist of whole tailings. All tailings materials pumped to the TMA will be in the form of slurries with varying solids contents. Fine tailings will have a solids content of 12 to 30 percent, while whole tailings will have a solids content ranging from 40 to 50 percent.

A portion of the waste rock generated during mining operations will also be used for backfilling depleted stopes. Overall it is estimated that about three percent of the backfill material will consist of waste rock.

Excess water from the backfilling process will drain to a sump in the mine where it will commingle with other mine water to become part of the mine drainage water. Excess water in the TMA cells will be recycled to the ore processing facilities. Treatment of mine drainage water, and on occasion process water from the TMA, using the planned combined lime and sulfide treatment processes, will produce solids. Both wastewater treatment and reclaim pond solids are considered to be Type II wastes and will be co-disposed with tailings materials in the TMA.

Mine drainage wastewater will include readily soluble substances, oxidation products and colloidal materials that have resulted from the reaction between groundwater and: 1) weathered and unweathered Type I waste rock; 2) unweathered ore and unweathered Type II waste rock; and 3) weathered ore and weathered Type II waste rock. Mine drainage wastewater will also include drainage water from the: 4) backfilled cemented stopes; and 5) backfilled uncemented stopes.

One of the objectives of the waste characterization program has been to generate leachates that will approximate the properties of components 2 through 5 of the mine drainage wastewater listed above. Component number 1 is equivalent to groundwater at the project site since that component of mine drainage wastewater will be groundwater that is intercepted prior to coming in contact with materials within or immediately adjacent to the mine. Components 2 through 5 were combined in proportion to the expected flows that will occur during mining operations to produce the raw mine drainage wastewater for use in the wastewater treatment pilot studies. The wastewater treatment solids produced during the pilot studies have been characterized. It is estimated that during the life of the project the wastewater facilities will produce approximately 100,000 tons of solids, which when placed in the TMA will constitute about 0.4 percent of the solids contained in the TMA. No additional testing of these solids has been conducted since these solids represent a small volume and acceptable disposal techniques have been developed which are well documented.

Reclaim pond solids will consist of fine particulate matter that has been transferred to the reclaim pond as suspended solids during the management of water levels within the TMA cells. The reclaim pond will act as a settling basin for this material, which would otherwise enter the recycled water returned to the mine process facilities. Reclaim pond solids will be similar to the fine tailings with the exception that the reclaim pond solids will contain smaller proportions of pyrite and greater proportions of phyllosilicates and quartz than the fine tailings, due to the density differential and thus the settleability of these minerals. For purposes of the environmental investigation, reclaim pond solids will be considered equivalent to fine tailings,

and therefore a Type II waste. Therefore no separate testing of reclaim pond solids was necessary or undertaken.

Overburden wastes will be produced during the construction of the mine and its facilities. Past studies have shown that the geochemistry of the soils above the ore body do not reflect the mineralization within the crystalline bedrock that begins at a depth of about 100 feet below the land surface (BHP, 1993). As discussed later in this section, the mean concentration in the soil of most of the parameters of environmental concern are less than the mean concentrations for all U.S. soils. The overburden is therefore considered to be a Type I waste and was not tested further during the present environmental investigation.

Small quantities of laboratory wastes, primarily geological and metallurgical test samples, will be produced during mining operations. These materials are considered to be Type II wastes and will be placed in the TMA. It is estimated that these solids will comprise approximately 0.001 percent of the wastes contained within the TMA. No additional testing of the laboratory wastes was undertaken.

Demolition wastes will be generated during the reclamation of the site. These wastes will consist of construction materials and concrete from on-site buildings. Accepted practices have been developed for the disposal of these wastes and no testing was considered necessary. These wastes will be disposed of either in the shaft opening at the completion of mining or as a grading layer in the top of the final TMA cell.

The current estimate of each type of waste expected to be generated during the preproduction, operational and reclamation phases of mining activities is summarized below in Table 3.5-14.

Table 3.5-14

Estimated Quantities of Mining Waste Generation

Waste	Estimated Total Generation (tons)
Type I Waste Rock	610,000
Type II Waste Rock	650,000
TMA Tailings	22,400,000
Backfill Tailings	22,400,000
Wastewater Treatment Solids	100,000
Reclaim Pond Solids	270,000
Laboratory	280
Demolition	230,000

Prepared by: REM
Checked by: JWS

The objectives of the waste characterization tests conducted during the environmental investigation have been to determine the behavior of the primary wastes generated during mine development and operations and the potential impact they could have on the environment. The minor uncharacterized wastes include the wastewater treatment solids, overburden, laboratory, and, demolition wastes.

The behavior of the primary wastes will depend upon the characteristics of the various rock units comprising the wastes, the processing of the wastes, and their methods and place of disposal. To establish this behavior a waste characterization program was developed with the objective of determining the following about each class of wastes:

1. Waste Rock

    a. Establish criteria for the classification of rock as Type I (for construction purposes outside the contained TMA) or as Type II (to be placed within the TMA).

    b. Estimate the feasibility of separation of the waste rock into Type I and Type II during the development and operation of the mine, and to propose a method that can be used to distinguish Type I/II waste rock in the field.

2. TMA Tailings

    a. Establish the expected behavior of the tailings during the operation of the TMA cells.

    b. Establish the expected behavior of the tailings during the consolidation phase of the TMA cells.

3. Backfill Tailings

    a. Establish the expected behavior of cemented and non-cemented tailings to be used in backfilling operations.

To address these issues, the following analyses and test procedures have been completed on various samples of Crandon Project waste rock and tailings expected to be generated during the development and operation of the mine:

1. Acid-base accounting (ABA) tests to determine: a) the potential of the materials to produce acid; and, b) the neutralization potential of the various wastes.

2. Kinetic leaching tests to determine the reactivity of waste rock and tailings materials under conditions simulating those expected to exist where these materials will be either used or stored.

3. Waste rock classification (WRC).

It should be noted that the purpose of completing a WRC evaluation, in addition to ABA and kinetic testing, is to determine if there is a good correlation between the WRC technique and ABA and waste leachability. This was done to determine if WRC could be considered as a

technique that could be used in the mine to assist in the segregation of waste rock into Type I and Type II materials.

In addition, petrographic and x-ray diffraction analyses to: a) identify sulfide and carbonate minerals; b) semi-quantitatively estimate the abundances of these minerals; and, c) delineate the distributions of these minerals in each of the relevant lithological units are in the process of completion. Preliminary results can be found in Appendix 4.2-12 of this EIR.

3.5.5.1 Methods and Quality Control

The specific material preparation and test protocols for each waste characterization program was dependent on the material being tested. Preparation procedures are discussed in this report on a material by material basis. Sampling procedures are described in Appendix 3.5-33 Table 1. Analytical methods, target detection limits, sample handling procedures, etc., are described in Appendix E, Project Quality Control Plan, of the project's NOI/SOS (Foth & Van Dyke, 1994), and in subsequent updates to that plan which are described in Appendix 3-1 of this EIR.

Throughout the waste characterization program WDNR personnel have observed the preparation and processing of the materials tested. In addition, the WDNR has collected split samples of both materials and leachates for independent analysis. The WDNR analyses have been performed by the State Laboratory of Hygiene (SLOH). A comparison of three leachate sample splits analyzed by Pace (CMC's contract laboratory) and SLOH is contained in Appendix 3.5-33 Tables 3-5. The results show excellent agreement between the two laboratories with the slight exception that the SLOH values for aluminum and iron were greater than those reported by Pace.

Subsamples of ore, mineral concentrates and tailings materials, originally collected and analyzed approximately 15 years ago (CMC, 1992; Hanks, 1992), were analyzed for their total sulfur and sulfate concentrations in 1992 to determine the long term stability of the sulfide minerals within these materials. The proportion of sulfate-sulfur to total sulfur was used as a measure of the degradation of the sulfide minerals within these samples. The results of the analyses indicate that the coarser grained ore samples were only slightly degraded during storage. Based upon these results, it was concluded that the use of waste rock samples collected in the past exploration work could be used for the current testing program and would produce results nearly identical to those that would be produced if fresh waste rock were used. Therefore, waste rock samples for the current testing program were collected from existing core preserved in CMC's core storage facility in Rhinelander, Wisconsin. A small portion of the waste rock samples used in the testing were collected from the confirmation drilling program conducted during 1993-1994.

3.5.5.2 Materials and Sample Preparation

Two types of testing of the waste materials (waste rock and tailings), static and kinetic tests, have been conducted during the past (B.C. Research, 1982a and 1982b, and Colorado School of Mines, 1982) and as part of the present studies. Static tests are those which are conducted almost instantaneously and produce a single set of results. Examples of static tests performed on the waste materials include the determination of bulk chemical composition, acid base accounting (ABA) and waste rock classification (WRC). A detailed discussion of the static test methods and results is presented in Section 3.5.5.3.1.

Kinetic tests are those that are performed over a period of time, and produce a series of time related results. Kinetic tests are used to measure reaction rates and completeness, or extent, of reaction. The leaching tests performed on the waste materials are kinetic tests. A detailed discussion of the kinetic test methods and results is presented in Section 3.5.5.3.2.

Waste materials and samples were prepared to perform each test. Each group of materials tested required different preparation for each type of test to meet the objectives of the program. The preparation of each tested waste is described in the following subsections.

3.5.5.2.1 Waste Rock

The current mining plans call for the development of underground facilities north of the ore body in two distinct regions during preproduction activities. The first region will include waste rock within the lowermost 100 feet of the Mole Lake Formation, the area that will contain the development of the stope accesses and drifts. The second area is approximately bounded on the west and north by the location of the production shaft, on the east by the location of the east ventilation shaft and on the south by the lower part of the Mole Lake Formation. The second region will include waste rock generated during the development of the production shaft, ventilation shafts and raises, internal access ramps, equipment and storage facilities, and the drifts ("cross cuts") connecting the mining areas with the production shaft.

The initial core examination of the current testing program was conducted for the purposes of collecting samples for ABA analysis, WRC evaluation and to gain a familiarity with the texture and mineralogy of the waste rock from these two areas. During this examination of the waste rock it was noted that: 1) the amount of sulfide minerals, mainly pyrite, observed within the rock matrix was generally at trace (<0.1 percent) concentrations; 2) concentrated sulfide minerals exist in few, scattered veinlets; 3) fine grained carbonate minerals exist within the matrix, potentially in greater concentrations than the sulfide minerals; 4) concentrated carbonate minerals exist in few, scattered veinlets; 5) the concentration and variability in concentration of sulfide minerals within the lowermost 100 feet of the Mole Lake Formation was greater than in the other waste rock units; and, 6) the lithologic differences between formations were sufficient enough to visually separate the formations.

Based upon these observations CMC decided to test each formation from which waste rock would be generated separately and to divide the Mole Lake Formation into: 1) a Lower Mole Lake Formation containing waste rock within 100 feet of the zinc ore body; and, 2) an Upper Mole Lake Formation containing the remainder of the rock within the originally defined Mole Lake Formation. Therefore for testing purposes the waste rock was divided into four formations (Skunk Lake, Rice Lake, Upper Mole Lake, and Lower Mole Lake), each of which was tested separately. Material collected from the Lower Mole Lake Formation is representative of the material expected to be encountered while developing the stope accesses and drifts, i.e., material from the first waste rock region. Material collected from the limited region encompassing the second waste rock region was collected from the Skunk Lake, Rice Lake and Upper Mole Lake Formations and is representative of the material expected to be similar to that encountered during the development of the facilities that are planned to be constructed within that region.

Representative composites for the Skunk Lake, Rice Lake and Upper Mole Lake Formations were prepared from about one third of the cores stored in CMC's Rhinelander facility that intersected the area containing the underground workings and facilities. The number of cores

selected was chosen to provide an even spatial distribution of samples within the test area, and to produce the volume of sample needed to conduct the tests. Three inch samples were collected from every two feet of core from the four geologic units intersected by the drill holes. The samples were placed in bags that were marked with the geologic formation name, the core (DDH) number and the interval sampled. In the case where the core had been split, approximately six inch samples were collected.

The bagged samples were inventoried and transported to the Lerch Brothers mineral processing facility in Hibbing, Minnesota, where the material in each bag was crushed to less than 1½ inches in diameter. The crushed samples were returned to CMC's Rhinelander core storage facility where they were logged off the truck and split using a Jones Riffle Splitter. By blending the sample splits, it was possible to produce a thoroughly mixed sample composite. The composites thus formed are referred to as the Master Waste Rock Composites since they statistically represent the material within each formation studied.

A master composite was similarly prepared for rocks in the Lower Mole Lake Formation. This composite differs from the other three master composites in that it statistically represents the Lower Mole Lake Formation across the entire length of the ore body. This larger area was sampled because it represents the extent of the stope accesses and drifts that will be constructed within this formation.

The location and geologic formation of the samples collected to prepare each of the four master waste rock composites is included in Appendix 3.5-31 Tables 1 and 1a. Sample selection, processing and compositing of all materials was observed by WDNR personnel.

Appendix 3.5-31 Table 1 contains the exploration intervals sampled from each boring during the preparation of the master waste rock composites by geologic formation. The table also contains all of the sulfur and sulfide mineral content data available for these intervals. A review of the data contained within the table shows that: 1) the results of nearly all of the sulfur assays of analyzed rock within the Skunk Lake, Rice Lake and Upper Mole Lake Formations are at trace level concentrations; 2) the average value of the sulfur assay values of the tested intervals within the Lower Mole Lake Formation are greater than those of the other three formations; 3) the sulfur concentrations within the Lower Mole Lake Formation are more variable than those of the other three formations; and, 4) the estimated sulfide mineral content of the intervals based on visual observations significantly overestimates the assay sulfur content of the intervals in nearly every case.

In addition, Appendix 3.5-31 Table 1 also contains the one foot subintervals that were analyzed as part of the ABA testing program, described in Section 3.5.5.3.1 of this report, and the results of the sulfur assays of those subintervals. Contained within the data are six 20-foot assayed waste rock intervals in the Rice Lake (DDH 021: 1120-1140) and Upper Mole Lake (DDH 131: 1196-1216, 1216-1236 and 1336-1356; DDH 160: 2412-2431 and 2432-2452) from which high sulfur content one foot intervals were collected for the ABA assays. It is evident from an inspection of data related to these intervals that the presence of high sulfur content veinlets within a 20-foot interval has little influence on the sulfur content of that 20-foot interval.

Appendix 3.5-31 Table 1a contains all of the intervals sampled to prepare the master waste rock composites arranged by boring number. In many cases the diamond drill holes intersected more than one formation in the region of interest. Collecting core from the multiformational

intercepts, such as DDH 09, provided an enhanced interpretation of the features of the waste rock formations.

In order to assess the variability of the potential to produce acid within each master waste rock composite, in 1994 30-foot continuous core intercepts were delineated in each core sampled to prepare the master waste rock composites. Ten percent of the intercepts in each formation were randomly selected, using a random number generator, for a waste rock classification (WRC) evaluation. The delineated, and the selected, 30-foot intervals are included in Appendix 3.5-31 Table 2.

In 1995, parameter variability within the master waste rock composites was further tested using a two level validation approach. For the first level, 46 core intervals that had been crushed, bagged and stored in CMC's Rhinelander facility were analyzed for their neutralization potential (using ABA techniques) and bulk chemical values. This core was the same material that has been used to prepare the master waste rock composites. The second level of validation consisted of collecting two-foot samples of continuous core per 10-foot core box in 13 of the 46 crushed core intervals. ABA and bulk chemical tests were performed on these two-foot intervals to assess parameter variability within the crushed core intervals. A detailed discussion of the testing and results is contained in Section 3.5.5.3.1 of this report.

For each geologic formation an additional composite was prepared which contained three to five percent sulfur. Rocks with such a sulfur content are not common within the Skunk Lake, Rice Lake and Upper Mole Lake Formations, but as noted above, are fairly common in the Lower Mole Lake Formation. In fact, most of the core used to prepare the high sulfur content composites for the Rice Lake and Upper Mole Lake Formations were selected from those that had high sulfur values which are found only in core intercepting these formations far to the west of the region that will generate preproduction waste rock from these formations. These composites were prepared to evaluate the worst case effect of increased sulfide mineral content and the potential to produce acidity and to characterize the leachability of the rocks in each formation. The data generated from testing these composites has also been used in establishing the lower limit of the NP:AP ratio that will not produce acidic leachate (see Section 3.5.5.3.1.3).

The samples used to prepare the high sulfur composites were chosen solely for their sulfur content, and therefore do not statistically represent the materials found throughout the region represented by the master waste rock composites. These composites are referred to as the High Sulfur Waste Rock Composites. The location and geologic formation of the samples collected to prepare the four High Sulfur Waste Rock Composites is included in Appendix 3.5-31 Table 3. Core collected to prepare these composites was bagged, labeled, crushed, split and blended similar to that collected to prepare the Master Waste Rock Composites as described above.

As mentioned above, all of the waste rock samples were crushed to a size less than 1½ inches in diameter. This size was chosen since it represents the finest crush that would be used if the waste rock were to be used for site construction purposes. All samples were sieved to verify that the material passed 1½ inches prior to charging the leaching columns. The measured particle size distribution and weight of each composite is included in Appendix 3.5-31 Figures 1 through 8. The physical durability of these rocks is evident in the coarse size distribution of the crushed material. This durability is attributed to the fact that these rocks have been partially silicified during lithification and/or metasomatic alteration processes. The sieved waste rock composites were recombined and were leached in modified large scale humidity cells similar to

those described by Brodie, et al. (1991). Details concerning the cells, the leaching process and results are contained in Section 3.5.5.3.2 below.

3.5.5.2.2 Tailings

Diamond drill core samples (DDH) of ore collected during the late 1993 through early 1994 zinc ore confirmatory drilling program at the project site were shipped to Lakefield Research (Lakefield) for metallurgical bench scale testing. Individual core sections were split, crushed, and assayed to provide data regarding the variation in ore mineral quantities through the ore body. A master zinc ore composite was prepared in 1994 by blending crushed drill core sections to approximate the projected average mill head grade of 9.2 to 9.6 percent zinc. Part of the metallurgical testing included the separation of ore mineral concentrates from tailings during lock cycle flotation testing.

The 1994 zinc master ore composite, representative of the zinc ore within the Crandon Formation, included ore from the lower, middle and upper portions of the zinc ore body. Ore composites rather than individual ore samples have been tested due to the fact that during the operation of the mine ores from several locations within the mine ore will be extracted simultaneously and blended in order to maintain as constant a mill head grade as possible. This will be done to maximize ore recovery from the flotation process. A letter (Erickson, 1994) discussing the representativeness of this composite, and comparing it to previously prepared zinc ore composites, is included in Appendix 3.5-31. Lakefield processed the composited ore, using a flotation process, to produce zinc, copper and lead mineral concentrates. A byproduct of the flotation process is the generation of tailings materials. Lakefield separated the tailings into two sized fractions: one containing materials typically coarser than 10 to 15 microns (referred to as the coarse tailings), and one containing materials typically finer than 10 to 15 microns (referred to as the fine tailings). Both size fractions were shipped in separate, sealed containers to Foth & Van Dyke's Green Bay office for use in the waste characterization program.

Upon receipt of the samples, the containers were weighed to determine the proportion of the whole tailings that each fraction represented. By weighing the containers it was determined that approximately 60 percent of the tailings were coarse tailings, and that approximately 40 percent of the tailings were fine tailings. These percentages were calculated on a moist tailings basis of the materials as received. Moist tailings were used to charge the columns to minimize potential oxidation. The weights of the tailings placed in the columns were recorded as moist weights. Some of the waste characterization tests required the use of whole tailings. Whole tailings were produced by Foth & Van Dyke, as required, by proportionately recombining the two tailings size fractions.

Tailings produced from the processing of the zinc ore have been used in the current waste characterization program because it is expected that tailings produced from that ore will contain greater amounts of environmentally sensitive materials than those produced from processing the copper ore. This conclusion is based on the differences in the composition of the two ores. A zinc ore composite was prepared and tested in 1979 by Lakefield using methods similar to those used in 1994, but the 1979 ore composite was produced from different drill core and was blended to a slightly lower zinc concentration. A copper ore composite was also prepared and tested in 1979 by Lakefield (Lakefield Research, 1979). A copy of the Lakefield report describing this work is included in Appendix 3.5-31. Data concerning the compositing and bulk chemical composition of the three tested ores is included in Appendix 3.5-31 Tables 4a and 4b. A

comparative summary of the ore compositions, converted to mg/kg units, is shown in Table 3.5-15 of this report.

A review of the data shows that the two zinc ore composites are remarkably similar in major and trace element composition thereby validating the statement that the blended zinc ores will have similar major and minor elemental composition independent of the locations of the individual ore samples used to produce the blend. This conclusion demonstrates the consistency of ore blends that are likely to be produced during mining operations and also demonstrates that lateral and depth variations in ore composition are small. The composition of the zinc ore does vary considerably in a north-south direction reflecting the stratibound nature of the deposit and the fact that several cycles of mineral deposition occurred during the development of the Crandon Formation (Erickson, 1994; Erickson and Côté, 1996). However, during removal of the ore by the stoping technique, the individual layers within a given stope in the ore body become homogenized, especially after the ore is crushed and milled. Therefore the use of blended composites for both metallurgical and environmental testing is appropriate in light of the manner in which the ore will be extracted and processed.

A comparison of the composition of the zinc and copper ore composites reveals that the copper ore contains more aluminum, silicon and copper than the zinc ore composite. This difference is due to the fact that the copper ore contains more quartz (SiO_2) and aluminosilicate minerals, minerals common to the soils at the site, than the zinc ore. It is expected that the copper content of tailings generated during the processing of the copper ore will contain copper concentrations similar to the tailings generated during the processing of the zinc ore. The zinc ore contains more arsenic, cadmium, calcium, iron, lead, total sulfur and zinc than the copper ore. The zinc ore contains more calcite ($CaCO_3$) than the copper ore and therefore has a greater neutralization potential than the copper ore. However, the zinc ore contains considerably more pyrite (FeS_2) than the copper ore. Since pyrite remains in the tailings following ore processing, tailings generated during the processing of the zinc ore will likely have a greater potential to produce acidic leachate under conditions of long term oxidation. Most of the lead and zinc will be recovered from the zinc ore during processing. Arsenic and cadmium are common trace constituents of pyrite and sphalerite (ZnS, the zinc ore mineral), respectively. Therefore environmental testing of the zinc ore tailings is a conservative approach to predicting the environmental impacts of the processing and disposal of the tailings. In fact about one half of the tailings deposited in the TMA (those from the copper ore) will contain equivalent, or in most cases, lower concentrations of environmentally sensitive constituents than the tailings used in the environmental testing.

3.5.5.2.2.1 TMA Tailings

During the operation of the mine, tailings will be mixed with process water and slurried to the TMA cells. The initial tailings deposited in the first TMA cell may be whole tailings since a depleted stope may not be available to accept backfill during this time period. It is estimated that approximately 80 percent of the tailings pumped to the TMA cells will be fine tailings. The remaining 20 percent of the tailings deposited in the TMA cells will be whole, or undifferentiated tailings, primarily when stopes are not available to accept backfill. The first tailings deposited in each TMA cell will be added to the cells subaqueously. Excess water will be pumped from the central pond and returned to the reclaim pond for recycling of this process water. In addition, leachate will be collected by the TMA leachate collection system located at the base of the cells and pumped to the reclaim pond.

Table 3.5-15

Bulk Chemical Composition of the Zinc and Copper Ore Master Composites Tested by Lakefield Research in 1979 and 1994

Parameter	Zinc Ore		Copper Ore
	1994 (mg/kg)	1979 (mg/kg)	1979 (mg/kg)
Aluminum	20,100	18,100	34,500
Antimony	85	230	110
Arsenic	2,700	2,100	590
Barium	<50	<40[a]	NA
Cadmium	260	220	21
Calcium	4,100	2,800	1,100
Carbon, T.	4,400	1,300[b]	NA
Chromium	70	31	NA
Cobalt	67	95	60
Copper	3,300	4,500	26,100
Gallium	13	<5[a]	NA
Gold	3.98	1.2	0.16
Iron	232,000	237,000	109,000
Lead	11,200	6,900	600
Magnesium	11,200	13,100	13,700
Manganese	460	500	580
Mercury	7	7	6
Molybdenum	<20	6	5
Nickel	100	31	25
Potassium	4,400	3,600	4,100
Selenium	42	9	100
Silicon	128,000	121,000	289,000
Silver	42	30	14
Sodium	1,800	400	600
Sulfur, T.	291,000	306,000	84,000

Table 3.5-15 *(Continued)*

Parameter	Zinc Ore		Copper Ore
	1994 (mg/kg)	1979 (mg/kg)	1979 (mg/kg)
Tin	23	60	50
Titanium	1,000	360[a]	NA
Uranium	<20	<10[a]	NA
Zinc	96,600	83,700	7,400

Notes:
[a]Quantitative analysis performed by Colorado School of Mines Research Institute (CSMRI)(1982).
[b]Semiquantitative analysis performed by CSMRI. Actual data provided was for carbonate carbon which has been converted to total carbon, assuming the carbonate carbon equals total carbonate.

In addition, CSMRI also semiquantitatively analyzed the 1979 zinc ore composite for the following parameters which were not detected (detection limits shown in parentheses):

Beryllium (<1 mg/kg);
Bismuth (<50 mg/kg);
Germanium (<50 mg/kg);
Tellurium (<500 mg/kg); and,
Thallium (<40 mg/kg).

Prepared by: JET
Checked by: DJL

In order to evaluate the stability of the tailings stored in this environment during the operational phase of the TMA cells, two sets of tests have been developed. In the first set of tests, composites of fine and whole tailings were emplaced in modified 30-gallon cylindrical polyethylene columns and reacted first with process water, under saturated conditions, to simulate the reactions of the tailings while saturated. These tailings composites were later drained and reacted with deionized (DI) water, under alternating wet and dry conditions, to simulate the conditions that may occur: 1) when excess water has been drained from the ponds (cells); and, 2) when precipitative water and air enter the stored tailings during the operation of the TMA cells at times when the ring discharge system is depositing the tailings slurry at other locations within the cell. As such, these tests were conducted under conservative conditions since: 1) tested tailings were maintained under warm, moist oxidizing conditions; 2) the tested tailings were exposed to these conditions for approximately 18 months, without the addition of fresh tailings. It is expected during operation that the tailings would be exposed to ambient weather conditions for only about 2 months before the ring spigot discharge system would deposit additional tailings on top of previously exposed tailings. The addition of fresh tailings on top of the impounded tailings will isolate tailings from the oxidizing conditions and will flush the accumulated tailings with alkaline process water, thereby quenching the oxidation process and neutralizing acidic products that may have formed during the time of exposure.

In the second set of tests, a composite of whole tailings and a composite of lime amended whole tailings were each emplaced in a modified 30-gallon cylindrical polyethylene column and were reacted with DI water under alternating wet and dry conditions. This test was designed to evaluate the reactions of the tailings materials added to the top of a tailings pond, during the final stage of pond operation, during which time the tailings are deposited in a manner to form a crown over which the TMA cover system will be installed.

Additional testing of the tailings to simulate: 1) the lower moisture conditions expected to exist at the surface of the exposed, crowned tailings during the one to two year consolidation of the tailings prior to the installation of the cover system; and, 2) reactions of the tailings during long term anoxic conditions have been conducted under the supplementary waste characterization program referred to above. Preliminary results of the supplementary tests are discussed in Appendix 4.2-12 of this EIR.

3.5.5.2.2.2 Backfill Tailings

Past testing on the backfilled tailings materials focused on the physical characteristics of these materials. One test measured the heat of reaction generated by the reaction of coarse and fine tailings materials with water (Spira and Rosenblum, 1981). The results of these tests indicated that backfilling the depleted stopes with these materials will be a slightly exothermic process with no danger of overheating or spontaneous combustion. These results apply equally to the tailings that will be placed in the TMA.

Permeability and rock mechanic tests have been conducted on various tailings fractions, with and without additives, to evaluate the properties of cemented and uncemented backfilled wastes (Smith, 1986; Dames & Moore, 1978). The laboratory results showed that tailings materials mixed with normal Portland cement (NPC) at a ratio of 10:1 (tails:NPC) produced the best overall reduction in permeability in the tailings for the greatest increase in cementation strength.

During backfilling, waste rock will be placed in some of the depleted stopes. It is expected that backfilled waste rock will comprise about three percent of the total backfill volume. The remainder of the stope volume will be filled with tailings, including the void spaces in the stopes containing backfilled waste rock. Approximately 60 percent of the stopes will receive either coarse tailings mixed with normal Portland cement (NPC) or whole tailings material thickened with NPC. The remaining stopes will receive uncemented coarse tailings or whole tailings. Cemented backfilling of the stopes will increase rock stability within the mine, while decreasing the permeability of the backfilled stopes. The bases of the depleted stopes will be bulkheaded with cement prior to filling the stope. Backfill tailings will be added to the depleted stopes in the form of either a slurry (for coarse tailings) or as a paste (thickened whole tailings). Excess water accumulated during this process will be wicked from the tops of the fillings stopes and will be added to the commingling mine waters in the mine sump from which the consolidated mine drainage water will be pumped to the wastewater treatment facility for treatment and discharge. Therefore the backfilled tailings will be stored under initially saturated conditions. The initially saturated backfill tailings will then either: 1) solidify as a highly alkaline cemented product in the case of the cemented coarse tailings; or, 2) in the case of uncemented backfill, the coarse tailings will be capped with a cemented layer of tailings, and will thus be sealed off from atmospheric conditions. The moisture content in the uncemented coarse tailings will slowly decrease over time due to lateral drainage of interstitial pore fluids through the bedrock surrounding the stopes. During mine reclamation, the mine drainage system will be shutdown and the mine will slowly fill with water. Therefore, the long term disposal of the backfilled tailings will be under saturated conditions.

To simulate the backfilled stope environment in which these materials will be stored, cemented and uncemented composites of coarse and whole tailings were prepared. Portions of the uncemented coarse and whole tailings composites were emplaced directly in 5-gallon cylindrical polyethylene columns. The remainder of the two composites were individually mixed with NPC and process water at an tailings:NPC ratio of 10:1, and added to several 4 by 8-inch standard plastic cement molds. The cemented tailings materials were allowed to cure for approximately 14 days, after which the molded cement was broken into fragments which were placed in 5-gallon cylindrical polyethylene columns. Each of the four materials was saturated with process water for 24 hours and then allowed to drain. After several weeks of draining, the materials were resaturated with site groundwater for an additional 24 hours and again allowed to drain. This additional flushing (saturation and drainage) was added to the evaluation to simulate the potential reaction between the stored tailings and the groundwater rewetting the backfilled stopes. Following the drainage or the resaturated backfilled tailings, the samples were permanently saturated with site groundwater to simulate the reflooded closed mine.

3.5.5.2.3 Mine Drainage Wastewater

The Crandon mine wastewater will consist of five components. Three of these components will include groundwater that has reacted with: 1) unweathered and weathered Type I waste rock; 2) unweathered and weathered Type II waste rock; and, 3) unweathered and weathered ore. Mine wastewater will also include drainage water from the: 4) cemented backfilled stopes; and, 5) uncemented backfilled stopes. These waters will contain varying proportions of dissolved substances, oxidation products and colloidal materials that have resulted from the interaction between groundwater and the first three sources, and from the interaction between process water and the backfilled tailings. These waters will commingle in the mine sump where they will be

collected and discharged to the project's wastewater treatment facility for treatment prior to discharge.

One of the tasks of the waste characterization program was to provide waters simulating sources two through five listed above for wastewater pilot studies. Site groundwater was reacted with composites prepared from selected mineral exploration cores which recovered unweathered and/or weathered ore and waste rock. The locations of the selected cores, chosen to represent the entire ore body, are shown in Appendix 3.5-31 Figure 9. The location and weight of samples collected to prepare the unweathered ore, and the weathered ore and waste rock composites is included in Appendix 3.5-31 Tables 5 and 6, respectively. Details regarding the collection of samples and generation of leachates were discussed with WDNR prior to the initiation of the process and during the performance of the leaching efforts. WDNR personnel witnessed the selection and processing of the core materials and the charging of the leaching columns.

The trace metal content of the unweathered ore composite was augmented by the addition of samples from the core intervals that contained above average amounts of arsenopyrite, galena, silver, chalcopyrite, and sphalerite. The enhancement of the unweathered ore composite was undertaken to specifically enhance the content of arsenic, lead, silver, copper, and zinc in the leachate produced by reaction between this composite and site groundwater. The unweathered ore samples were crushed by hand to produce fragments smaller than 3-inches in diameter. The crushed fragments were placed in a 30-gallon, conical bottom polyethylene column. Leachate was produced by reacting the composited ore with site groundwater under alternating wet and dry conditions. Acidic leachate containing elevated concentrations of the desired substances could not be generated by the unweathered ore composite in time to complete the wastewater treatment pilot study due to the high carbonate mineral content of the unweathered ore. With approval of WDNR leachate collected from the high sulfur waste rock composites that were producing acidic leachate was substituted for the planned unweathered ore leachate. The results of prior analyses of the acidic waste rock leachate showed that this leachate contained elevated concentrations of the parameters of interest.

The weathered ore and waste rock samples were also crushed by hand to produce fragments smaller than 3-inches in diameter. The crushed fragments were placed in a 5-gallon cylindrical polyethylene column and reacted with site groundwater to produce a leachate containing abundant colloidal matter. This leachate was prepared within 24 hours before the beginning of each phase of the wastewater treatment pilot study.

Drainage water from the backfilled stopes was also generated within 24 hours before the beginning of each phase of the pilot test. These waters were produced by reacting coarse tailings materials, with and without NPC, with simulated process water.

During the pilot tests, components 2 through 5 of mine drainage water (as listed above), were combined according to the proportion expected to be intercepted by the operational mine drainage system. The first mine drainage water component is equivalent to site groundwater and was not used in the simulation of the final mine wastewater mixture since it would only serve to dilute the substances contained within the other four components.

A detailed description of the blending of the mine drainage wastewater components and the pilot test results is contained in the project's *Preliminary Engineering Report for Wastewater Treatment Facilities for the Crandon Project* (Foth & Van Dyke, 1995e).

3.5.5.3 Laboratory Methods, Analyses and Calculations

The analyses conducted as part of the waste characterization program fall into two broad categories: static and kinetic tests. Additional tests and interpretations of test results are discussed in the following subsections.

3.5.5.3.1 Static Tests

Static tests conducted on the Crandon waste materials include: 1) site soil bulk chemical analysis; 2) bulk chemical analysis of waste rock, tailings, ore, and process water; 3) acid base accounting (ABA) of waste rock and tailings; 4) waste rock classification (WRC) evaluations; 5) extraction procedure (EP) toxicity tests performed on waste rock, ore and tailings; 6) radiological testing of tailings, ore and waste rock; and, 7) asbestiform mineral investigations of tailings, ore and waste rock. The methods and results of tests 1 through 4 are described below in this section of the report. The methods and results of tests 5 through 7 are discussed below in Section 3.5.5.3.3, Miscellaneous Studies.

3.5.5.3.1.1 Site Soil Bulk Chemical Analysis

Two hundred forty-four soil samples were systematically collected along traverses perpendicular to, and above, the zinc ore body in the area of the plant site. This work was conducted in 1993 by BHP Minerals International, Inc. (BHP, 1993) as part of a site geochemical survey. The results of the analyses of the soils are included in Appendix 3.5-32. A statistical summary of the analytical results is presented in Table 3.5-16 along with mean parameter concentrations of a wide range of U.S. soils analyzed by the USGS (cited in Sparks, 1995). As seen in the table, the mean concentration of most of the environmentally sensitive parameters, such as arsenic, cadmium, chromium, lead, manganese, silver, uranium, and zinc, in the Crandon site soils are less than the median concentrations found in a wide range of U.S. soils.

Comparing the analytical results contained in Table 3.5-16 to the master waste rock leachate analyses contained in Appendix 3.5-34 reveals that those parameters most abundant in the site soils, such as aluminum, calcium, iron, magnesium, and potassium, are the same parameters most abundant in the master waste rock leachate. In addition, those parameters least abundant in the site soils, such as arsenic, cadmium, mercury, and silver, are the parameters least abundant in the master waste rock leachate.

3.5.5.3.1.2 Bulk Chemical Composition of Waste Rock, Ore, Tailings, and Process Water

Bulk chemical analyses were conducted by Lakefield on the master and high sulfur waste rock composites from each formation. The results of these analyses are included in Appendix 3.5-32. The units used by Lakefield (% and g/T) have been converted to milligrams per kilogram (mg/kg). This conversion, along with a calculation of the quantity of each parameter per waste rock composite used in the leaching tests, is contained in Appendix 3.5-32 Table 1. A summary of the bulk chemical analyses of the master waste rock composites is presented in Table 3.5-17, and for the high sulfur waste rock composites in Table 3.5-18.

Table 3.5-16

Crandon Site Soil Bulk Chemical Composition and Median U.S. Soil Composition

Parameter	Crandon Site Soils			U.S. Soils
	Range[1] (mg/kg)	Mean[a] (mg/kg)	Standard Deviation[a]	Median[3] (mg/kg)
Aluminum	2,500-42,900	14,300	4,600	72,000
Antimony	<2-2	1.0[2]		NA
Arsenic	<2-22	2.3	2.2	7.2
Barium	28-274	89	35	580
Boron	<2-8	3[2]		33
Bismuth	<2-4	1[2]		NA
Cadmium	<0.2-0.9	0.20	0.17	0.35[4]
Calcium	400-18,700	1,700	1,800	24,000
Chromium	5-198	24	16	54
Cobalt	<1-12	4.3	1.7	9.1
Copper	<1-50	10.4	6.0	25
Iron	1,200-37,200	19,400	6,600	26,000
Lead	<2-25	8.3	3.3	19
Magnesium	300-6,800	2,740	950	9,000
Manganese	18-3,730	290	370	550
Mercury	<1-2	0.6[2]		0.09
Molybdenum	<1-1	0.7[2]		0.97
Nickel	<1-64	13.0	6.4	19
Phosphorous	50-1,170	380	210	430
Potassium	300-1,600	630	160	15,000
Selenium	NA			0.39
Silver	<0.1-0.3	0.07[2]		0.1[4]
Sodium	<100-400	90[2]		12,000
Strontium	6-34	14.4	4.5	240
Sulfur, T.	NA			1,600

Table 3.5-16 *(Continued)*

Parameter	Crandon Site Soils			U.S. Soils
	Range[1] (mg/kg)	Mean[a] (mg/kg)	Standard Deviation[a]	Median[3] (mg/kg)
Thorium	<2-7	2.5	1.4	9.4
Tin	<1-18	<0.5[2]		1.3
Titanium	100-1,200	650	180	2,900
Tungsten	<1-2	1[2]		NA
Uranium	<5-12	<2.5[2]		2.7
Vanadium	5-99	31	10	80
Zinc	5-93	39.4	14.0	60

Notes:

[a] All non detects replaced with one-half the detection limit.

[1] Data from 244 analyses by BHP Minerals International, Inc. (BHP, 1993).

[2] Mean estimated from data included in above listed source. Data has a very limited range and most of the values are below the detection limit.

[3] Median values from USGS, 1984 (cited in Sparks, 1995).

[4] Mean values from Bowen (1979).

NA = not analyzed.

Crandon site soils were also analyzed for their gold and thallium content. No gold or thallium was detected in these soils.

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Checked by: DJL

Table 3.5-17

Bulk Chemical Composition of the Master Waste Rock Composites

Parameter	Skunk Lake (WD-05) (mg/kg)	Rice Lake (WD-06) (mg/kg)	Upper Mole Lake (WD-07) (mg/kg)	Lower Mole Lake (WD-08) (mg/kg)
Aluminum	63,600	68,000	71,000	68,300
Antimony	20	20	30	30
Arsenic	61	<40	<40	61
Barium	390	340	360	290
Cadmium	5.0	7.0	6.0	8.0
Calcium	1,100	7,700	13,400	9,900
Carbon, T.	800	3,300	5,300	4,400
Chromium	7.0	11	12	9.0
Cobalt	21	19	25	28
Copper	860	210	240	330
Gallium	14	14	15	13
Iron	46,000	62,100	65,900	70,400
Lead	140	150	260	180
Magnesium	21,200	36,000	32,100	28,700
Manganese	630	1,400	1,300	1,300
Mercury	<0.3	<0.3	<0.3	<0.3
Molybdenum	<20	<20	<20	<20
Nickel	6.0	15	10	10
Potassium	17,900	12,400	11,400	11,900
Selenium	<3	<3	<3	<3
Silicon	311,000	285,000	285,000	273,000
Silver	<0.01	<0.01	<0.01	0.045
Sodium	1,100	5,100	6,900	7,300
Sulfur, T.	100	<100	400	2,200
Tin	<10	<10	60	<10
Titanium	560	380	690	620

Table 3.5-17 *(Continued)*

Parameter	Skunk Lake (WD-05) (mg/kg)	Rice Lake (WD-06) (mg/kg)	Upper Mole Lake (WD-07) (mg/kg)	Lower Mole Lake (WD-08) (mg/kg)
Uranium	<10	<10	<10	<10
Zinc	240	190	190	360

Notes:

All of the master waste rock composites were analyzed for the following parameters which were not detected (detection limits shown in parentheses):

Beryllium (<1 mg/kg);
Bismuth (<50 mg/kg);
Germanium (<5 mg/kg);
Gold (<0.02 g/T);
Tellurium (<3 mg/kg); and,
Thallium (<10 mg/kg).

Prepared by: JET
Checked by: DJL

Table 3.5-18

Bulk Chemical Composition of the High Sulfur Waste Rock Composites

Parameter	Skunk Lake (WD-09) (mg/kg)	Rice Lake (WD-10) (mg/kg)	Upper Mole Lake (WD-11) (mg/kg)	Lower Mole Lake (WD-12) (mg/kg)
Aluminum	64,300	65,600	66,800	63,500
Antimony	20	20	20	60
Arsenic	61	61	46	190
Barium	230	270	330	260
Cadmium	9.0	7.0	7.0	16
Calcium	3,800	1,700	3,600	6,600
Carbon, T.	2,400	500	1,600	3,800
Chromium	9.0	10	9.0	9.0
Cobalt	13	16	19	25
Copper	160	490	56	490
Gallium	13	13	15	12
Iron	54,900	56,100	65,500	78,300
Lead	160	220	160	480
Magnesium	29,800	22,500	26,400	19,800
Manganese	710	390	480	640
Mercury	0.70	<0.3	0.70	2.3
Molybdenum	<20	<20	<20	<20
Nickel	<5	<5	18	8.0
Potassium	18,000	16,300	18,400	21,200
Selenium	4.0	5.0	<3	<3
Silicon	303,000	313,000	286,000	280,000
Silver	<0.01	<0.01	0.01	0.28
Sodium	1,200	2,800	3,000	3,500
Sulfur, T.	39,300	33,300	44,400	44,400
Tin	<10	20	<10	60
Titanium	460	440	650	540

Table 3.5-18 *(Continued)*

Parameter	Skunk Lake (WD-09) (mg/kg)	Rice Lake (WD-10) (mg/kg)	Upper Mole Lake (WD-11) (mg/kg)	Lower Mole Lake (WD-12) (mg/kg)
Uranium	<10	<10	<10	<10
Zinc	1,300	200	180	4,200

Notes:

All of the high sulfur waste rock composites were analyzed for the following parameters which were not detected (detection limits shown in parentheses):

Beryllium (<1 mg/kg);
Bismuth (<50 mg/kg);
Germanium (<5 mg/kg);
Tellurium (<3 mg/kg); and,
Thallium (<10 mg/kg).

In addition, all of the high sulfur waste rock composites were analyzed for gold. Gold was not detected (<0.02 g/T) in the Skunk Lake, Rice Lake and Upper Mole Lake High Sulfur composites. Gold was detected (0.59 g/T) in the Lower Mole Lake High Sulfur composite.

Prepared by: JET
Checked by: DJL

A review of the data contained in Table 3.5-17 shows a compositional similarity between the Rice Lake, Upper Mole Lake and Lower Mole Lake Master composites and that they contain more calcium, iron and silicon than the Skunk Lake Master composite. The Rice Lake, Upper Mole Lake and Lower Mole Lake Master composites contain considerably more calcium, total carbon, iron, manganese and sodium, and considerably less copper, than the Skunk Lake Master Composite. The Lower Mole Lake Master composite contains considerably more total sulfur than the other three composites as would be expected by its proximity to the zinc ore body.

Comparing the data contained in Table 3.5-18 to that contained in Table 3.5-17 shows that all of the high sulfur waste rock composites contain more total sulfur than the master waste rock composites. However, the high sulfur and master waste rock composites contain similar quantities of iron. The high sulfur waste rock samples representing these composites were selected such that they would contain total sulfur in the range of 3 to 5 percent. When collecting the samples that were used to prepare the high sulfur waste rock composites, it was noted that these materials contained considerably more pyrite (FeS_2) than the materials used to prepare the master waste rock composites. Based upon this observation it was concluded that most of the iron in the master waste rock composites is in the form of iron oxyhydroxides and that most of the iron in the high sulfur composites is in the form of sulfide minerals, especially pyrite, a conclusion supported by the results of the petrographic analyses of representative rocks used to prepare these composites.

The highest zinc concentration observed in any of the composites exists in the Lower Mole Lake High Sulfur Composite as would be expected due to the proximity of this formation to the zinc ore body. The second highest zinc concentration exists in the Skunk Lake High Sulfur Composite.

In addition, it can be seen that the calcium and total carbon contents of the Rice Lake, Upper Mole Lake and Lower Mole Lake Master composites are greater than those of the corresponding High Sulfur composites. The calcium and total carbon contents of the Skunk Lake Master composite are less than those in the Skunk Lake High Sulfur composite. Assuming that all of the total carbon and a portion of the calcium are combined in the form of the mineral calcite ($CaCO_3$), and comparing the calculated neutralization potential with the maximum acid potential calculated from the total sulfur, indicate that: 1) none of the master waste rock composites would be expected to generate acidic leachate; 2) all of the high sulfur waste rock composites were expected to be net acid generating; and, 3) the Rice Lake and Upper Mole Lake High Sulfur composites would be expected to generate acidic leachate sooner than the Skunk Lake and Lower Mole Lake High Sulfur composites. The potential for acid generation is further discussed in the following subsection, 3.5.5.3.1.3, where the ABA results are presented.

Comparing the site soil compositional data contained in Table 3.5-16 with the master waste rock composites contained in Table 3.5-17 it is evident that the site soils contain less, and generally considerably less, of the components common to both the site soils and the master waste rock composites. However, the general proportions of the components in both materials are approximately the same with two exceptions. The first is the presence of greater or equal amounts of chromium and titanium in the soil compared to the master waste rock composites. Both of the elements are usually concentrated in minerals (chromite and magnetite, and rutile and ilmenite, respectively) that are very resistant to weathering (Kabata-Pendias and Pendias, 1985). The second exception is that the soil analyses show a significant depletion in the alkali

metals, sodium and potassium. Both of these substances are readily leached from soils during pedogenesis in northern humid environments (Kabata-Pendias and Pendias, 1985).

In 1995, parameter variability within the master waste rock composites was tested using a two level validation approach. For the first level, 46 core intervals that had been crushed, bagged and stored in CMC's Rhinelander core storage facility were analyzed for their bulk chemical constituents and ABA values. This was the same core material used to create the master waste rock composites. The second level of validation consisted of collecting 2-foot samples of continuous core per 10-foot core box in 13 of the 46 crushed core intervals. Bulk chemical and ABA tests were also performed on these 2-foot intervals to assess parameter variability within individual crushed core intervals. A flow sheet showing the collection and processing of the core used for all of the waste characterization tests is included in Appendix 3.5-32 Figure 1. The results of these bulk chemical analyses, also contained in Appendix 3.5-32, show that parameter values in each formation, and within large intervals within each formation, are related to the proximity of the geological formation to the Crandon ore body. The lower Mole Lake Formation, which is adjacent to the Crandon Formation, contains the highest concentrations of metals associated with the zinc ore body and the greatest variability in concentrations of these metals. Overall, however, the parameter variabilities are small and demonstrate the appropriateness of using statistically prepared composites to characterize the waste rock.

The reactivity (fizz) of the waste rock samples to dilute hydrochloric acid indicated the presence of strongly reactive carbonate minerals. For this reason, and to quantify the carbonate mineralization, CO_2 analyses were included in the suite of parameters analyzed.

Bulk chemical analyses were also conducted on the 1994 zinc ore master composite, and the fine and coarse tailings composites. The results of these analyses are included in Appendix 3.5-32, along with a conversion of the units used by Lakefield (% and g/T) to milligrams per kilogram (mg/kg) (Appendix 3.5-32 Table 2).

The converted concentrations of the 1994 zinc ore master composite, and the fine and coarse tailings composites, are presented in Table 3.5-19. Processing the zinc ore typically yields about 20 percent ore concentrates and 80 percent tailings materials. It is expected that during full scale operations tailings materials will generally consist of about 50 percent fine tailings and 50 percent coarse tailings. In the 1994 Lakefield locked cycle bench scale test the actual split was 60 percent coarse tailings and 40 percent fine tailings.

A review of the data presented in Table 3.5-19 reveals that the zinc ore composite contains more copper, lead, silver, and zinc than in the tailings composites. These substances were concentrated within the ore concentrates which would leave the site. Since the purpose of operating the mine is to extract copper, lead, silver, and zinc from the ore these results were expected. The zinc ore composite also contains more cadmium and nickel than the tailings composites. These two metals are common trace substances in the zinc and copper ore minerals in the deposit (sphalerite and chalcopyrite, respectively) (Lambe and Rowe, 1987). It is therefore expected that the cadmium and nickel content of the ore concentrates that leave the site will be enhanced.

Table 3.5-19

Bulk Chemical Composition of the 1994 Zinc Ore Master Composite and the Fine and Coarse Tailings Composites

Parameter	Zinc Ore Master Composite (mg/kg)	Fine Tailings Composite (mg/kg)	Coarse Tailings Composite (mg/kg)
Aluminum	20,100	48,800	18,400
Antimony	85	64	70
Arsenic	2,700	2,300	2,600
Barium	<50	60	50
Bismuth	20	<20	20
Cadmium	260	40	20
Calcium	4,100	8,600	5,600
Carbon, T.	4,400	5,800	4,400
Chromium	70	210	30
Cobalt	67	55	79
Copper	3,300	1,400	500
Gallium	13	21	13
Gold	3.98	0.85	1.11
Iron	23,200	177,000	268,000
Lead	11,200	6,300	2,900
Magnesium	11,200	20,500	11,200
Manganese	460	670	520
Mercury	7	1.0	2.0
Molybdenum	<20	<20	<20
Nickel	100	40	<20
Potassium	4,400	13,100	3,900
Selenium	42	30	38
Silicon	128,000	180,000	150,000
Silver	42	29.4	17.4
Sodium	1,800	2,700	800
Sulfur, T.	291,000	176,000	297,000

Table 3.5-19 *(Continued)*

Parameter	Zinc Ore Master Composite (mg/kg)	Fine Tailings Composite (mg/kg)	Coarse Tailings Composite (mg/kg)
Tin	23	28	22
Titanium	1,000	1,700	1,200
Thallium	10	20	10
Uranium	<20	<20	<20
Zinc	96,600	11,200	6,000

Notes:

All of the high sulfur waste rock composites were analyzed for the following parameters which were not detected (detection limits shown in parentheses):

Beryllium (<50 mg/kg);
Germanium (<1 mg/kg); and,
Tellurium (<3 mg/kg).

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Checked by: DJL

A whole tailings composite was also used in the waste characterization studies. This composite was, as mentioned above, prepared by physically mixing coarse and fine tailings at a 60:40 ratio. No bulk chemical analysis was conducted on the whole tailings composites since the composition of the whole tailings composite can be calculated using the composition of the fine and coarse tailings materials in the appropriate ratio.

Bulk chemical composition and neutralization (ABA) testing of the fine and coarse tailings composites was also conducted in 1995 (see Appendix 3.5-32). It was found that the tailings samples contained between 1.0 to 1.76 percent CO_2, equivalent to a range of 2.27 to 4.0 percent calcite. Even though the tailings samples contain 24 to 30 percent sulfide sulfur, the presence of the carbonate minerals will delay the onset of net acid generation under oxidizing conditions.

The process water used to float the ore concentrates during the locked cycle pilot testing of the ore has been analyzed. The results of the analysis are included in Appendix 3.5-32 and have been used in the evaluation of the changes in leachate composition of the TMA and backfill tailings composites.

3.5.5.3.1.3 Acid Base Accounting

An initial screening of the potential reactivity of a wide range of waste rock that could be produced was conducted during the spring and summer of 1994. The purpose of the screening was to determine: 1) the widest range of acid base accounting (ABA) values that might be encountered; 2) the relative chemical reactivity of waste rock samples by examining the sulfide mineral content and grain size distribution coupled with the neutralizing mineral content and grain size distribution; and, 3) if valid waste rock composites could be prepared for kinetic testing based upon sulfide mineral content alone. To accomplish the screening, diamond drill core that intercepted areas of potential preproduction waste rock development were examined by a qualified geologist (Richard Côté, Rio Algom) and characterized according to relative concentration of sulfide and neutralizing minerals content (Collison, 1994b). Each core intercept, which ranged from about 25 to 200 feet in length, was divided into large continuous areas of low, average and/or high sulfide mineral content. Within each of these categories a 1-foot interval was identified as representative of each range of sulfide mineral content. Upon completion of the core evaluation for sulfide mineral content, and before sampling, the cores were examined by John E. Thresher, Jr. (Thresher & Son, Inc.) and Ken Markart (WDNR). With few minor exceptions, both individuals concurred with the Côté evaluation. Samples for ABA testing were then selected primarily from the highest sulfide mineral concentrations within a core. Samples containing high sulfide mineral concentrations were also selected from the Crandon Formation (the zinc ore horizon) to expand the range of sulfide mineral content in the data base.

Approximately 75 percent of the waste rock intervals chosen for the 1994 evaluation and analysis were from core sections containing the highest relative sulfide mineral content, in some cases even if that interval represented less than one percent of the entire core interval. No intervals containing the lowest sulfide mineral concentration were chosen for evaluation and analysis. The sample selection was not intended to be a statistical representation of the waste rock that might be encountered but, as stated above, was to obtain data from a wide range of sulfide mineral content alone.

All ABA tests conducted as part of the waste characterization program used the modified Sobek method described in Brodie, et al. (1991). An explanation of the ABA terms used in this text and tables is included in Appendix 3.5-32 Table 3, along with a comparison of these terms with those used by Lakefield Research and by Chemex Labs. The results of the ABA testing of the selected intervals is contained in Appendix 3.5-32 and are summarized in Appendix 3.5-32 Table 4. The resulting neutralization potential (NP) and maximum potential acidity (AP) values for the samples are shown in Figure 3.5-48a. A few data sets containing high AP and/or NP values were not plotted so that the scale of all of the NP/AP plots in Figure 3.5-48a would be the same.

Traditionally it has been considered that those waste rock materials in surface piles with an NP/AP value of: 1) less than 1 are considered to be potentially acid producing; 2) greater than 3 are considered to be non-acid producing; and, 3) between 1 and 3 are considered to be potentially acid or non- acid producing (Brodie, et al., 1991). The results of the 1994 ABA tests indicate that about one-quarter of the samples have an NP/AP value of less than 1, thus indicating that they have the potential to produce acid, which was expected considering the fact that relatively high sulfide mineral content was emphasized in the sampling. What was unexpected is that about two-thirds of the high sulfide mineral content samples would be classified as potentially non-acid producing. These results suggest that sulfide and neutralizing mineral content vary independently in the waste rock materials.

Several observations regarding the overall sulfide and neutralizing mineral type, content and variability in distribution within the waste rock were made while visually inspecting the selected core used for the 1994 ABA screening. Observations regarding the sulfide minerals included: 1) most of the sulfide minerals in the waste rock exist as tiny disseminated grains within the rock matrix in very low concentrations (usually much less than 0.5 percent); 2) the highest concentration of sulfide minerals in the waste rock are contained within scattered, thin veinlets generally parallel to the lithologic layering; 3) the dominant sulfide mineral in both the matrix and veinlets is pyrite; 4) the variability in sulfide mineral content within the waste rock is primarily related to the abundance and thickness of the sulfide-bearing veinlets; and, 5) the sulfide mineral content, and sulfide mineral variability, within the waste rock was greatest in that portion of the Mole Lake Formation within 100 feet of the contact with the Crandon ore deposit (known as the hanging wall contact). Observations regarding the neutralizing minerals included: 1) carbonate mineral-filled veinlets are not abundant; 2) the primary neutralizing mineral identified in the veinlets was calcite (very few veinlets are filled with dolomite); and 3) acid neutralizing minerals are common in the waste rock matrix as evidenced by the reaction of the samples with dilute hydrochloric acid but are not readily recognized in hand specimens within the rock matrix possibly due to their fine grain size within the matrix.

Two conclusions regarding additional waste rock testing were reached based upon the results of the ABA testing and the observations made during the collection of the 1994 ABA samples. The first conclusion was test the Mole Lake rocks within 100 feet of the zinc ore body separately from the rest of the Mole Lake rocks. As a matter of convenience, the Mole Lake rocks within 100 feet of the hanging wall contact were categorized as the Lower Mole Lake Formation while the rest of the Mole Lake rocks were categorized as the Upper Mole Lake Formation (the terms lower and upper are used in the standard stratigraphic sense).

Secondly, it was concluded that sufficient testing of the oxidation and leachability (kinetic testing) of the waste rock could be performed by preparing and testing a representative composite for

each of the four hanging wall formations, as described above in Section 3.5.5.2.1, due to the very low sulfide mineral content of the waste rock. The four waste rock composites, referred to as the master waste rock composites, were prepared from statistically representative samples of each formation in which mining will occur and included matrix and veinlet materials. Four additional composites, referred to as the high sulfur waste rock composites, were prepared from veinlet-rich portions of each of corresponding formation. These composites, prepared in 1994, were used for the kinetic testing discussed in Section 3.5.5.3.2. ABA and bulk chemical testing was performed on each of the eight waste rock composites.

The results of the waste rock ABA and bulk chemical tests are also included in Appendix 3.5-32 and are summarized in Table 3.5-20. The data presented in Table 3.5-20 shows that: 1) the NP/AP ratios for the Rice Lake and Upper Mole Lake Master composites are considerably greater than 3, and would be expected to be non-acid generating; 2) the Skunk Lake Master composite has an NP/AP ratio of 0 due to the absence of detectable neutralization potential, even though the bulk chemical composition of this composite indicates the presence of a carbonate mineral; and, 3) the NP/AP ratio of the Lower Mole Lake Master composite was 4.2 due primarily to a sulfur content higher than those measured in the other master waste rock composites.

As mentioned above, parameter variability within the master waste rock composites was further tested in 1995 using a two level validation approach. ABA tests, in addition to bulk chemical analyses, were performed on the collected samples. The results of these additional analyses are also included in Appendix 3.5-32. As shown in Figure 3.5-48b, nearly all of the plotted NP/AP values are within the zone predicted to be non-acid generating, which is also the case for the master waste rock composites shown in Figure 3.5-48c. The NP/AP values for the corresponding high sulfur waste rock composites are also plotted in Figure 3.5-48c. The range of NP/AP values within the selected intervals of all four waste rock formations is very limited which demonstrates that the variation in NP and AP values within each formation is on a scale greater than 30 feet, thereby suggesting that it is not likely that major ABA changes would be expected in rock removed while developing, for instance, a 14-foot diameter drift. The range of NP/AP values within the selected intervals and master composites of the Rice Lake and Upper Mole Lake formations are shown in Figures 3.5-49a and 3.5-49b, respectively. It should be noted that essentially all of the tested Rice Lake and Upper Mole Lake materials have NP/AP values greater than 3 and would be expected to be non-acid generating.

Based on the 1995 data and calculations it was observed that: 1) the range of NP/AP values increases from the Skunk Lake to the Rice Lake to the Upper Mole Lake and Lower Mole Lake Formations; 2) nearly all of the NP/AP values are greater than 3 indicating that the waste rock will be non-acid producing; 3) the range of NP/AP values within the selected intervals of all four formations is very limited and that variations within each formation is on a scale greater than 30 feet, thereby suggesting that it is likely that major ABA changes would not be expected in rock removed while developing, for example, a 14-foot diameter drift.

Two major conclusions were formed from a review of the 1995 two-level ABA validation test results. The first conclusion is that the 1995 data validates the 1994 conclusion that oxidation of the master waste rock composites will not likely produce acidic leachate, a conclusion supported by the results of the kinetic testing discussed below. The second conclusion is that the samples collected to prepare the master waste rock composites comprise a statistically valid representation of each formation.

Table 3.5-20

Acid Base Accounting (ABA) Values and Calculated Calcite Contents for the Waste Rock Composites

Waste Rock Composite	Measured Sulfur Content (%)[1]	Measured Sulfur Content (%)[2]	Calculated Calcite Content (%)[3]	Neutralization Potential (NP)[4]	Acid Potential (AP)[4]	NP/AP[4]	Net Neutralization Potential (NNP)[4]
Skunk Lake Master (WD-05)	0.01	0.14	0.67	0	4.4	0	-4.4
Rice Lake Master (WD-06)	<0.01	0.05	2.8	30	1.6	19	+28
Upper Mole Lake Master (WD-07)	0.04	0.10	4.4	48	3.1	15	+45
Lower Mole Lake Master (WD-08)	0.22	0.34	3.7	46	11	4.2	+35
Skunk Lake High Sulfur (WD-09)	3.93	3.95	2.0	11	123	0.09	-112
Rice Lake High Sulfur (WD-10)	3.33	3.26	0.42	0	102	0	-102
Upper Mole Lake High Sulfur (WD-11)	4.44	4.49	1.3	6.8	140	0.05	-133
Lower Mole Lake High Sulfur (WD-12)	4.44	4.15	3.2	21	130	0.16	-109

[1] Data from bulk chemical analyses.
[2] Data from ABA analyses.
[3] Calculated from total carbon analyses (bulk chemical data).
[4] Calculated from ABA data.

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Checked by: DJL

One of the screening tests routinely performed as part of the ABA testing is the paste pH test (Sobek, et al., 1978). This test was performed on all of the waste rock master and high sulfur composites in addition to the 1994 screening and the two level validation tests. The paste pH is dependent on the degree of weathering that the sample has undergone at the time of testing. The paste pH values for the waste rock composites were all greater than 7.0 with the exception of the Lower Mole Lake High Sulfur Composite which had a paste pH of 5.8. A paste pH greater than 7.0 is considered to indicate that at least the early leachate derived from these materials will not be acidic. A material with a paste pH of less than 6.0 is considered to contain weathering products from a prior weathering event, and will likely produce acidic leachate immediately.

It should be noted that total sulfur values were used to calculate the AP value in the ABA determinations. Total sulfur concentrations represent the sulfur contained in all of the sulfide minerals (the potentially acid generating sulfide minerals pyrite and chalcopyrite, and the non-acid generating sulfide minerals sphalerite and galena), plus the trace amounts of sulfate-sulfur (non-acid generating) in the rocks. Therefore the AP values may overestimate the potential for acid generation.

3.5.5.3.1.4 Waste Rock Classification

Waste Rock Classification (WRC) is another static predictive estimation of the potential for waste rock to produce acidic leachate. It is based on the quantification of a series of visual observations of rock hand specimens or core. It is rapidly performed and does not require laboratory data to compute a net WRC value. Numerical values are given to the factors considered in the WRC evaluations. The values are multiplied by empirically derived relative weights and the products are summed to compute the WRC value.

The factors considered in WRC evaluations include: 1) the type of sulfide mineral in the waste rock; 2) the proportion of sulfide surface area exposed; 3) the type of neutralizing mineral in the waste rock; 4) the proportion of neutralizing mineral surface exposed; 5) the grain size of the waste rock; and, 6) the amount of weathering and/or slaking that the rock has either undergone or can undergo (Brodie, et al., 1991).

WRC evaluations were performed during the spring and summer of 1994 screening evaluation of the hanging wall waste rock formations on the one-foot sections selected for ABA analysis. Following the preparation of the master waste rock composites, further WRC evaluations were performed during the fall of 1994. The additional WRC evaluations were performed on ten percent of the 30-foot core intercepts within the area in which the samples were collected to prepare the waste rock master composites. They were performed to determine the variability in the acid generation potential of the waste rock used to form the composites. The results of both sets of WRC evaluations are included in Appendix 3.5-32.

The maximum potential range of WRC values was divided into four evenly spaced categories. A summary of the WRC values calculated for the 30-foot waste rock intercepts is presented by geologic formation in Appendix 3.5-32 Table 4. A review of the data shows that most of the WRC values fall within the category referred to as potentially non-acid generating. A few of the Rice Lake and Upper Mole Lake intercepts had WRC values that fell into the category referred to as likely non-acid generating. In addition, a few of the Lower Mole Lake intercepts had WRC values that fell within the category referred to as potentially acid generating.

Table 3.5-21 has been prepared to summarize the predicted waste rock behavior based on ABA and WRC values compared to the measured behavior of the waste rock during leaching. The WRC values accurately predicted the measured leachate behavior for the composites evaluated. Although no WRC evaluations were performed for the high sulfur waste rock composites, it is expected that had they been performed that the results would have predicted that all of the high sulfur waste rock composites would have been likely acid generating. Although not specifically included in the table, the paste pH values of the composites also accurately predicted the measured behavior of the waste rock leachate.

3.5.5.3.2 Kinetic Tests

Kinetic tests conducted as part of the project's waste characterization program include leaching tests of waste rock and tailings materials, and extraction procedure (EP) toxicity tests of waste rock, ore and tailings. The results of the EP toxicity tests are summarized below in Section 3.5.5.3.3. The design, operation and results of the leaching tests, the most extensive testing conducted on the potential Crandon waste materials, are discussed in this section.

As stated above in the introduction to Section 3.5.5, the objectives of the waste characterization program have been to determine the behavior of the wastes generated during the development and operations of the mine and the potential impact that these wastes could have on the environment. Studies published in the professional literature and experience of the consultants conducting this work has shown that the potential reactions of wastes of this type, all of which contain differing amounts of various sulfide minerals: 1) tend to proceed slowly when these materials are reacted under realistic environmental conditions; and 2) that the potential impact of these materials on the environment can be evaluated by determining the leachability and potential for sulfide mineral oxidation of the wastes. Such tests have been conducted on the project primary waste materials under conditions closely approximating the conditions under which these materials could be used and/or disposed of at the site. It was therefore expected that the tests would require a lengthy time to complete. Tests have been completed and the results are the focal point of the remainder of this section.

Salient features of the kinetic test methods, sampling, leachate analysis, test conditions, and methods used to record and analyze the data from the tests are included in Appendix 3.5-33 Tables 1, 1a, and 1b. Specifically, test methods, and the sampling and analysis schedule, for the kinetic tests is included in Appendix 3.5-33 Table 1. The physical dimensions and test conditions used in the leaching (kinetic) tests of the waste rock and tailings composites are included in Appendix 3.5-33 Table 1a. The tabulated leachate data and notes regarding modifications to the analytical data base are also included in Appendix 3.5-33. An explanation of the tabulated leachate analysis data sheets and calculations is included in Appendix 3.5-33 Table 1b.

The relationship between the intensity parameters pH and conductivity measured weekly, and the analyses of total alkalinity (referred to as alkalinity), and in some cases total acidity (referred to as acidity, plotted as the negative or opposite of alkalinity), and the leachate cycle and pore volumes (PV) leached for each waste material tested are included in Figures 3.5-50 through 3.5-65. Figures 3.5-50 through 3.5-53 contain data obtained from the master waste rock composite leaching tests. Figures 3.5-54 through 3.5-57 contain data obtained from the high sulfur waste rock composite leaching tests. Figures 3.5-58 through 3.5-61 contain data obtained from the TMA tailings leaching tests. Finally, Figures 3.5-62 through 3.5-65 contain data obtained from the backfill tailings leaching tests.

Table 3.5-21

Predicted Waste Rock Composite Behavior Based on ABA and WRC Evaluations and the Measured Kinetic Behavior of the Composites[1]

Waste Rock Composite	Calculated Calcite Content (%)[2]	Predicted Behavior Based on ABA Values	Predicted Behavior Based on WRC Values	Measured Behavior Based on Leachate pH
Skunk Lake Master (WD-05)	0.67	potentially acid generating	potentially non-acid generating	initial pH > 6.0, increased to ≈ 7.0
Rice Lake Master (WD-06)	2.8	potentially non-acid generating	potentially non-acid generating	initial pH > 7.0, increased to > 8.0
Upper Mole Lake Master (WD-07)	4.4	potentially non-acid generating	potentially non-acid generating	initial pH > 7.0, increased to > 8.0
Lower Mole Lake Master (WD-08)	3.7	potentially non-acid generating	potentially non-acid generating	initial pH > 7.0, increased to > 8.0
Skunk Lake High Sulfur (WD-09)	2.0	potentially acid generating	ND	initial pH > 6.0, slowly declined to ≈ 3.0
Rice Lake High Sulfur (WD-10)	0.42	potentially acid generating	ND	initial pH > 6.0, rapidly declined to ≈ 2.5
Upper Mole Lake High Sulfur (WD-11)	1.3	potentially acid generating	ND	initial pH > 6.5, rapidly declined to ≈ 2.5
Lower Mole Lake High Sulfur (WD-12)	3.2	potentially acid generating	ND	initial pH ≈ 4.0, slowly declined to < 3.0

[1] The measured kinetic behavior is based on the pH measured, and the changes recorded, in the leachate generated from each composite for the duration of the testing, about 25 months for the Skunk Lake and Rice Lake Master, and the Skunk Lake High Sulfur Composites, and about 15 months for the other composites.

[2] Calculated from total carbon analyses.

ND = not determined.

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Leachate pH can be considered to be a measure of the "free acidity" of the leachate. It is common practice to describe solutions with a pH of: 1) 7 standard units (S.U.) as neutral; 2) >7 S.U. as alkaline; 3) <7 as acidic; and often, 4) 5 to 8 S.U. as near neutral or circumneutral. Total alkalinity and total acidity can be considered as measures of the "free alkalinity" or "free acidity", respectively, of a solution. As such, these parameters reflect the potential buffering of the solution pH, or the relative resistance to change in pH if small amounts of acid or base are added to the solution. The greater the alkalinity or acidity value the greater the free alkalinity or free acidity, respectively, and the greater the resistance of the solution pH to change due to the addition of either acid or base.

Conductivity, or more correctly specific electrical conductivity, is the inverse of electrical resistivity and expresses the ability of a solution to conduct electricity. Conductivity is proportional to the concentrations of electrolytes in solution. Therefore, conductivity is a simple estimate of the total amount of dissolved ions (electrolytes) in a dilute solution. If the relative proportions of ions in solution remains fairly constant then a decrease or increase in conductivity indicates that the total quantity of ions in solution has decreased or increased, respectively.

The weekly measurement of leachate pH and conductivity has provided data that can be used to evaluate the time dependent progress of: 1) the oxidation of the sulfide minerals in the wastes; 2) the neutralization of acidity that may occur during sulfide mineral oxidation; and, 3) relative ionic strength of the leachate. This data has been supplemented by chemical quantification of leachate constituents. Analyses of constituents (total analyses) were performed rather than analyses of dissolved substances because: 1) it was desired to determine the potential total loading to the environment of individual leachate constituents; and 2) it was conservatively assumed that fine grained particulate matter containing certain substances could dissolve in the environment over an extended period of time, thereby potentially releasing these substances to the environment. Most of the leachate samples collected for chemical analysis at the start of the waste characterization program were collected on a geometric time scale, i.e., at cycles 1, 2, 4, 8, etc., since experience has shown that for non acid generating geologic materials most of the potential leaching of substances occurs early in the testing program. Later testing was conducted on either a weekly or monthly basis for a group of substances which were selected based upon the results of the initial analyses.

Four of the most frequently analyzed parameters included sulfate, calcium and magnesium, and either alkalinity or acidity depending upon the pH of the leachate. As previously mentioned, the results of the alkalinity, or where appropriate acidity, as a function of time and pore volumes (PV) leached are shown in Figures 3.5-50 through 3.5-65. Sulfate in the leachate is considered to have resulted primarily from the oxidation of pyrite, the most abundant sulfide mineral in these wastes. Calcium and magnesium in the leachate are considered to have resulted primarily from the dissolution of carbonate minerals within the wastes. Minor dissolution of carbonate minerals can occur from the reaction between these minerals and water, but occurs to a much greater extent during the neutralization of acid that may be produced during pyrite oxidation.

Sulfate, and calcium plus magnesium fluxes (in mmol/kg) were calculated from the results of the leachate analyses. Sulfate, and calcium plus magnesium fluxes are also plotted in Figures 3.5-50 through 3.5-65 as a function of time and PVs leached. Assuming that all of the sulfate in the leachate has resulted from pyrite oxidation, and that all of the calcium and magnesium in the leachate has resulted from the neutralization of acid generated during pyrite oxidation, it would be expected that leachates containing equal sulfate, and calcium plus magnesium fluxes would

have pHs near neutral since the equal flux quantities would indicate that all of the acid generated was neutralized. If the sulfate flux was consistently greater than the calcium plus magnesium flux, it would be expected that the leachate would be acidic. Conversely if the calcium plus magnesium flux were consistently greater than the sulfate flux, it would be expected that the leachate pHs would be approximately 8.3 S.U., the buffered pH value for aqueous carbonate dissolution in the presence of an excess of calcium and/or magnesium carbonate.

The rate of sulfate production in the reacting waste material, as measured by the sulfate flux in the leachate flushed from the material, is related to the rate of sulfide mineral oxidation and consequently, in the case of pyrite oxidation, the rate of acid generation. The rate of calcium plus magnesium production in the reacting waste material is related to the consumption rate of acid neutralization potential.

It is expected that a portion of the sulfate and calcium solubilized during the oxidation and neutralization processes is retained within the waste mass in the form of secondary minerals, especially in the form of hydrous calcium, iron and/or aluminum sulfates. Therefore the quantities of sulfate, and calcium plus magnesium measured in the leachate collected from the base of the test columns is related to, but is likely less than, the total amount of these parameters solubilized under the given test conditions. As such, these measurements somewhat underestimate the sulfide oxidation and acid neutralization rates.

As compared with the actual test conditions, if greater quantities of water had been used to leach the wastes it is expected that greater quantities of sulfate, and calcium plus magnesium would have been leached from the waste per reaction cycle, and that smaller portions of these parameters would have been retained within the wastes in the form of secondary minerals. Conversely, if smaller amounts of water, i.e., amounts more closely approximating normal Crandon area precipitation, had been used to leach the wastes it is expected that smaller quantities of sulfate, and calcium plus magnesium would have been detected in the waste leachate, and that a greater portion of these parameters would have been retained within the waste mass in the form of secondary minerals. Since the potential impact of these wastes on the environment is a function of the quantity of substances that could be leached from the wastes, leaching of the wastes with greater than expected quantities of simulated precipitative waters overestimates this potential impact and therefore the results of the tests are considered to be conservative in nature.

Due to the differences in the wastes and the potential use and/or disposal at the site, testing of the waste rock, TMA tailings and backfill tailings composites are described and discussed separately in the following subsections.

3.5.5.3.2.1 Waste Rock

The waste rock composites were reacted in columns configured as modified large scale humidity cells constructed from 30-gallon polyethylene columns. The calculated sample volume, exposed surface area, porosity, pore volume and pore volumes leached during the leaching of the composites are included in Table 3.5-22. Each cell received saturated aeration for two, four-hour periods per day, from 0400-0800 and from 1600-2000. The saturated air was injected into each column slightly above the base, at two ports 180 degrees apart. Deionized water was added to each column to simulate precipitative inputs in two different ways. First, deionized water was added to each column twice daily, at 1200 and 2400. The twice daily inputs occurred during six

Table 3.5-22

Calculated Composite Volume, Exposed Surface of Test Column, Porosity, Pore Volume, and Number of Pore Volumes Leached for the Waste Rock Composites

Composite	Sample Volume (L)	Exposed Surface Area of Column (m^2)	Porosity[1] (%)	Pore Volume (L)	Volume Leachate Extracted[2] (L)	Pore Volumes Leached
Skunk Lake Master	58.4	1.64	42	24.0	446[a]	18.2[a]
Rice Lake Master	79.2	1.64	36	28.5	433[a]	15.2[a]
Upper Mole Lake Master	83.3	1.64	36	30.0	306[b]	10.2[b]
Lower Mole Lake Master	50.0	1.64	38	19.0	306[b]	16.1[b]
Skunk Lake High Sulfur	43.8	1.64	33	14.5	460[a]	31.7[a]
Rice Lake High Sulfur	45.8	1.64	29	13.3	293[b]	22.0[b]
Upper Mole Lake High Sulfur	47.9	1.64	35	16.8	284[b]	16.9[b]
Lower Mole Lake High Sulfur	43.8	1.64	32	14.0	295[b]	21.1[b]

Notes:
[1]Assumes average particle density of 2.5 g/cm^3.
[2]4.8 L of DI water was used per week to leach each composite.
[a]Leaching period of 26 months.
[b]Leaching period of 15 months.

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successive days per week, or cycle, during which time the average Crandon area weekly precipitation was added to each cell. The six-day daily precipitation, which is like a cross between a mist and a drizzle, was applied to each column through orifices located beneath the column cover in one of the quadrants perpendicular to the two quadrants shared by the air inlets. The drizzle/mist orifices were rotated 180 degrees to the unoccupied quadrant at the end of each weekly cycle. This aeration and precipitation scheme was undertaken to create optimal conditions within the columns for the establishment and growth of lithotrophic bacterial populations.

The second type of precipitative input to each column occurred on the seventh day of each weekly leaching cycle. During this second input, a volume of deionized water equivalent to the average Crandon area weekly precipitation was added to the top of the entire composite to simulate a storm event. The simulated storm input was used to initiate each successive leaching cycle. The storm events flushed a portion of the stored oxidation products from the composites during each leaching cycle.

The waste rock leaching columns were designed to be free draining. Leachate was allowed to collect for a week prior to sampling. Sampling was conducted prior to the addition of each simulated storm event which began a new leaching cycle. Leachate volume collected, pH, conductivity, and temperature were measured weekly by Foth & Van Dyke personnel. Pore volumes and cumulative pore volumes leached were calculated from the weekly leachate collected data and the pore volume calculations contained in Table 3.5-22. The results of the weekly measurements and calculations are included in Appendix 3.5-34 Table 1.

Leachate aliquots were collected and submitted to a contract laboratory for digestion and analysis of the parameters listed in Appendix 3.5-33 Table 1, which also contains the sampling schedule. These results have been organized chronologically for each waste rock composite in Appendix 3.5-34 Tables 2 through 57 (see Appendix 3.5-33 Table 1b regarding the organization of these tables).

The results of the weekly leachate analyses, and the calculated sulfate, and calcium plus magnesium fluxes versus time and PVs leached for the four master waste rock composites are shown in Figures 3.5-50 through 3.5-53. The leaching of all four composites showed several trends in common: 1) the pH of the leachate was lowest during the first few leaching cycles; 2) the long term leachate pH was greater than 7 S.U., i.e., slightly alkaline; 3) the calcium plus magnesium flux was always greater than the sulfate flux; and, 4) the leachate conductivity, alkalinity, and sulfate, and calcium plus magnesium flux values were greatest in leachate collected during the first few cycles. The long term leachate pH from the Rice Lake, Upper and Lower Mole Lake Master composites ranges from about 7.8 to 8.3 S.U. and that from the Skunk Lake Master composite ranges from approximately 6.5 to 7.0 S.U. Based upon the discussion regarding pH contained in the first part of this subsection, it has been concluded that the long term pH of the leachate from the Rice Lake, and the Upper and Lower Mole Lake Master composites is strongly buffered by the dissolution of carbonate minerals and that the long term pH of the leachate from the Skunk Lake Master composite is somewhat less buffered by the dissolution of these minerals.

A review of the data contained in Appendix 3.5-34 Tables 2 through 29 shows that: 1) the maximum quantities of substances leached from these composites occurred during the first few leaching cycles; 2) the leaching (extraction) rate of all substances declined to low, nearly steady

state values; and, 3) the quantities of substances extracted from the composites was generally much less than one percent of the waste rock mass. It is considered that the initial lower pH and higher substance concentrations in the leachate from these composites is due to the leaching of readily soluble materials which form a very small portion of the waste rock mass. The readily soluble substances are related to weathering of these materials prior to testing. The long term pH and substance concentrations in the leachate have resulted from the oxidation (weathering) of these materials during the testing.

The results of the weekly leachate analyses, and the calculated sulfate, and calcium plus magnesium fluxes versus time for the four high sulfur waste rock composites are shown in Figures 3.5-54 through 3.5-57. As seen in the figures, the leaching behavior of the Skunk Lake High Sulfur composite was quite different from that of the Lower Mole Lake High Sulfur composite, and from that of Rice Lake and Upper Mole Lake High Sulfur composites (which were similar to each other). The results of the leaching tests of the high sulfur composites are discussed in three groups (Skunk Lake; Rice Lake and Upper Mole Lake; and, Lower Mole Lake) exhibiting similar leaching behavior since each group demonstrates a different aspect of the weathering of high sulfur content waste rock.

Leaching the Skunk Lake High Sulfur composite generated leachate that had an initial pH of approximately 6 S.U. which increased rapidly to about 8 S.U. as shown in Figure 3.5-54. Thereafter the pH of the leachate slowly declined for about 70 weeks to a value of about 7 S.U. Following week 80, the leachate pH rapidly declined to about 3 S.U. at week 105. At the same time the initial conductivity rapidly declined to a low at about week 10, and thereafter slowly increased to values which at the end of the test approximated the initial conductivity values. It is considered that the initial lower leachate pH was related to the leaching of small amounts of stored oxidation products similar to the master waste rock composites and that the circumneutral pH values recorded during most of the testing were the result of acid dissolution of the carbonate minerals within the rocks.

A preliminary petrographic review of the Skunk Lake rocks indicated that sphalerite (ZnS) is about as abundant as pyrite within the formation and that some of the pyrite grains are rimmed with sphalerite. Oxidation (weathering) of sphalerite produces sulfate but does not directly generate acid. However, oxidation of sphalerite does generate ferric iron which, under acidic conditions, can accelerate the oxidation of pyrite. Therefore acid produced by the oxidation of the pyrite within the composite proceeded slowly until the upper portion of the composite became acidic, after which time the rate of oxidation and acid generation accelerated due to the activation of ferric iron oxidation. In addition, the oxyhydroxides could also affect the NP determination in the ABA test.

The Rice Lake and Upper Mole Lake High Sulfur composites exhibited similar leaching characteristics. Both high sulfur composites initially generated circumneutral pH leachates which quickly declined to the pH 4-5 S.U. range. Thereafter the leachate pH values slowly declined to values of about 2.5 S.U. The conductivity values measured in the leachates initially declined somewhat, then slowly increased, and eventually increased rapidly. Calculated sulfate flux in these leachates appeared to follow trends similar to those exhibited by conductivity. The leachate acidity values slowly increased at first and then more rapidly during the testing. Leachate pH appeared to have achieved near steady state values by the termination of the testing. In both leachates the change from slowly increasing conductivity, acidity and sulfate flux values occurred at about the time that the leachate pHs declined below 3 S.U., which is in the

range of optimal lithotrophic bacterial sulfide oxidation by *Thiobacillus ferrooxidans* (Evangelou, 1995). The pH of the Rice Lake High Sulfur composite leachate declined below 3 S.U. at about week 20, and that in the Upper Mole Lake High Sulfur composite declined below 3 S.U. at about week 40.

A preliminary petrographic review of rocks from the Rice Lake and Upper Mole Lake Formations indicated that virtually all of the sulfide minerals in these rocks are pyrite. The high sulfur composites prepared from these formations have very low NP values, especially when compared to the corresponding master composites. Based upon the very low neutralization potential (NP) values of the two high sulfur composites, a rapid generation of acidic leachate was anticipated and was measured. It is interesting to note that the difference in NP between the two composites had no apparent effect upon the initial oxidation of, and acid generation by, the two composites. However, the time required to generate strongly acidic leachate (i.e., leachate with a pH of less than 3 S.U.) appears to be related to the difference in the NP between the two composites, since the Upper Mole Lake High Sulfur composite has a greater NP than the Rice Lake High Sulfur composite and required twice as long to develop strongly acidic leachate.

Leachate collected from the Lower Mole Lake High Sulfur composite was always acidic despite the significant neutralization potential of that material (the largest NP of all of the high sulfur composites). During the testing of this composite leachate pH slowly declined from an initial value of approximately 4 S.U. to slightly less than 3 S.U. Initial leachate conductivity values declined rapidly, then declined more slowly, and then increased slowly. The initial leachate acidity values also declined very rapidly, after which they slowly increased and then increased more rapidly. The late increase in conductivity, and more rapid increase in acidity, occurred after the leachate pH declined below about 3.5 S.U. The leaching behavior of this composite appears to be related primarily to the fact that some parts of this formation had undergone extensive geologic weathering due to the proximity of this material to the hanging wall contact (Foth & Van Dyke, 1995a). The high hydrous iron oxide mineral content of the weathered rocks would tend to buffer leachate pH in the range of approximately 3.8 to 4.3 S.U. In addition, inorganic oxidation products stored in the weathered material appear to have been strongly acidic and readily leachable, which when combined with the buffering of the hydrous iron oxides could account for the rapid consumption of the NP in the composite.

One of the objectives of the waste characterization program has been to determine if waste rock expected to be generated during the preproduction phase of mine development can be used for construction purposes, such as road grade and/or railroad ballast, wherein the waste rock would be in direct contact with the soils at the site. It is expected that the mineral composition of the individual rock fragments within a layer of crushed waste rock will vary somewhat with regards to their sulfide and carbonate mineral content. It is therefore expected that the composition of the interstitial water surrounding each rock fragment would vary somewhat. The leachate exfiltrating from the base of a waste rock layer will have a composition which represents the commingled composition of the various interstitial waters similar to that which occurred during the waste characterization testing. The potential impact to the site soils will primarily be related to the composition of the commingled leachate and its potential impact on the pore water composition of the soil.

As noted above, the maximum concentrations of substances in the master waste rock composite leachates were measured during the first two leaching cycles. As previously mentioned, material flushed from the waste rock composites during the initial few leachings is considered to represent

the flushing of readily soluble/mobilized substances. The maximum flux from each of the master waste rock composites that could be classified as Type I (Skunk Lake, Rice Lake and Upper Mole Lake) for the first two leaching cycles were first calculated by averaging the weekly flux (in mg/kg/week) for each measured parameter. In order to assess parameter flux exfiltrating from a waste rock mass it is necessary to establish a standard waste rock unit (WRU). This was accomplished by choosing a columnar shaped waste rock unit 18 inches in diameter (the diameter of the test columns) by 12 inches high (the minimum master waste rock height used in the testing). The tested waste rock composites from the different formations had different masses due primarily to differences in sample height. The calculated fluxes were corrected to the standard unit height of 12 inches by multiplying the average fluxes by the fraction 12/test column height (in inches). This correction is valid because the quantity of readily soluble/mobilized substances is proportional to waste rock mass which is related to height for composites with equal cross sectional areas (see Sposito and Jury, 1990; Warrick, 1990). Unlike the master waste rock composites, waste rock crushed for road grade material will have the fines screened from the material prior to utilization of the crushed waste rock. This action will diminish the reactivity of the waste rock and thus will diminish the quantities of readily soluble/mobilized substances that can be leached. Therefore use of the results of the laboratory testing is conservative.

The flux values were further modified to represent daily fluxes in mmols per standard waste rock unit. These final corrections were made so that the flux units are comparable to the most commonly used units in the literature concerning soil solution chemistry (mmol/unit of soil). The use of a daily flux was used since a 24-hour period represents the maximum time normally required for soil solution reactions involving the inorganic processes of sorption, precipitation/dissolution and exchange to occur (Sparks, 1995; Wolt, 1994).

The calculated potential maximum daily mass fluxes from Rice Lake and Upper Mole Lake Master WRUs to a unit of underlying site soil (USU), similar in cross section to the waste rock unit but 10 feet thick, are presented in Tables 3.5-23 and 3.5-24, respectively, along with a corresponding representative soil solution parameter mass (assuming 10 percent soil moisture) for parameters available from the literature (Wolt, 1994). As seen within the tables, some of the maximum daily waste rock fluxes are approximately equivalent to the representative soil solution parameter masses. The maximum daily waste rock fluxes of the other parameters are as much as two orders of magnitude less than the corresponding representative soil solution parameter masses.

Also included in Tables 3.5-23 and 3.5-24 are predicted long-term daily waste rock fluxes for the Rice Lake and Upper Mole Lake formations based on cycle 33 leachate composition. As seen in the tables, the long-term predicted daily waste rock fluxes of most of the parameters are several orders of magnitude lower than the corresponding calculated maximum daily waste rock fluxes and representative soil solution parameter masses.

In the natural environment the composition of the soil solution in the surficial soil horizons is primarily a function of the pedogenic processes operating within those horizons which are mainly processes that result in the release, or leaching, of substances to the soil solution. The composition of the soil solution in the subsurface soil horizons is primarily a function of the interactions between the soil solution generated in the surficial horizons and the materials and physicochemical environment within the subsurface horizons. Many of the subsurface soil horizon reactions with the transported surficial soil solutions result in the retention of certain substances within the subsurface horizons. The combined processes of removal (leaching) of

Table 3.5-23

Calculated Potential Maximum Daily Mass Flux and Predicted Long Term Daily Mass Flux from a Unit of Rice Lake Master Waste Rock (WRU) Composite to a Unit of Underlying Site Soil (USU) and a Representative Soil Solution Parameter Mass (at 10% Moisture Content) for that Soil Unit

Parameter	Calculated Rice Lake Maximum Daily Flux (mmol/WRU/d)	Predicted Rice Lake Long Term Daily Flux (mmol/WRU/d)	Representative Soil Solution Parameter Mass (mmol/USU)
Aluminum	1.2E-0	2.2E-3	8E-1
Arsenic	2.9E-4	1.6E-4	9.8E-4
Calcium	2.2E-1	1.5E-1	6.0E+1
Chromium	4.8E-4	NA	8E-4
Cobalt	2.7E-4	ND	6E-3
Copper	5.7E-3	4.7E-5	4E-2
Iron	8.0E-1	7.8E-4	2E-1
Lead	1.5E-4	NA	4E-4
Magnesium	1.1E-0	1.1E-1	1.3E+1
Manganese	1.7E-2	2.9E-4	3E-2
Molybdenum	2.9E-4	NA	3E-5
Nickel	2.5E-4	NA	2E-2
Potassium	2.4E-1	2.7E-2	7E-0
Selenium	ND	NA	4E-3
Sodium	8.3E-1	2.9E-2	4.9E+1
Sulfate	2.1E-1	3.8E-2	3.6E+1
Zinc	3.7E-3	ND	8E-3

ND = not detected
NA = not analyzed

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Table 3.5-24

Calculated Potential Maximum Daily Mass Flux and Predicted Long Term Daily Mass Flux from a Unit of Upper Mole Lake Master Waste Rock (WRU) Composite to a Unit of Underlying Site Soil (USU) and a Representative Soil Solution Parameter Mass (at 10% Moisture Content) for that Soil Unit

Parameter	Calculated Upper Mole Lake Maximum Daily Flux (mmol/WRU/d)	Predicted Upper Mole Lake Long Term Daily Flux (mmol/WRU/d)	Representative Soil Solution Parameter Mass (mmol/USU)
Aluminum	3.2E-1	1.9E-3	8E-1
Arsenic	7.0E-4	9.9E-5	9.8E-4
Calcium	1.6E-1	1.8E-1	6.0E+1
Chromium	1.3E-4	NA	8E-4
Cobalt	ND	NA	6E-3
Copper	1.6E-3	3.4E-5	4E-2
Iron	2.3E-1	6.2E-4	2E-1
Lead	ND	NA	4E-4
Magnesium	3.8E-1	1.3E-1	1.3E+1
Manganese	4.0E-3	9.3E-5	3E-2
Molybdenum	2.7E-4	ND	3E-5
Nickel	ND	NA	2E-2
Potassium	1.8E-1	4.1E-2	7E-0
Selenium	7.2E-5	4.6E-5	4E-3
Sodium	9.4E-1	3.5E-2	4.9E+1
Sulfate	2.4E-1	4.6E-2	3.6E+1
Zinc	1.3E-3	2.1E-4	8E-3

ND = not detected
NA = not analyzed

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substances from the surficial horizons and the retention of some of these substances within subsurface horizons leads to the development of recognizable soil horizons.

A portion of the surficial soil horizons (topsoil) will be removed during the development of the surface facilities at the Crandon mine. This action will result in the removal of the soil horizons primarily responsible for the generation of the soil solution constituents. Some of the exposed subsurface soil could be covered with crushed Type I waste rock used as road grade material or as railroad ballast. As seen in Tables 3.5-23 and 3.5-24, the maximum parameter flux from crushed waste rock to the subsurface soil horizons will generally be much less than the parameter flux that had formerly been generated within the surficial soil horizons. Therefore the placement of crushed Type I waste rock from the Rice Lake and Upper Mole Lake formations: 1) will not lead to a release of substances that would markedly change soil pore water characteristics; and 2) will not lead to an increase of these substances in the groundwater beneath the site.

The above discussion applies to the results obtained from the leaching experiments conducted with statistically representative composites from the Rice Lake and Upper Mole Lake formations, now classified as Type I material. ABA and bulk chemical analyses of samples selected from the Rice Lake and Upper Mole Lake formations have been shown to have a limited range of sulfide mineral variability and ABA values (Foth & Van Dyke, 1995d). The results of these tests and calculations clearly indicate that, if all of the waste rock generated from the Rice Lake and Upper Mole Lake formations were to be crushed and mixed prior to being used as site construction material that would be placed in direct contact with site soils, no adverse impacts to soil or groundwater would occur.

All of the Lower Mole Lake waste rock will be classified as Type II due to: 1) the high degree of sulfide mineral variability observed within the formation; and 2) the presence of significant amounts of acidic oxidation products resulting from past geologic weathering. In addition, all of the Skunk Lake waste rock will also be classified as Type II due to generally low quantity of neutralizing minerals within this formation.

3.5.5.3.2.2 TMA Tailings

Four TMA tailings composites were reacted in columns configured as large scale humidity cells constructed from 30-gallon polyethylene columns. Two of the composites consisted of a fine (RS-18) and whole (RS-13) tailings materials that were leached under saturated, followed by alternating W/D, conditions to simulate reactions that could occur within the TMA tailings during the operation of the cells. The other two composites consisted of whole tailings materials that were leached solely under alternating wet and dry (W/D) conditions to simulate reactions that could occur at the top of the emplaced tailings during the consolidation of tailings under moist conditions. One of the W/D whole tailings composites was amended with lime (WD-14) and the other (WD-13) was not.

The calculated sample volume, exposed surface area, porosity, pore volume and pore volume equivalents displaced during the leaching of the composites are included in Table 3.5-25. The thickness of the tailings composites plus their support sand layers is small compared to the width of the column. Therefore, the height of the 30-gallon columns were reduced to 12 inches to maximize aeration of the surface of the composites. No forced aeration of the tailings composites was used since it was assumed that nearly all of the oxidation would occur top-down

Table 3.5-25

Calculated Composite Volume, Exposed Surface of Test Column, Porosity, Pore Volume, and Number of Pore Volumes Leached for the Tailings Composites

Composite	Sample Volume (L)	Exposed Surface Area of Column (m^2)	Porosity[4] (%)	Pore Volume (L)	Volume Leachate Extracted[5] (L)	Pore Volumes Leached
TMA Fine Tailings (RS-18)[1]	11.8	1.68	53	6.25	321[a]	51.4[a]
TMA Whole Tailings (RS-13)[1]	10.4	1.73	34	3.54	311[a]	87.9[a]
TMA Whole Tailings (WD-13)[2]	16.7	1.73	45	7.52	278[a]	37.0[a]
TMA Lime Amended Whole Tailings (WD-14)[2]	19.4	1.80	46	8.92	193[b]	21.6[b]
Backfill Coarse Tailings (AL-15)[3]	8.07	0.611	70	5.65	82.5[b]	14.6[b]
Backfill Cemented Coarse Tailings (AL-17)[3]	38.9	0.611	80	31.1	87.1[b]	2.80[b]
Backfill Whole Tailings (AL-13)[3]	6.97	0.611	69	4.81	82.7[b]	17.2[b]
Backfill Cemented Whole Tailings (AL-16)[3]	38.9	0.611	80	31.1	87.7[b]	2.82[b]

Notes:
[1]Leached under saturated, followed by alternating W/D, conditions.
[2]Leached under alternating W/D conditions.
[3]Leached under alternating W/D, followed by saturated, conditions.
[4]Assumes average tailings density of 3.3 g/cm^3. Uncemented tailings saturated with process water (assumed specific gravity of 1.0 g/cc). Porosity of cemented composites measured from volume of water needed to fill pore spaces.
[5]4.8 L of DI water was used per W/D cycle, most saturated leachings extracted lower volumes.
[a]Total leaching period of 26 months.
[b]Total leaching period of 15 months.

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Checked by: SGL

within tailings placed in a TMA cell. Aeration, and hence oxidation, occurred at the surface of the exposed composites and, to a small extent, through the open sampling spigot at the base of each cell.

Two TMA tailings composites, a fine (RS-18) and whole (RS-13) tailings composite, were initially leached under saturated conditions for a period of 17 weeks (cycles) with process water to simulate the reactions that may occur during the initial accumulation of tailings in a TMA cell. These cells were later leached with deionized water under alternating W/D conditions to simulate the reactions that may occur during the later subaereal deposition and drainage of tailings in a cell. Deionized water was applied to the entire exposed surface of the tailings in each cell weekly, in a quantity approximating twice the average weekly precipitation for the Crandon area. The upper surface of these composites was originally horizontal. During the first W/D leaching of these composites it was observed that a portion of the applied precipitative water percolated along the interface between the tailings and the side wall of the modified polyethylene columns. Prior to the second W/D leaching (cycle 19, 022895) the upper surface of each composite was dimpled to minimize the flow along the sidewall and to maximize the flow through the tailings mass. During the dimpling process no tailings were removed from, or added to, the test composite. The composite configurations listed in Appendix 3.5-33 Table 1a are the final dimpled configurations.

Sequential additions of tailings to these cells was planned to simulate the accumulation of tailings in an operational TMA cell. However, when it was found during the testing that rapid oxidation, and the consequent generation of acidic leachate, did not occur, the planned additions were not made. The TMA tailings columns were designed to be free draining during the alternating W/D leaching. Leachate was collected from the base of each cell on a weekly basis prior to the next addition of DI water. Leachate volume, pH, conductivity, and temperature were measured in the leachate by Foth & Van Dyke personnel. The weekly pore volumes (PVs) and the cumulative pore volumes leached were calculated from the weekly data and the calculated sample pore volume contained in Table 3.5-25. The results of the weekly measurements and calculations are included in Appendix 3.5-35 Table 1.

Leachate aliquots were collected twice during the period when the tailings were saturated for 17 weeks with process water. When the cells were converted to alternating W/D leaching conditions, leachate aliquots were collected on an approximate geometric time scale similar to those collected from the waste rock composites. The collected leachate aliquots were submitted to a contract laboratory for digestion and analysis of the parameters listed in Appendix 3.5-33 Table 1, which also contains the sampling schedule. A summary of the contract laboratory analyses is also included in Appendix 3.5-33. The results of the TMA tailings analyses have been organized chronologically for each composite in Appendix 3.5-35 Tables 2 through 15 (see Appendix 3.5-33 Table 1b regarding the organization of these tables). The results of the weekly analyses, and the calculated sulfate, and calcium plus magnesium fluxes versus time and pore volume equivalents (PVs) displaced for the two tailings composites leached under saturated, followed by alternating W/D, conditions are shown in Figures 3.5-58 (RS-18) and 3.5-59 (RS-13).

The leachate measurements and calculations for the fine tailings composite (RS-18) show that the pH of the leachate was circumneutral during the time that the tailings were saturated and that the leachate pH decreased to about 4 S.U. in approximately eight weeks following the beginning of the alternating W/D leaching of the composite (see Figure 3.5-58 and Appendix 3.5-35 Table 3). The leachate pH remained at about 4 S.U. for approximately

20 weeks, after which it rapidly returned to circumneutral values. The circumneutral pH values have slowly decreased from about 7 S.U. to about 6 S.U. during the following 70 weeks. The alkalinity and acidity values measured in the leachate samples collected from RS-18 show changes over time that reflect the changes in leachate pH. The long term alkalinity values in the RS-18 leachate are relatively low (<20 mg/L) and are similar to the long term alkalinity values measured in the Skunk Lake master waste rock composite (WD-06) leachate.

The long term RS-18 sulfate and calcium plus magnesium flux values measured in the fine tailings composite leachate are low in value and are nearly equal which reflects the circumneutral pH and low alkalinity values. The low sulfate, and calcium plus magnesium fluxes and alkalinity values, along with the circumneutral pH values indicate that changes in RS-18 leachate pH will not occur rapidly. During the leaching of RS-18, conductivity values initially decreased to about cycle (week) 75 after which conductivity values increased. Since there were no significant changes recorded in pH, alkalinity, sulfate flux and calcium plus magnesium flux values measured in the leachate collected beyond cycle 75, the increase in leachate conductivity is considered to be the result of leaching of neutralized oxidation products from the tailings.

During the W/D leaching of the fine tailings material it was noted that oxidation products developed and/or accumulated along the interface between the tailings mass and the sidewall of the leaching column, probably as a result of greater oxygen penetration along the interface than through the tailings mass. The decrease in constituent concentrations in leachate collected shortly after the test changed to alternating wet and dry conditions probably related to the generation of low pH oxidation products along the mass/column interface. The enhanced tailings oxidation along the tailings/column interface appears to have continued until the most readily oxidizable sulfide minerals along this interface were either consumed and/or blinded by the accumulation of oxidation products on the sulfide mineral surfaces. The return of pH values measured in the RS-18 leachate to circumneutral values is likely an indication of the limits of oxygen penetration into the moist tailings.

Net accumulations of aluminum, selenium, arsenic, sulfate, potassium, calcium, and, cobalt were observed in the RS-18 composite test result data. Net accumulations were considered to have occurred when the calculated mass of a constituent in the leachate draining from the base of the composite was less than the calculated mass of a constituent in the volume of process water percolated through the composite during the saturated leaching. Net accumulations result from the retention of substances from the percolating fluids by the tailings material. The mechanisms most likely to have caused the parameter retentions include: 1) the formation of secondary minerals via precipitation; and 2) ion sorption. All net accumulations of substances by tailings composites are shown as mass flux values preceded by a negative sign in the Appendix 3.5-35 cumulative mass flux tables. The negative signs indicate that the cumulative mass of a constituent measured in the leachate is less than the constituent mass added to the tailings composite during the two saturated leachings with process water. Leaching of the accumulated constituents began during the W/D leaching with DI water. The sign of the cumulative mass flux value for a constituent was changed to positive, representing true mass flux, when the cumulative mass of the constituent leached from the composite exceeded the mass added from the process water.

The leachate measurements and calculations for the whole tailings composite (RS-13) show that the pH of the leachate has remained at circumneutral values during the course of the testing (see Figure 3.5-59 and Appendix 3.5-35 Table 9). Net accumulations of aluminum, selenium,

chromium, arsenic, copper, and, potassium were observed in the RS-13 composite, similar to those observed in RS-18. RS-13 conductivity values initially declined rapidly, then declined very slowly followed by a slow increase in value beyond the 90th leaching cycle. The alkalinity values measured in the leachate from RS-13 have slowly declined during leaching. The alkalinity values measured in the whole tailings composite have always been greater than those measured in the fine tailings leachate. During the leaching, sulfate, and calcium plus magnesium flux values declined rapidly during the beginning of the alternating W/D leaching and thereafter remained at steady low values. The slow decline of alkalinity values measured in the RS-13 leachate is considered to represent the slow consumption of acid neutralization minerals within the tailings during tailings oxidation. The low, long term sulfate, and calcium plus magnesium leachate fluxes are nearly equal in value which is consistent with the leachate circumneutral pHs.

The rate at which these tailings will oxidize under conditions simulating an operational TMA cell were unknown during the conception of the waste characterization program. To cover the possibility that tailings oxidation might occur rapidly, and that tailings might have to be amended with an alkaline material as they were added to an operational cell to control potential acidification, two additional TMA tailings composites were prepared and tested. These composites consisted of an unamended whole (WD-13) and a lime amended whole (WD-14) tailings composite. Each of these composites was tested solely under alternating W/D conditions. These composites were leached in columns, and the surfaces were configured, similar to those used for the TMA tailings composites described above. Test conditions and sampling were identical to those used in the W/D leaching portion of the tailings composites described above. The weekly measurements and calculations are also contained in Appendix 3.5-35 Table 1.

Two additional whole tailings composites, WD-13 and WD-14, were leached with DI water under alternating W/D conditions. The leaching, sampling and analysis of the leachates produced were conducted similarly to those methods used for the W/D leaching of composites RS-13 and RS-18. The results of the leachate analyses are included in Appendix 3.5-33, which have been re-organized chronologically for each composite in Appendix 3.5-35 Tables 16 through 29. The results of the weekly analyses, and the calculated sulfate, and calcium plus magnesium fluxes versus time and PVs displaced for these composites are shown in Figures 3.5-60 and 3.5-61. Figure 3.5-60 contains the results for the unamended whole tailings composite (WD-13) and Figure 3.5-61 contains the results for the lime amended whole tailings composite (WD-14).

The leachate measurements and calculations for the whole tailings composite leached under alternating W/D conditions (WD-13) show that leachate pH was in the circumneutral range for approximately the first 50 weeks (cycles) of leaching as seen in Figure 3.5-60. After that time, leachate pH declined rapidly at first to values of about 4 S.U. and thereafter declined slowly to values of approximately 2.5 S.U. by week 80. Conductivity and acidity values, and sulfate, and calcium plus magnesium fluxes attained their maximum values after about cycle 80, suggesting that the leachate pHs in the 4 S.U. range were buffered, probably by hydrous iron oxides, prior to developing strongly acidic conditions. In comparison, the maximum conductivity value and the sulfate, and calcium plus magnesium fluxes measured and calculated for WD-13 were more than an order of magnitude greater than the corresponding measurements and calculations for any of the high sulfur waste rock composites (see Figures 3.5-54 through 3.5-57). Other metal fluxes calculated in the WD-13 leachate were similarly greater than those calculated for the high sulfur waste rock leachates.

The results of the W/D leaching of the whole tailings composite suggest that, if moisture conditions within the upper part of the consolidating tailings within a TMA cell were similar to those in the laboratory test, whole tailings will not produce strongly acidic leachate during at least the first one and one-half years that the tailings are exposed to continuous oxidation. In reality this time period would likely be greater in the field due to diminished oxidation and leaching during the winter months.

A parallel leaching test with lime amended whole tailings composite (WD-14) was conducted under alternating W/D conditions similar to that for the unamended whole tailings composite (WD-13). Leachate pH values were initially found to be approximately 11.5 S.U. which slowly declined over a 30 week period to circumneutral values which were maintained for an additional 40 weeks until the test was terminated. Most of the metal fluxes calculated for the lime amended whole tailings composite, especially lead, were significantly greater than those for the unamended whole tailings composite. The elevated metal fluxes were probably the result of complexing reactions at the elevated pHs and the rapid oxidation of polythionates and galena (PbS) which are known to occur at very high pH levels (Colorado School of Mines, 1982). The tests showed that, if an amendment were necessary to control interstitial water pH in consolidating TMA tailings, lime should not be used due in particular to the unacceptably high lead flux that could develop at the very high pH levels.

Unlike the TMA tailings leached under saturated, followed by alternating W/D, conditions, the TMA whole tailings leached only under alternating W/D conditions did not exhibit net accumulations of constituents.

3.5.5.3.2.3 Backfill Tailings

The main emphasis of the backfill tailings testing has been to characterize the reactions of uncemented (AL-15) and cemented (AL-17) coarse tailings, the most likely materials that will be used to backfill the depleted stopes. Uncemented (AL-13) and cemented (AL-16) whole tailings have been similarly tested in case CMC should elect to use a paste method for backfilling the stopes. Both cemented composites were prepared using a mixture of 10 percent NPC with 90 percent tailings and adding sufficient process water to form a cement which cured in approximately two weeks time. The cemented tailings were then broken by hand to form fragments less than 2 inches in diameter and were placed in separate 5-gallon cylindrical polyethylene columns. Samples of the uncemented tailings composites were placed in similar separate polyethylene columns.

All backfill tailings composites were leached under alternating W/D, followed by saturated, conditions. The composites were leached once with process water after they were placed in the columns. A second leaching with site groundwater was conducted nine weeks later, after which the composites were saturated with site groundwater for the remainder of the testing. Samples of the two W/D leachings were collected and analyzed with the exception that no leachate could be collected from the second W/D leaching of the uncemented (AL-15 and AL-13) composites due to the development of a relatively impermeable crusting on the surface of these composites during the time between the two W/D leachings. Prior to the initiation of the saturated leaching these crusts were broken by hand, thereby increasing the composite permeabilities. Samples of saturated leachate were collected from the base of each column on a geometric time scale similar to that used for the waste rock composites. Following the collection of a saturated leachate

sample, a volume of site water was added to each column equal to the volume removed in order to maintain saturated conditions in the columns.

The collected leachates were submitted to a contract laboratory for digestion and analysis of the parameters listed in Appendix 3.5-33 Table 1, which also contains the sampling schedule. A summary of the contract laboratory analyses is also included in Appendix 3.5-33. The results of the backfill tailings analyses have been organized chronologically for each composite in Appendix 3.5-35 Tables 30 through 57. The results of the weekly analyses, and the calculated sulfate, and calcium plus magnesium fluxes versus time and saturated pore volumes (PVs) leached are shown in Figures 3.5-62 through 3.5-65.

The pH of the uncemented backfill coarse tailings composite (AL-15) leachate slowly increased from an initial value of 6 S.U. to about 7.5 S.U. by the end of the testing as shown in Figure 3.5-62. The saturated alkalinity values increased to a maximum value at about cycle 25 and thereafter slowly declined and apparently stabilized at a level about one-half the maximum value. The leachate conductivity values and all fluxes were at maximum values in either the one unsaturated sample collected or in the first saturated sample collected. Conductivity values and fluxes declined rapidly to much lower values where they apparently stabilized. The measured alkalinity and initial parameter fluxes calculated in the AL-15 leachate were greater than those measured and calculated in the TMA fine tailings (RS-18) composite leachate. No net accumulations of constituents were observed in this composite.

As shown in Figure 3.5-63, the pH of the cemented backfill coarse tailings composite (AL-17) leachate very slowly declined from an initial value of about 12 S.U. to a value of about 11 S.U. by the end of the testing at week 67. Conductivity and alkalinity values, and parameter fluxes slowly declined during the testing. The AL-17 leachate contained higher flux values for potassium and sodium, and much lower flux values for the other parameters analyzed, than the cemented backfill coarse tailings (AL-15) leachate. Net accumulations of copper and magnesium were observed in this composite. The overall leachability of the cemented backfill coarse tailings is lower than for AL-15.

The pH of the uncemented backfill whole tailings composite (AL-13) leachate was stable at a value of about 7 S.U. throughout the test period as shown in Figure 3.5-64. Leachate alkalinity values declined very slowly during the testing. Conductivity values and calculated leachate fluxes also declined during the test period but more abruptly than the alkalinity values. The calculated sulfate, cadmium, cobalt, magnesium, potassium, silver, and, zinc fluxes in the AL-13 leachate were lower than those calculated for the uncemented backfill coarse tailings composite (AL-15) leachate. No net accumulations for any constituents was observed for AL-13.

As shown in Figure 3.5-65, the pH of the cemented backfill whole tailings composite (AL-16) leachate increased from values of about 6.5 S.U. to values of about 9.5 S.U. during the test period. During this period conductivity values slowly declined and alkalinity values increased slightly. The calculated parameter fluxes slowly declined during testing. All parameter fluxes in the AL-16 leachate were considerably lower than those in the AL-13 leachate. Parameter fluxes in the AL-16 leachate were generally greater than those calculated in the backfill coarse tailings composite (AL-17) leachate. Net accumulations of zinc and magnesium were observed for the AL-16 composite when tested under saturated conditions.

3.5.5.3.3 Miscellaneous Studies

Miscellaneous studies conducted during the waste characterization work have included extraction procedure (EP) toxicity, radiological testing, and asbestiform and carbonate mineral investigations. Each is described in the following subsections.

3.5.5.3.3.1 Extraction Procedure (EP) Toxicity

EP toxicity tests were performed on all of the waste rock composites tested by B.C. Research during the 1982 waste characterization program (B.C. Research, 1982a and 1982b). EP toxicity tests were also performed on all ore and tailings samples tested by the Colorado School of Mines Research Institute as part of the 1982 waste characterization program (Colorado School of Mines, 1982). This test was used to determine if a material will leach metals under acidic conditions. The results of the EP toxicity tests indicated that the concentrations of leachable metals measured during these tests were lower than current state and federal threshold limits as defined by 40 CFR 261. The most commonly used current method to determine if a substance will leach is the TCLP method. The TCLP method is considerably more accurate for the determination of leachable volatile organics (not an issue of concern for this project), but provides similar results to the EP toxicity test for leachable metals. Although the method of preference to determine leachability has changed from EP toxicity to TCLP, the two methods produce similar results for metals extractability. Therefore, the previously collected data are still valid, and no additional extractive testing was conducted.

3.5.5.3.3.2 Radiological Testing

Extensive radiological analyses were performed on the fine tailings, ore and waste rock during the previous environmental investigations (Hazelton, 1981a and 1981b; Colorado School of Mines, 1982). The results of the chemical and radiation tests, conducted and verified by several organizations, showed that these materials contain less uranium, thorium and radium, and have lower radioactivity, than nearby unmineralized crystalline rock.

Although no additional radiological analyses are necessary to characterize these materials, uranium analyses were performed during the current waste characterization studies. Uranium analyses were performed as part of the bulk chemical analyses, and leachate analyses from the first few leachate samples collected from each material being reacted. There were no definite detects of uranium in any of these samples. Definite detects are considered to be those that are at least three times greater than the instrumental detection limit for single digit detection limits. In addition, approximately two-thirds (50) of the leachate samples tested for uranium by CEP (Controls for Environmental Pollution) were reanalyzed by the PACE Minnesota laboratory using the remaining aliquots from the first set of analyses. The results of both analyses are included in Appendix 3.5-33. A comparison between the two sets of analyses is included in Appendix 3.5-33 Table 2. As can be seen in this table, the results of these analyses are quite comparable with the exception of one analysis. The CEP uranium analyses are considered valid based on the high degree of comparability of the two sets of independent analyses.

At the request of the USEPA, a further review of the radiological properties of the Crandon ore and waste rock was conducted on core stored in the CMC core storage facility in Rhinelander, Wisconsin on May 8, 1996. During this screening investigation, a calibrated scintillometer was used by CMC and several participants to screen these materials for radiological emissions. An

examination of core, including some black argillite, selected by the participants determined that the Crandon materials produced only background levels of emissions. These results further validated the results of previous investigations which had also found no radiological emissions above background levels. These results were predictable based upon the previously reported data which showed that the Crandon ore and waste rock contain only very minute quantities of uranium, thorium and radium. Notes concerning this investigation are included in Appendix 3.5-32.

3.5.5.3.3.3 Asbestiform Minerals

Petrographic thin sections of selected ore and waste rock samples were prepared during the past environmental investigations and were examined by optical microscopy for the presence of asbestiform minerals (Lambe, 1979). This work, which was verified by the Wisconsin Geological and Natural History Survey (Ostrom, 1982), found no asbestiform minerals in the analyzed samples. Samples of fine tailings material were examined by transmission electron microscopy by a laboratory recommended by WDNR. No asbestiform minerals were found in the fine tailings material (Yamate, 1984a and 1984b). No additional evaluations of asbestiform minerals have been performed.

3.5.5.3.3.4 Carbonate Minerals

Minor and variable amounts of carbonate minerals (mainly calcite, $CaCO_3$) have been found in the waste rock and ore from the site (Nimjee, 1979; Rowe, 1980). These studies used chemical and petrographic techniques in determining that the carbonate mineral content of these materials varied from about one to four percent. Cherry's evaluation (1983) of the acid generation potential of the Crandon tailings concluded that it is likely that these tailings will not develop acidic pore water due to the carbonate mineral content, particularly if the surface of the tailings is covered soon after impoundment.

An evaluation of the carbonate mineralogy of the Crandon ore, tailings and waste rock is being undertaken. Methods of analysis being used in this evaluation include: optical microscopy; x-ray diffraction (XRD); scanning electron microscopy and energy dispersive spectroscopy (SEM/EDAX). The preliminary results of this evaluation (see Appendix 4.2-12 of this EIR) indicate that the main carbonate mineral present in these materials in ferroan calcite. The final results of this evaluation will be included in the final report for the supplementary waste characterization studies.

3.5.5.4 Proposed Method for Determining the Type I/Type II Waste Rock Separation During Mining Operations

It has been shown that the four hanging wall waste rock formations that will be encountered during the construction of the preproduction underground facilities at the Crandon mine have differing ABA and WRC values, and leaching characteristics (see Sections 3.5.5.3.1 and 3.5.5.3.2, respectively). Based upon this data the following conclusions have been reached regarding the practicality of separating waste rock from each of the four hanging wall formations into Type I or Type II waste rock:

- Skunk Lake Formation. Rock from the Skunk Lake Formation contains a variable amount of sulfide minerals and generally has a very low neutralization potential (NP).

Due to the very low NP values, all material excavated from this formation will be considered as Type II waste rock.

- Rice Lake Formation. Rock from the Rice Lake Formation contains only small amounts of sulfide minerals and generally has a moderate NP. It is expected that nearly all (>90 percent) of the waste rock excavated from this formation will be classified as Type I waste rock.

- Upper Mole Lake Formation. Rock from the Upper Mole Lake Formation contains only small amounts of sulfide minerals and generally has a moderate NP. It is expected that nearly all (>90 percent) of the waste rock excavated from this formation will be classified as Type I waste rock.

- Lower Mole Lake Formation. Rock from the Lower Mole Lake Formation generally contains low to moderate, highly variable, concentrations of sulfide minerals, and moderate to high, highly variable, NP. Due to the high degree of variability in sulfide mineral content and NP, all material excavated from this formation will be considered as Type II waste rock.

As mentioned above, it is expected that nearly all of the waste rock excavated from the Rice Lake and Upper Mole Lake Formations will be classified as Type I material. It is expected that the working face of an excavation will be advanced by 10-15 foot intervals. Since it has been demonstrated that the characteristics (S, NP) for waste rock from these formations is consistent over distances greater than 30 feet (see Section 3.5.5.3.1, ABA) it is reasonable to expect that the rock removed from a particular shot will be very similar to that exposed on the working face. It is therefore reasonable to characterize the waste rock on the basis of the characteristics of the working face.

The results of the leaching tests conducted on the statistically representative Rice Lake and Upper Mole Lake master waste rock composites have shown that even the worse case leachate generated during these tests will not adversely impact the underlying soils at the site.

The results of the 1995 ABA tests for multiple samples from each of these formations (plotted in Figures 3.5-49a and 3.5-49b) show that all of the samples contained less than 0.5 percent sulfur, or 0.9 percent sulfide mineral content which is equivalent to an AP of 16 kg/tonne (assuming that all of the sulfur is in the form of the mineral pyrite, a reasonable assumption for these rocks). The results of the ABA tests conducted on Rice Lake and Upper Mole Lake waste rock have shown that virtually all of these materials will have NP/AP values greater than 3. The data also shows that most of the waste rock containing NP/AP values less than 3 had sulfide sulfur contents greater than 1 percent. The relationship between sulfide sulfur content and NP/AP for rocks from these two formations is shown in Figures 3.5-66a and 3.5-66b. The area to the left of the 0.5 percent sulfide sulfur content (or 0.9 percent sulfide mineral (pyrite plus chalcopyrite) content) line and above the NP/AP = 3 line is the proposed domain for Type I waste rock. Note that all tested samples, with the exception of the high sulfur composites, plotted within the Type I domain.

Classification of Type I and Type II waste rock will therefore be undertaken as follows:

Step 1- Planning. The boundaries of the hanging wall waste rock formations are well defined based on the data gathered during the exploration drilling. Three dimensional plots of the space occupied by each formation will be prepared to show where each formation will be intersected during construction of the underground facilities. It is therefore possible to accurately predict where the different formations will be encountered. Through advance planning, areas in the Rice Lake and Upper Mole Lake Formations will be identified where Type I/Type II evaluations will have to be performed.

Step 2- Field Control. All waste rock that will be excavated from the Skunk Lake and Lower Mole Lake Formations will be considered as Type II waste rock and will be handled as described in the MPA (Foth & Van Dyke, 1995f). All waste rock that will be excavated from the Rice Lake and Upper Mole Lake Formations will be classified as either Type I or Type II by following the method listed below:

1. Determination of sulfide mineral (pyrite plus chalcopyrite) content. The sulfide mineral (pyrite plus chalcopyrite) content of each working face will be determined by using the tables included in Appendix C of the MPA (Foth & Van Dyke, 1995f). If the rock exposed on a working face from either formation has a sulfide mineral (pyrite plus chalcopyrite) content greater than 0.9 percent equivalent to 0.5 percent sulfur used in the Appendix C tables), the next successive waste rock removed will be classified as Type II material and will be handled as described in the MPA. For waste rock with a sulfide mineral (pyrite plus chalcopyrite) content of less than or equal to 0.9 percent, the Type I/Type II classification will be based upon the estimated NP/AP value.

2. Estimation of NP/AP value. Experience conducting the WRC and ABA tests has shown that most of the rock core from the Rice Lake and Upper Mole Lake formations evaluated during these investigations reacted vigorously with dilute hydrochloric acid and had NP/AP values greater than 3.

   a. The percent sulfide mineral (pyrite plus chalcopyrite) as estimated in (1) above will be used to calculate the AP as follows:

      AP = sulfide mineral content X 16.7 $kgCaCO_3$ eq/tonne (calculated conservatively assuming pyrite).

   b. The reactivity of the face samples to hydrochloric acid will be used to estimate the NP. A calibration program will be developed in which samples with a known NP will be reacted with dilute hydrochloric acid of different strengths (molarity). The reaction intensity will be given a fizz rating, which will then be correlated with the NP value. This correlation will then be used to estimate the NP of the sample. For example, it is anticipated that ten samples, distributed to approximate the composition of the waste rock matrix exposed on each working face will be collected and spot tested at the working face to determine the reactivity rating, from which the average NP would be estimated. If the resulting estimated NP/AP is greater than 3, the rock will be classified as Type I.

3. Quality Assurance. To provide quality assurance of the proposed field control program, grab samples will be obtained at regular intervals from the waste rock produced. These samples will be submitted for ABA testing, and the actual NP/AP ratios will be

determined. These will be compared with the field program results to verify correct classification of the waste rock.

For the development of the field testing program, a series of standards for sulfide mineral (pyrite plus chalcopyrite) content and NP values will be prepared from existing Rice Lake and Upper Mole Lake formation core prior to the commencement of underground excavations. These materials will be used to train the CMC mining geologists responsible for performing the differentiation between Type I and Type II waste rock during excavations in these formations. The standards will be maintained by the project's QA/QC officer and will be available for reference as required.

3.5.5.5 Conclusions

Several conclusions have been reached regarding the behavior of the wastes that were tested during the project's waste characterization program. These conclusions are listed below in the form of responses to the program's objectives listed in the beginning of Section 3.5.5:

1. Waste Rock

   a. It is expected that more than 90 percent of waste rock that will be excavated from the Rice Lake and Upper Mole Lake Formations during the preproduction phase of mine development can be classified as Type I.

      Rock from the Skunk Lake Formation has been found to have a very low neutralization potential and a has a very low pyritic sulfide mineral content. It would not be practical to perform a Type I/Type II classification regarding this material at a working face within the mine due to the very low concentrations of key diagnostic minerals.

      Rock from the Lower Mole Lake Formation has a moderate, highly variable sulfide mineral content and a moderate to high neutralization potential. It would not be practical to separate rock from this formation into Type I and Type II due to the high degree of sulfide mineral content variability.

   b. A method for performing a conservative practical separation of waste rock into Type I and Type II has been included in Section 3.5.5.4.

2. TMA Tailings

   a. TMA tailings materials similar to those expected to be found near the margins of the TMA cells and those expected to be found within the central portions of the cells have been tested under conditions simulating those expected to occur within the operational cells. The results of these tests show that acidic leachate will not be generated within the operational cells and that the worst case leachate composition will be similar to, but will have lower concentrations than the process water.

      During operations it is expected that the fluxes from the TMA cells of certain solutes contained in the process water will be lower than those calculated from the laboratory results since leachate will be collected from the base and sidewalls of the cells and because secondary minerals are expected to develop within the tailings mass.

b. Tailings behavior during the consolidation phase of the TMA cells is addressed in the interim report for the supplementary waste characterization study (Appendix 4.2-12 of this EIR). The data presented above demonstrated that the tailings are not likely to become acid generating if exposed for less than 18 months, if moist conditions similar to the test conditions are maintained.

   The results of the parallel W/D leaching tests of the unamended and the lime amended whole tailings composites has shown that if it were desirable to add an amendment to the consolidating tailings to neutralize potential acid generation the amendment should not be lime.

c. The best engineering judgement and practical worst case water quality in the TMA is discussed in the interim report on the supplemental waste characterization program contained in Appendix 4.2-12 of this EIR.

3. Backfill Tailings

   a. A source term has been calculated for the reflooded mine (SRK, 1997b). The calculation of this source term used data from the waste characterization studies as part of the data base for the calculations.

4. Miscellaneous Studies

   a. The results of the EP toxicity testing have shown that the tested tailings and waste rock will leach metals lower than the current state and threshold limits as defined by 40 CFR 261.

   b. The verified results of the radiological testing of fine tailings, ore and waste rock has shown that these materials contain less uranium, thorium and radium, and have lower radioactivity, than nearby unmineralized crystalline rock. No definite detects of uranium were found in the more than 75 uranium analyses of leachate generated during the project's kinetic studies.

   c. No asbestiform minerals were found during the verified examinations of ore and waste rock performed by optical microscopic techniques nor during the examination of fine tailings materials using transmission electron microscopic techniques.

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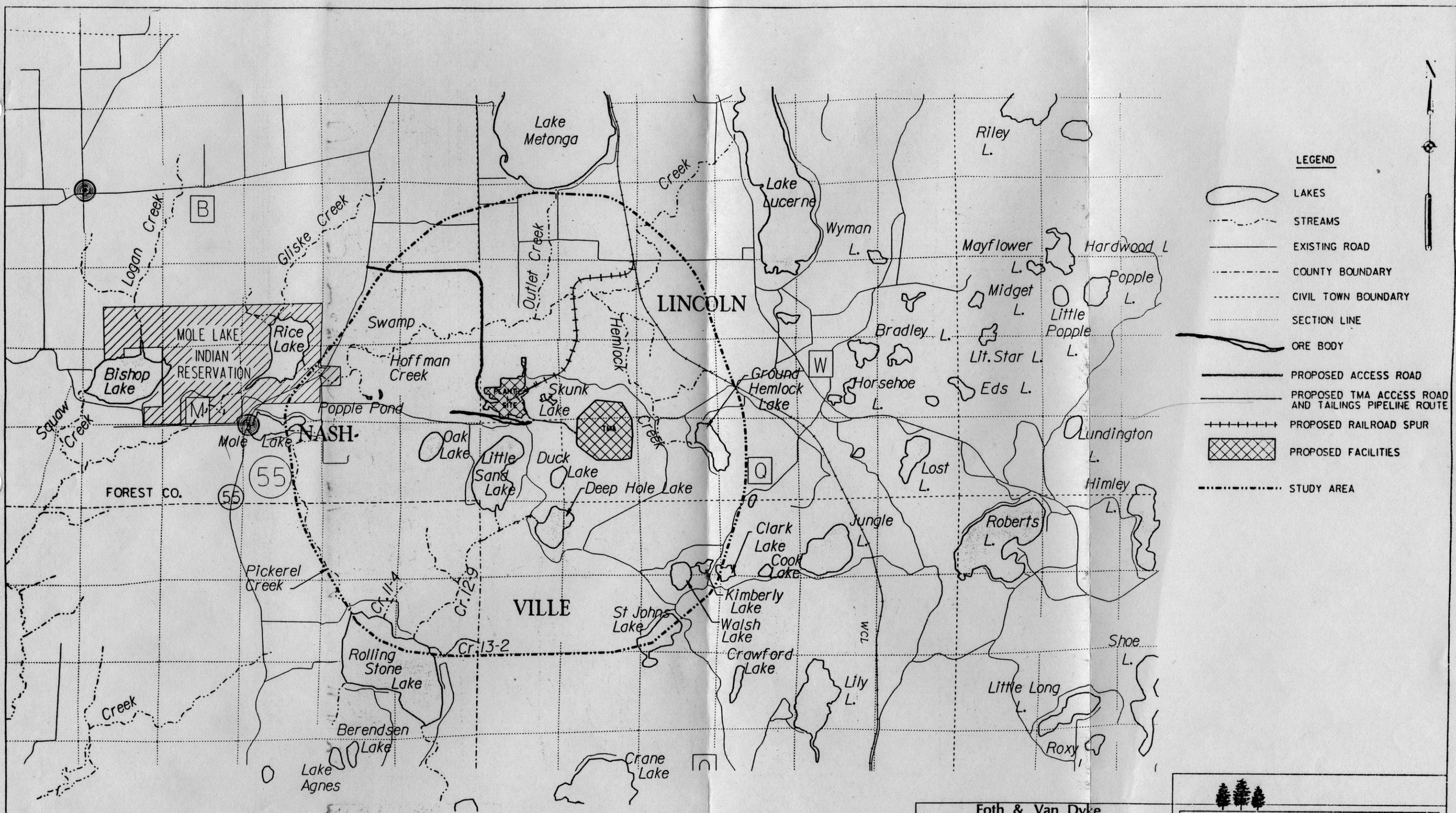
FIGURES FOR SECTION 3.5



NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-1
GEOLOGY AND GROUNDWATER STUDY AREA

Scale: 0 3000' 6000' | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: BSH

/d3/dl/users/jprl/4c33f90a.dgn

93C049

2,275,000 E

2,280,000 E

120,000 N

PLANT

LITTLE SAND LAKE

LEGEND

- LAKES
- EXISTING ROAD
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- 123 EXPLORATION HOLE COLLAR LOCATION AND NUMBER

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-2
CORE HOLE COLLAR LOCATION MAP

Scale: 0 300' 600' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: BSH

/d3/d1/users/jpr1/4c33f125.dgn

93C049

N

2274000E 2274400E 2274800E 2275200E 2275600E 2276000E 2276400E 2276800E 2277200E 2277600E 2278000E 2278400E 2278800E 2279200E 2279600E 2280000E 2280400E 2280800E

2279450E

119200 N
118800 N
118400 N
118000 N
117600 N
117200 N
116800 N
116400 N
116000 N
115600 N

LEGEND

CORE HOLE TRACE

ORE BODY

0 250 500 1000

BAR SCALE (FEET)

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY:	JKS1		DATE: MAY '95
APPROVED BY:	AJE JR./SVD1		DATE: MAY '95
APPROVED BY:	GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-3

PLAN MAP SHOWING DRILL HOLE TRACE IN VICINITY OF CRANDON FORMATION SUBCROP

Scale:	SEE BAR SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JRB

93C049

2,250,000 E | 2,260,000 E | 2,270,000 E | 2,280,000 E | 2,290,000 E | 2,300,000 E

140,000 N | 130,000 N | 120,000 N | 110,000 N | 100,000 N | 90,000 N

DMA-39 DMA-38 DMA-43 DMA-42 DMA-36 DMA-37 DMA-14 DMA-16 DMA-30 DMC-2 EX-6 DMA-34 DMA-35 DMA-33 EX-2 EX-3 DMA-27 DMA-27A DMA-29 DMA-29AU DMA-29AL DMA-44 DMA-45 DMA-7 DMA-32A DMA-22B DMA-22

B M K Q 55

Lake Metonga

Lake Lucerne

Devils Lake

Wabikon Lake

Indian Lake

Wyman Lake

Midget Lake

Bradley Lake

Lil Star Lake

Horseshoe Lake

Eds Lake

Lost Lake

Grand Hemlock Lake

Roberts Lake

Jungle Lake

Kimberly Lake

Cook Lake

Clark Lake

Crawford Lake

Lily Lake

St Johns Lake

Deep Hole Lake

Welsh Lake

Stone Lake

Rolling Stone Lake

Lake Agnes

Berendsen Lake

Crane Lake

Pickerel Lake

Bishop Lake

Rice Lake

Oak Lake

Mole Lake

Little Sand Lake

Duck Lake

Skunk Lake

Hollman Creek

Popple Pond

Logan Creek

Gibbs Creek

Outlet Creek

Pickerel Creek

Stone Creek

Hemlock Creek

Swamp

MOLE LAKE INDIAN RESERVATION

FOREST CO.

NASH-

VILLE

LINCOLN

PROPOSED ACCESS ROAD

SPUR

PROPOSED R.R.

WISCONSIN CENTRAL LIMITED RAILROAD

PLANT SITE

TMA

AREA OF DETAIL ON FIGURE 3.5-5

Cr. 114 Cr. 109 Cr. 132

WP-1 WP-2 WP-3 G40-G7 G40-M13 G40-J15 G40-H16 G40-E16 G40-M15 G40-G19 G40-L19 G40-J20 G40-E22 G40-L9 G40-D24 G40-G24 G40-G26 G40-H27 G40-L23 G40-R23 G40-Y22 G40-Y26 G40-T30 G40-K13 G40-M14 G40-C24

DMB-10 DMB-20 DMB-20A DMB-23 DMB-22 DMB-21 DMB-18 DMB-19 DMA-13 DMB-14 DMB-17 DMB-13 DMB-12 DMA-17 DMB-25 DMB-24 DMB-26 DMB-27 DMB-28 DMB-7 DMB-29 DMC-1 DMC-3

G41-E22A G41-E22 G41-K21A G41-G21 G41-K21 G41-N21 G41-L23 G41-Q22 G41-F24 G41-M24 G41-P24 G41-A23 G41-A24 G41-K26 G41-L25 G41-C32 STS-DHL-1

DMA-48 DMA-40 DMA-18

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- DMA-39 SOIL BORING
- G40-G26 MONITORING WELL BORING

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-4

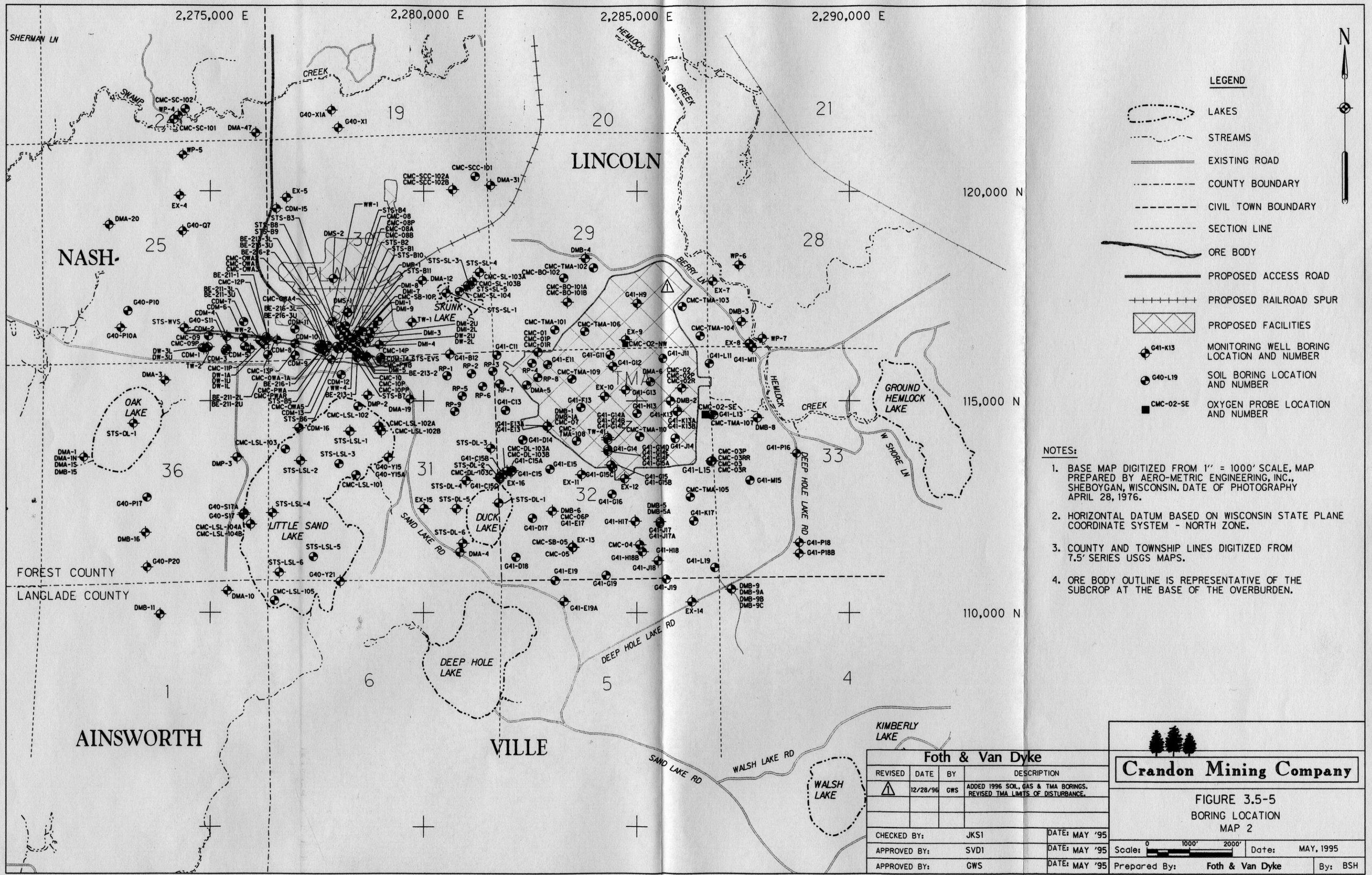
BORING LOCATION MAP 1

Scale: 0 3000' 6000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: BSH

/d3/dl/users/jprl/4c33f119.dgn

93C049



NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/28/96	GWS	ADDED 1996 SOIL, GAS & TMA BORINGS. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-5
BORING LOCATION
MAP 2

Scale: 0 1000' 2000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: BSH

C:\cadwork\4c33f118.dgn

93C049

2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E 2,290,000 E

125,000 N

120,000 N

115,000 N

FVD-AR-1 FVD-AR-2 FVD-AR-3 FVD-AR-4 FVD-AR-5 FVD-AR-6 FVD-AR-7 FVD-AR-8 FVD-AR-9 FVD-AR-10 FVD-AR-11 FVD-AR-12 FVD-AR-13 FVD-AR-14 FVD-AR-15 FVD-AR-16 FVD-AR-17 FVD-AR-18 FVD-AR-19 FVD-AR-20 FVD-AR-21 FVD-AR-22 FVD-AR-23 FVD-AR-24 FVD-AR-25 FVD-AR-26 FVD-AR-27 FVD-AR-28 FVD-AR-29 FVD-AR-30 FVD-AR-31

AR-1 AR-1A AR-2 AR-2A AR-3 AR-4

FVD-RR-1 FVD-RR-2 FVD-RR-3 FVD-RR-4 FVD-RR-5 FVD-RR-6 FVD-RR-7 FVD-RR-8 FVD-RR-9 FVD-RR-10 FVD-RR-11 FVD-RR-12 FVD-RR-13 FVD-RR-14 FVD-RR-15 FVD-RR-16 FVD-RR-17 FVD-RR-18 FVD-RR-19 FVD-RR-20 FVD-RR-21 FVD-RR-22 FVD-RR-23 FVD-RR-24 FVD-RR-25 FVD-RR-26 FVD-RR-27 FVD-RR-28 FVD-RR-29 FVD-RR-30 FVD-RR-31 FVD-RR-32 FVD-RR-33 FVD-RR-34 FVD-RR-35

RR-1 RR-2

PLANT SITE

TMA

SHERMAN LK

SAND LAKE RD

LITTLE SAND LAKE RD

DEEP HOLE LAKE RD

KEITH SIDING RD

BERRY LK

AIRPORT RD

COUNTY PARK RD

SWAMP LK

WISCONSIN CENTRAL LIMITED RAILROAD

GERDE LK

HWY 55

OFFUT CREEK

SWAMP CREEK

HEMLOCK CREEK

SKUNK LAKE

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

DEEP HOLE LAKE

GROUND HEMLOCK LAKE

FOREST COUNTY

LANGLADE COUNTY

13 18 17 16 24 19 20 21 23 25 26 30 29 28 35 36 31 32 33 2 1 6 5

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- FVD-RR-15 SOIL BORING NUMBER AND LOCATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-6

ACCESS ROAD AND RAILROAD BORING LOCATIONS

Scale: 0 1000' 2000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JOW

/d3/dl/users/lprl/4c62f54.dgn

93C049

2,275,000 E
2,280,000 E
2,285,000 E
2,290,000 E
120,000 N
115,000 N
110,000 N
SHERMAN LN
SWAMP
CREEK
HEMLOCK CREEK
BERRY LN
HEMLOCK CREEK
W SHORE LN
DEEP HOLE LAKE RD
SAND LAKE RD
WALSH LAKE RD
DEEP HOLE LAKE RD
SAND LAKE RD
CMC-SC-102
CMC-SC-101
CMC-SCC-101
CMC-SCC-102A
CMC-SCC-102B
01
STS-SL-4
STS-SL-3
CMC-SL-104
STS-SL-1
STS-SL-2
F12
CMC-SL-103A/B/C
STS-SL-5
SKUNK LAKE
CMC-BO-102
F15
CMC-BO-101A
CMC-BO-101B
PLANT SITE
TMA
F10
CMC-LSL-102
CDM-16
STS-LSL-1
CMC-LSL-102A
CMC-LSL-102B
F29
STS-DL-3
CMC-LSL-103
G40-Y15
G40-Y15A
STS-LSL-3
STS-LSL-2
CMC-LSL-101
F28
G41-C15B
STS-DL-2
CMC-DL-103A/B
CMC-DL-103C
F9
STS-DL-4
G41-C16D
STS-DL-5
STS-DL-1
DUCK LAKE
STS-DL-6
G40-S17A
G40-S17
LITTLE SAND LAKE
STS-LSL-4
CMC-LSL-104A
CMC-LSL-104B
STS-LSL-5
STS-LSL-6
CMC-LSL-105
STS-DHL-1
DEEP HOLE LAKE
OAK LAKE
STS-OL-1
GROUND HEMLOCK LAKE
KIMBERLY LAKE
WALSH LAKE
NASH-
LINCOLN
AINSWORTH
VILLE
FOREST COUNTY
LANGLADE COUNTY
19
20
21
25
30
29
28
36
31
32
33
1
6
5
4

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- CDM-16 MONITORING WELL BORING
- CMC-BO-102 SOIL BORING LOCATION
- F15 INVESTIGATED WETLAND AREA BOUNDRY

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

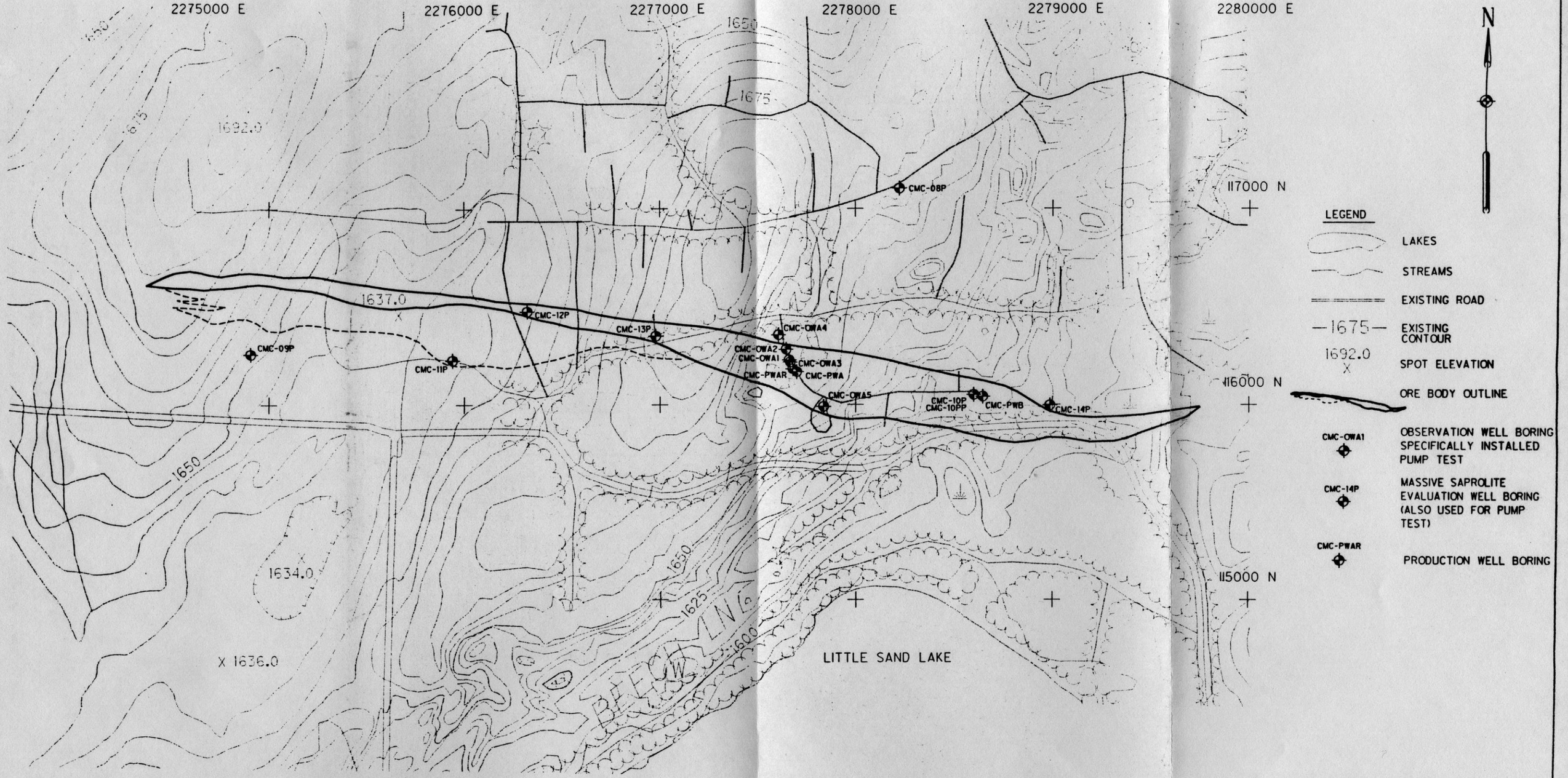
FIGURE 3.5-7

BORING LOCATIONS FOR LAKEBED AND WETLAND CHARACTERIZATION

Scale: 0 1000' 2000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: BSH

93C049



NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.5-8

LOCATION OF MASSIVE SAPROLITE MONITORING WELL BORINGS

Scale: 0 250' 500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: BSH

/d3/dl/users/jprl/4c33f133.dgn

93C049

2,280,000 E

2,285,000 E

115,000 E

110,000E

SITE

SKUNK LAKE

LITTLE SAND LAKE

LITTLE SAND LAKE RD

SAND LAKE RD

DUCK LAKE

DEEP HOLE LAKE

DEEP HOLE LAKE RD

BERRY LN

FOREST COUNTY

LANGLADE COUNTY

25 30 29 28 31 32 33 6 5

T31N

STS-TP-80-1 STS-TP-80-2 STS-TP-80-3 STS-TP-80-4 STS-TP-80-5 STS-TP-80-6 STS-TP-80-7 STS-TP-80-8 STS-TP-80-9 STS-TP-80-10 STS-TP-80-11 STS-TP-80-12 STS-TP-80-13 STS-SAF-1 STS-SAF-2 STS-SAF-3 STS-SAF-4 STS-SAF-5 STS-SAF-6 STS-SAF-7 STS-SAF-8 STS-SAF-9 STS-SAF-10 STS-SAF-11 STS-SAF-12 STS-SAF-13 STS-SAF-14 STS-SAF-15 STS-SAF-16

TP-1 TP-2 TP-3 TP-4 TP-5 TP-6 TP-7 TP-8 TP-9 TP-10 TP-11 TP-12 TP-13 TP-14 TP-15 TP-16 TP-17 TP-18 TP-19 TP-20

TP-84-1 TP-84-2 TP-84-3 TP-84-4 TP-84-5 TP-84-6 TP-84-7 TP-84-8 TP-84-9 TP-84-10 TP-84-11 TP-84-12 TP-84-13 TP-84-14 TP-84-15 TP-84-16 TP-84-17 TP-84-20 TP-84-21 TP-84-22 TP-84-23 TP-84-24 TP-84-30 TP-84-31 TP-84-32 TP-84-33

TP-85-1 TP-85-2 TP-85-3 TP-85-4 TP-85-5 TP-85-6 TP-85-7 TP-85-8 TP-85-9 TP-85-10 TP-85-11 TP-85-12 TP-85-13 TP-85-14 TP-85-15 TP-85-16 TP-85-17

TP-41 TP-TW-41

1594.0 1591.8 1593.0 1597.8

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- TP-85-14 TEST PIT NUMBER AND LOCATION

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON WISCONSIN STATE PLANE DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-9

HISTORICAL TEST PIT LOCATIONS

Scale: 0 500' 1000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW

/d3/dl/users/jprl/4c33f93.dgn

93C049

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- 1675 — EXISTING CONTOUR
- 1692.0 X — SPOT ELEVATION
- TREES/BRUSH
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- INVESTIGATED ABSORPTION AREA
- ■ TPE-4 — APPROXIMATE LOCATION OF TEST PITS FOR SOIL ABSORPTION FIELD INVESTIGATION
- ■ TP-F1 — APPROXIMATE LOCATION OF TEST PITS FOR FRAGIPAN INVESTIGATION

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON WISCONSIN STATE PLANE DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/27/96	GWS	ADD FRAGIPAN TEST PITS. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	WJS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-10

1994 & 1996 TEST PIT LOCATIONS

Scale: 0 1000' 2000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: BSH

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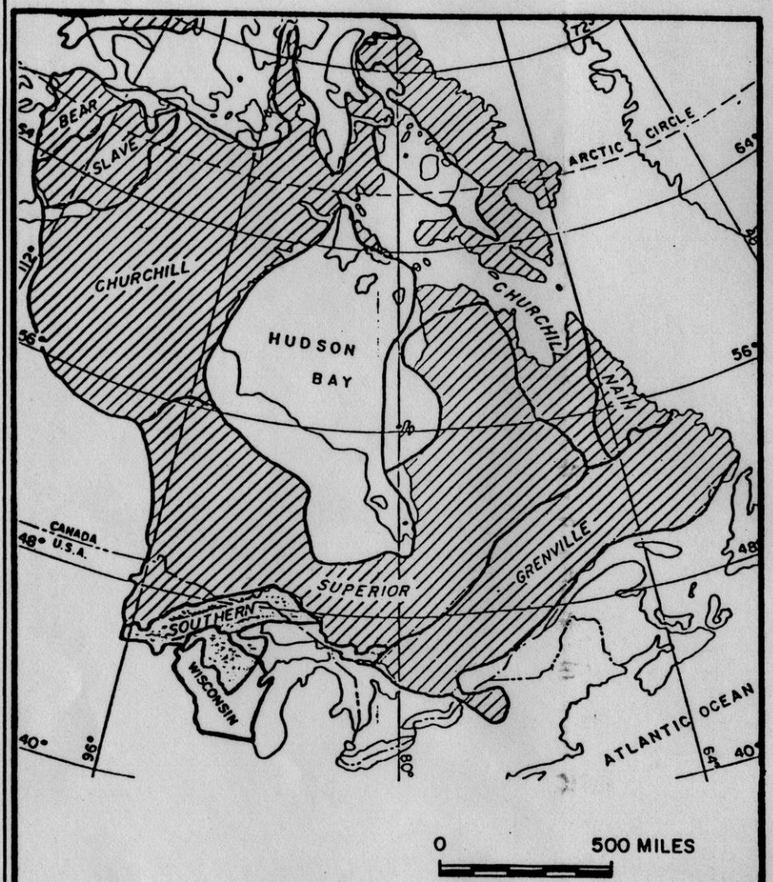
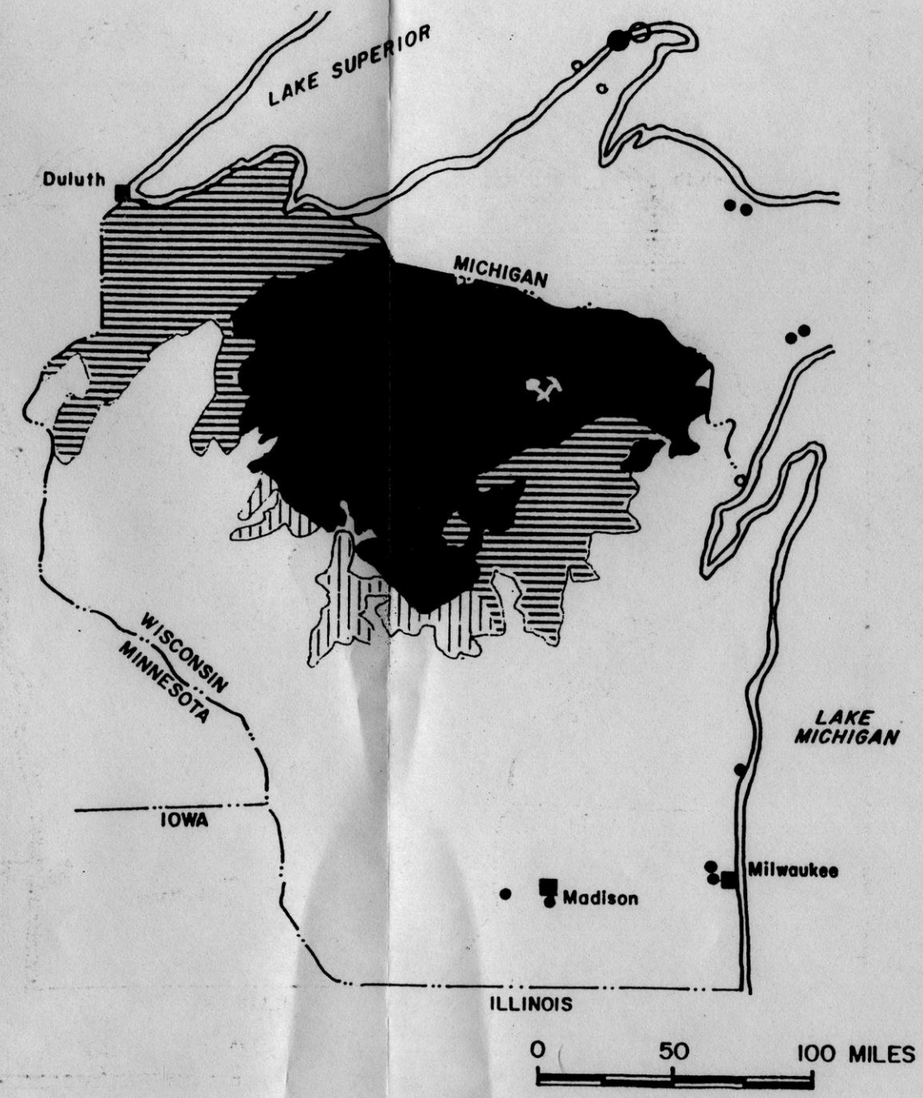
93C049



LOCATION OF THE SOUTHERN PROVINCE, CANADIAN SHIELD



EXPLANATION:

- PALEOZOIC SEDIMENTARY ROCKS
- LATE PRECAMBRIAN: 600-1600 M.Y.
- MIDDLE PRECAMBRIAN: 1600-2500 M.Y.
- EARLY PRECAMBRIAN: 2500 M.Y. AND OLDER

EPICENTER MODIFIED MERCALLI INTENSITY

- ● I - IV
- ○ I - IV AND II - VI
- ○ VII
- ● VIII
- CRANDON DEPOSIT

REFERENCE:

1. U.S.G.S. AND AAPG, 1962.
2. SIMS, 1976.
3. DOCEKAL, 1970.
4. KING AND ZIETZ, 1971.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

Crandon Mining Company

FIGURE 3.5-11
REGIONAL GEOLOGY AND
EARTHQUAKE EPICENTER MAP

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

/d3/dl/users/jprl/4c33fig.dgn

93C049

2,260,000 E 2,265,000 E 2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E 2,290,000 E

130,000 N

125,000 N

120,000 N

115,000 N

110,000 N

105,000 N

100,000 N

LEGEND

- LAKES
- STREAMS
- 1675 — EXISTING CONTOUR, 25' INTERVAL
- EXISTING CONTOUR, 5' INTERVAL
- x 1692.0 — EXISTING SPOT ELEVATION
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95
APPROVED BY:		DATE:

Crandon Mining Company

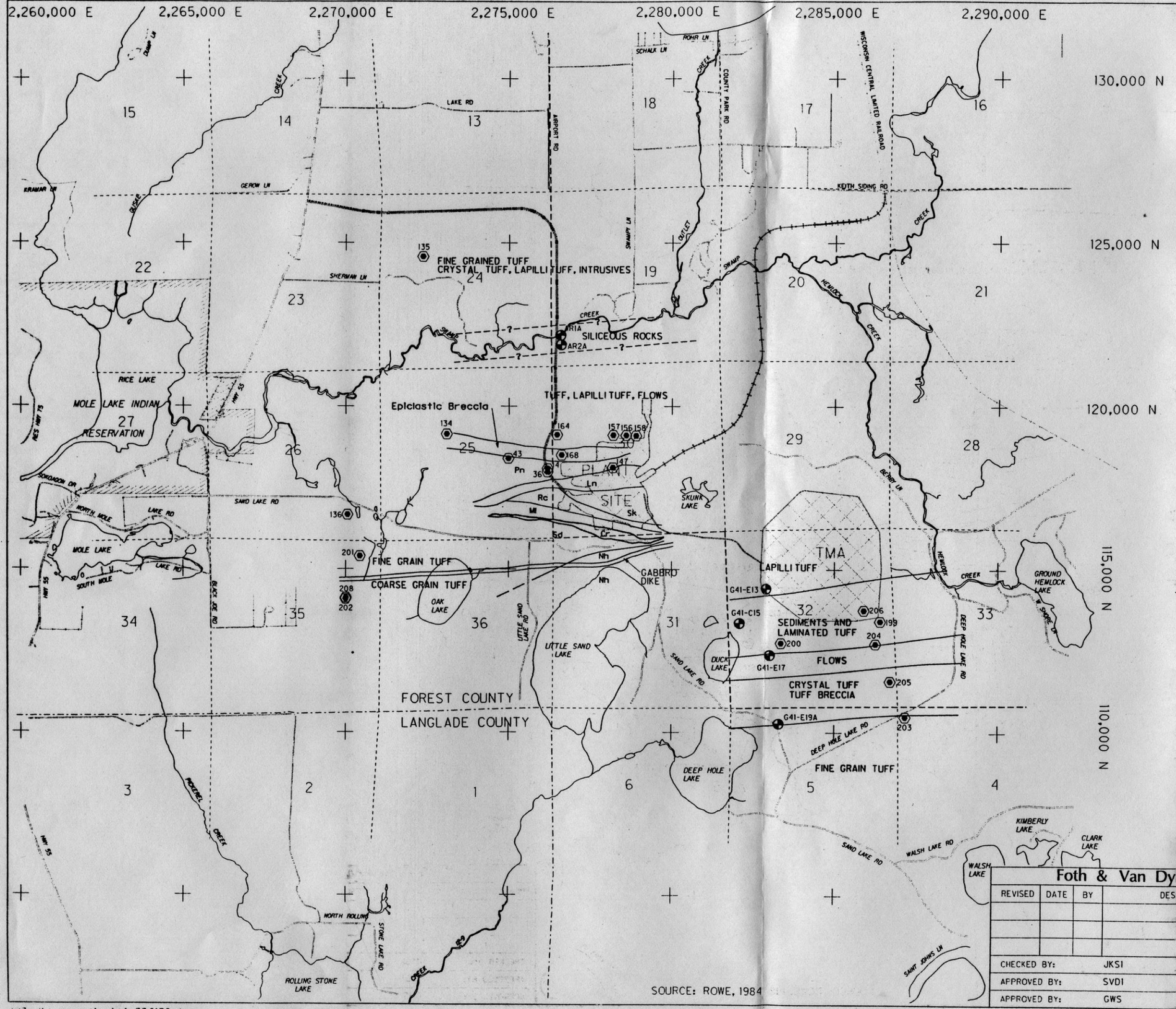
FIGURE 3.5-12
STUDY AREA
TOPOGRAPHIC CONTOURS

Scale: 0 1750' 3500' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: BSH

/d3/dl/users/jprl/4c33f135.dgn

93C049



LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- G41-C15 ENVIRONMENTAL BORING
- EXPLORATION BORING

Sd = SAND LAKE FORMATION
Cr = CRANDON FORMATION
Ml = MOLE LAKE FORMATION
Rc = RICE LAKE FORMATION
Sk = SKUNK LAKE FORMATION
Ln = LINCOLN FORMATION
Pn = PINE FORMATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

SOURCE: ROWE, 1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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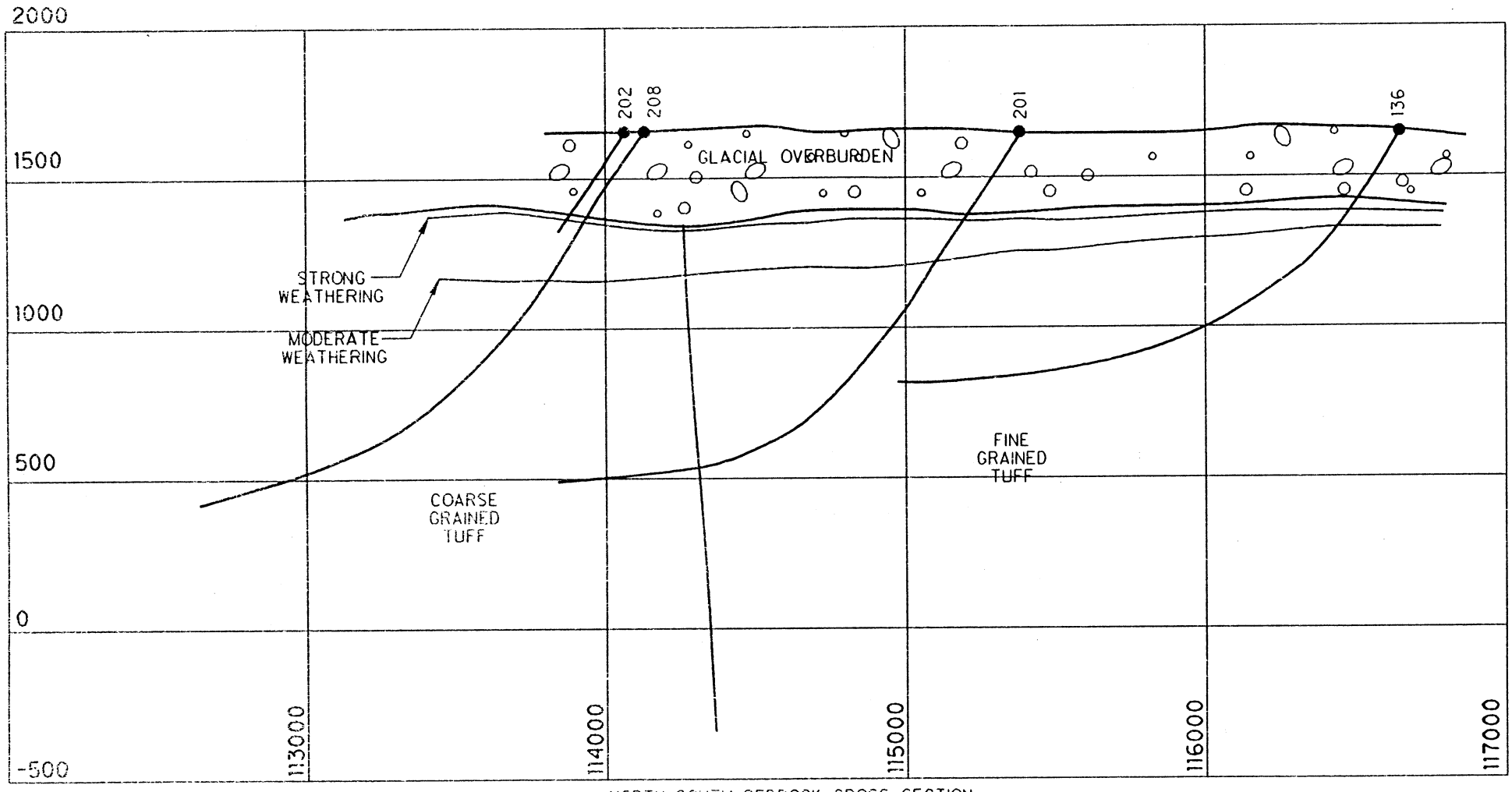
FIGURE 3.5-13
BEDROCK GEOLOGY
OF THE SITE AREA

Scale: 0 1500' 3000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: KMP

/d3/dl/users/prl/4c33f136.dgn

93C049



NORTH-SOUTH BEDROCK CROSS SECTION
APPROXIMATELY 2,270,000 EAST

LEGEND

201 CORE HOLE TRACE

SOURCE:
ROWE 1984

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI			DATE: MAY '95
APPROVED BY:	SVDI			DATE: MAY '95
APPROVED BY:	GWS			DATE: MAY '95

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FIGURE 3.5-14
NORTH AND SOUTH BEDROCK CROSS SECTION
WEST OF ORE BODY

Scale:	1"=500'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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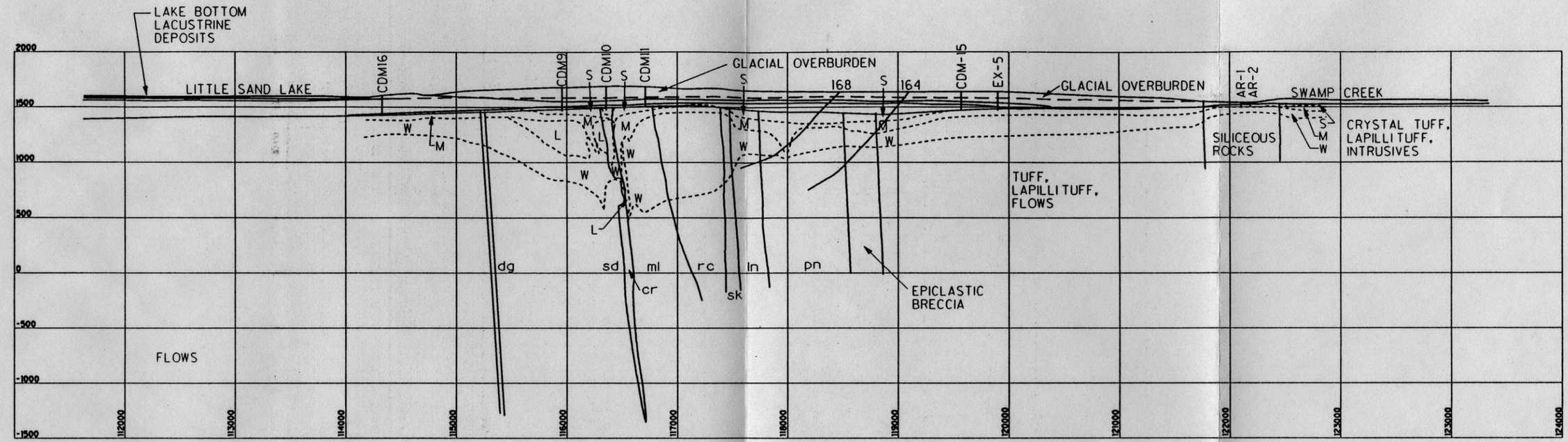
93C049



NORTH-SOUTH CROSS SECTION FROM LITTLE SAND LAKE TO SWAMP CREEK
GLACIAL AND BEDROCK GEOLOGY WITH WEATHERING PROFILE
(APPROXIMATELY AT 2,278,000 FT. EAST)

LEGEND

dg = DUCK LAKE GABBRO
sd = SAND LAKE FORMATION
cr = CRANDON FORMATION
ml = MOLE LAKE FORMATION
rc = RICE LAKE FORMATION
ln = LINCOLN FORMATION
pn = PINE FORMATION
S = STRONGLY WEATHERED BEDROCK
M = MODERATELY WEATHERED BEDROCK
L = LOW WEATHERED BEDROCK
W = WEAKLY WEATHERED BEDROCK
CDM9 = ENVIRONMENTAL BORING
168 = CORE HOLE TRACE

SOURCE:
ROWE, 1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.5-15
NORTH-SOUTH BEDROCK CROSS SECTION
THROUGH ORE BODY

Scale:	1" = 1000'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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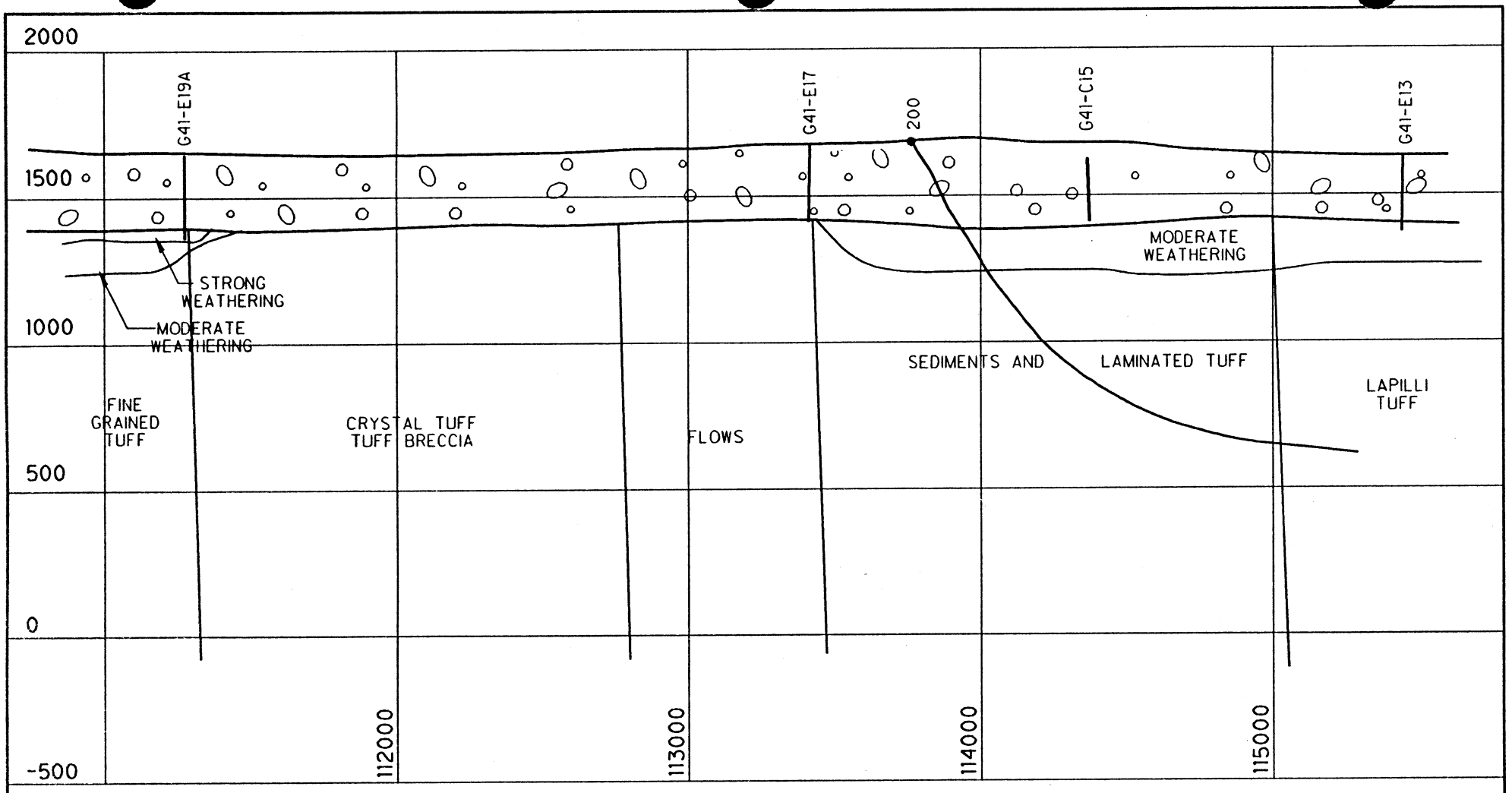
93C049



NORTH-SOUTH BEDROCK CROSS SECTION
APPROXIMATELY AT 2,282,500 EAST

LEGEND

G41-E19A ENVIRONMENTAL BORING

200 CORE HOLE TRACE

SOURCE:
ROWE, 1984

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-16
NORTH AND SOUTH BEDROCK CROSS SECTION
IN THE VICINITY OF TMA

Scale:	1"=500'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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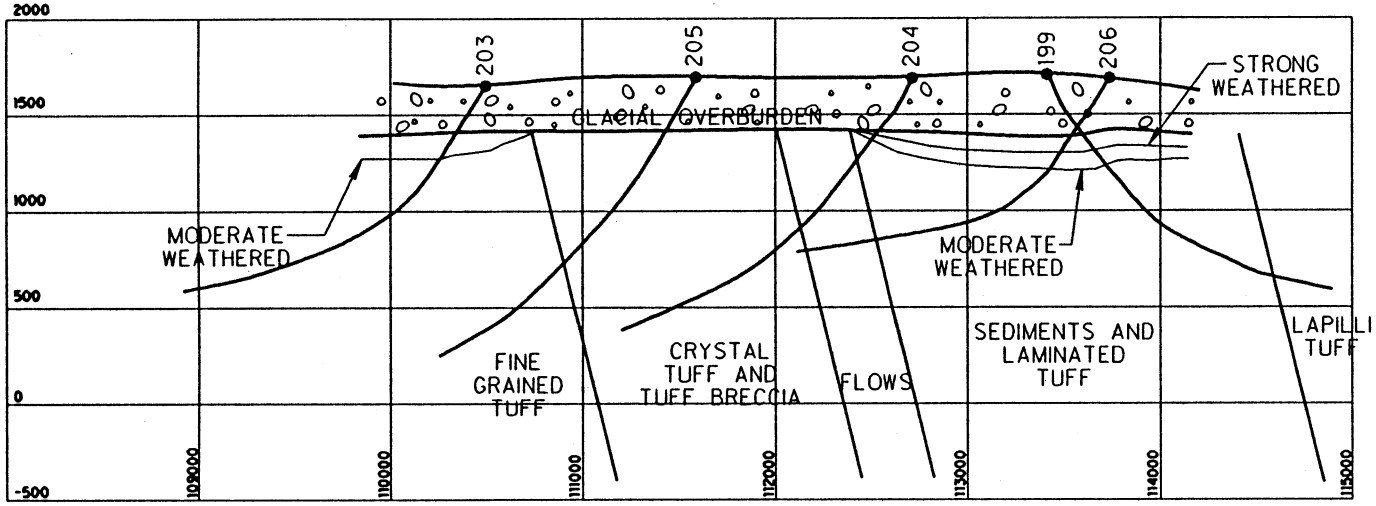
93C049



NORTH-SOUTH BEDROCK CROSS SECTION
APPROXIMATELY 2,287,000 EAST

LEGEND

203 CORE HOLE TRACE

SOURCE:
ROWE, 1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-17

NORTH AND SOUTH BEDROCK CROSS SECTION IN VICINITY OF TMA

Scale:	1"=1000'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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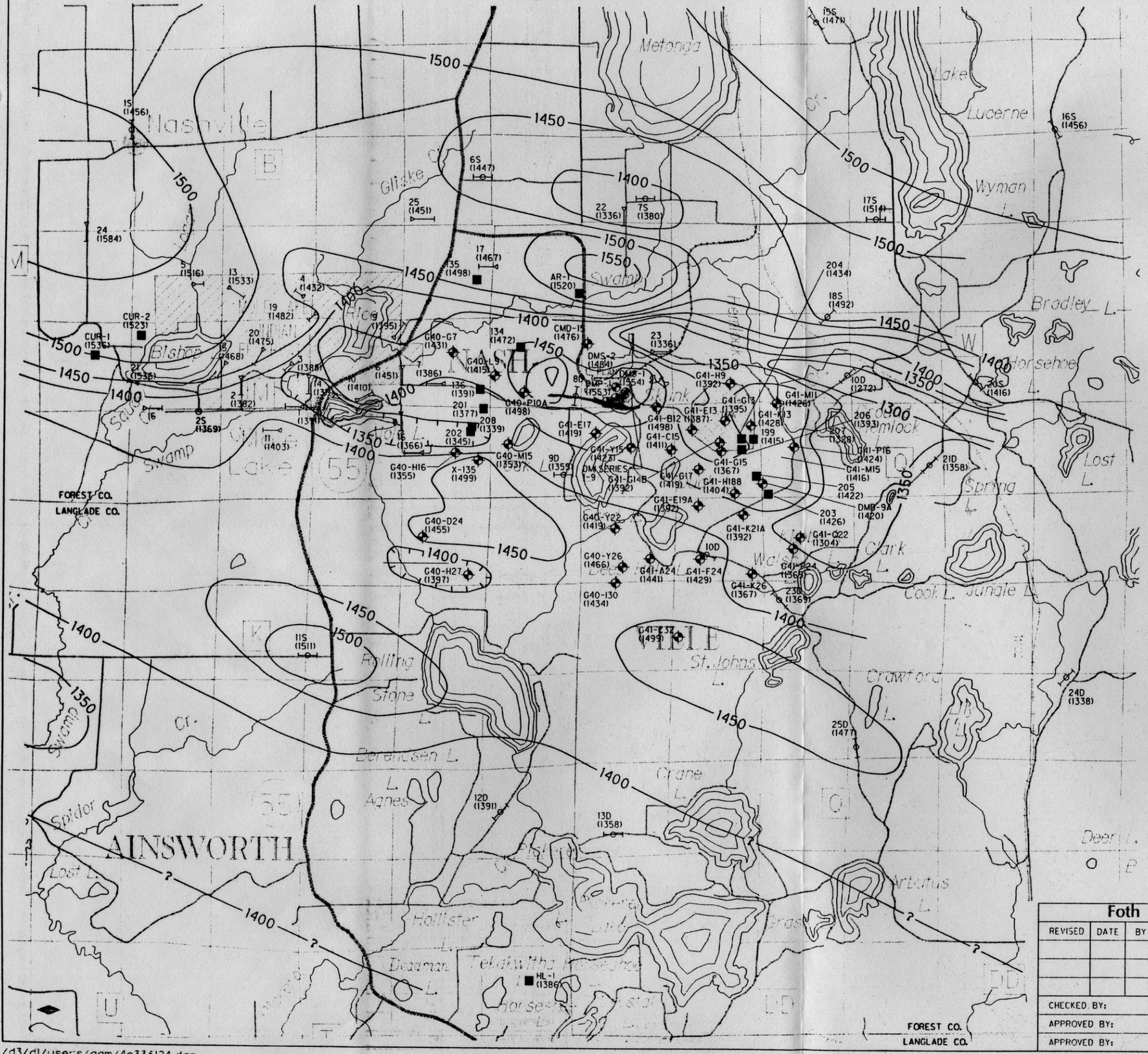
93C049



NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
3. DERIVED FROM GOLDER ASSOCIATES, 1982. GEOHYDROLOGIC CHARACTERIZATION, CRANDON PROJECT

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.5-18

REGIONAL BEDROCK CONTOUR MAP

Scale: 0 3000' 6000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: BSH

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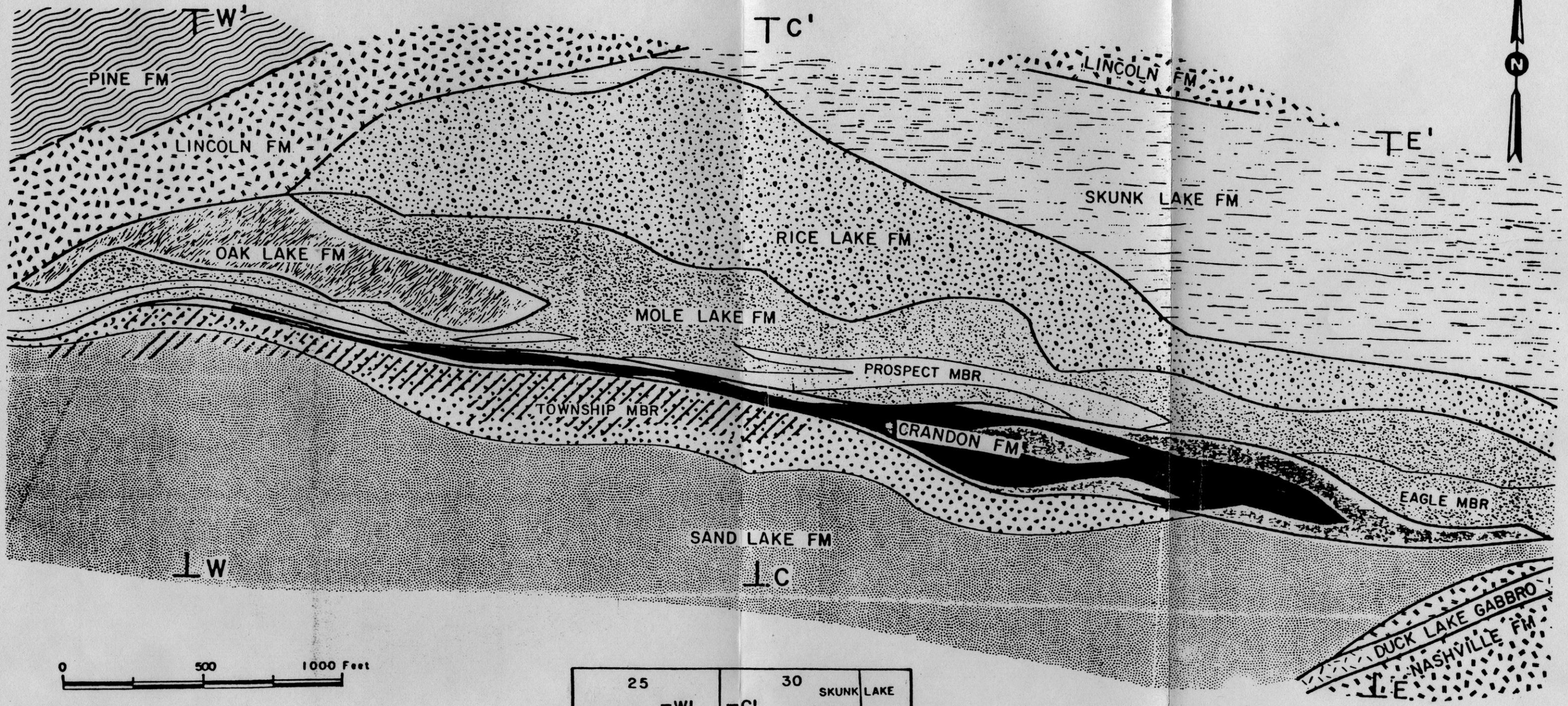
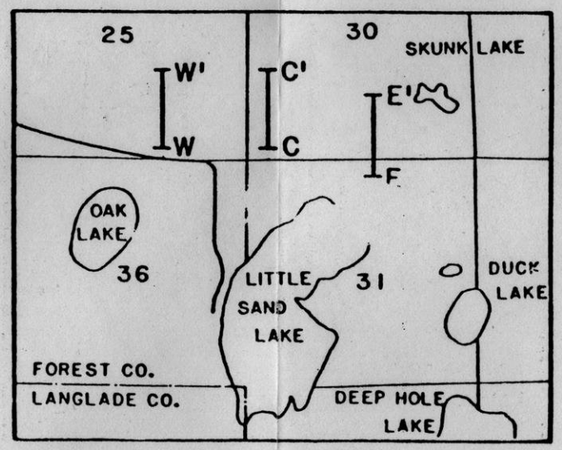
93C049



0 500 1000 Feet

ZINC ORE

COPPER ORE



SOURCE:
CRANDON MINING COMPANY

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE:	MAY'95
APPROVED BY:	SVDI		DATE:	MAY'95
APPROVED BY:	GWS		DATE:	MAY'95

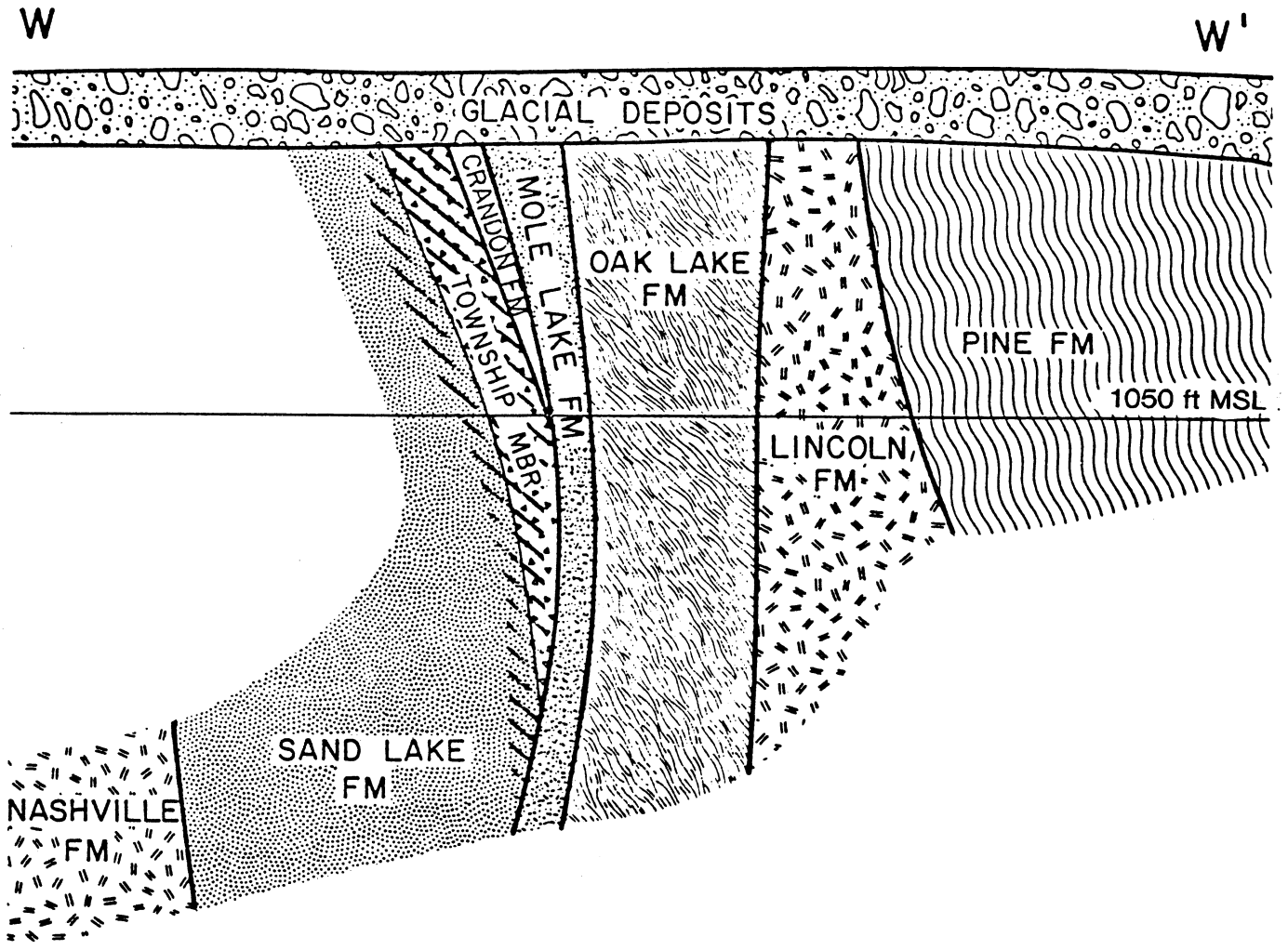
Crandon Mining Company

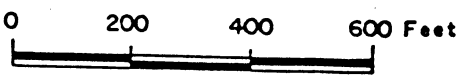
FIGURE 3.5-19
BEDROCK GEOLOGY IN VICINITY OF ORE BODY - PLAN VIEW

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

c:\cadwork\4c33flg.dgn

93C049





COPPER ORE

SOURCE:
CRANDON MINING COMPANY

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

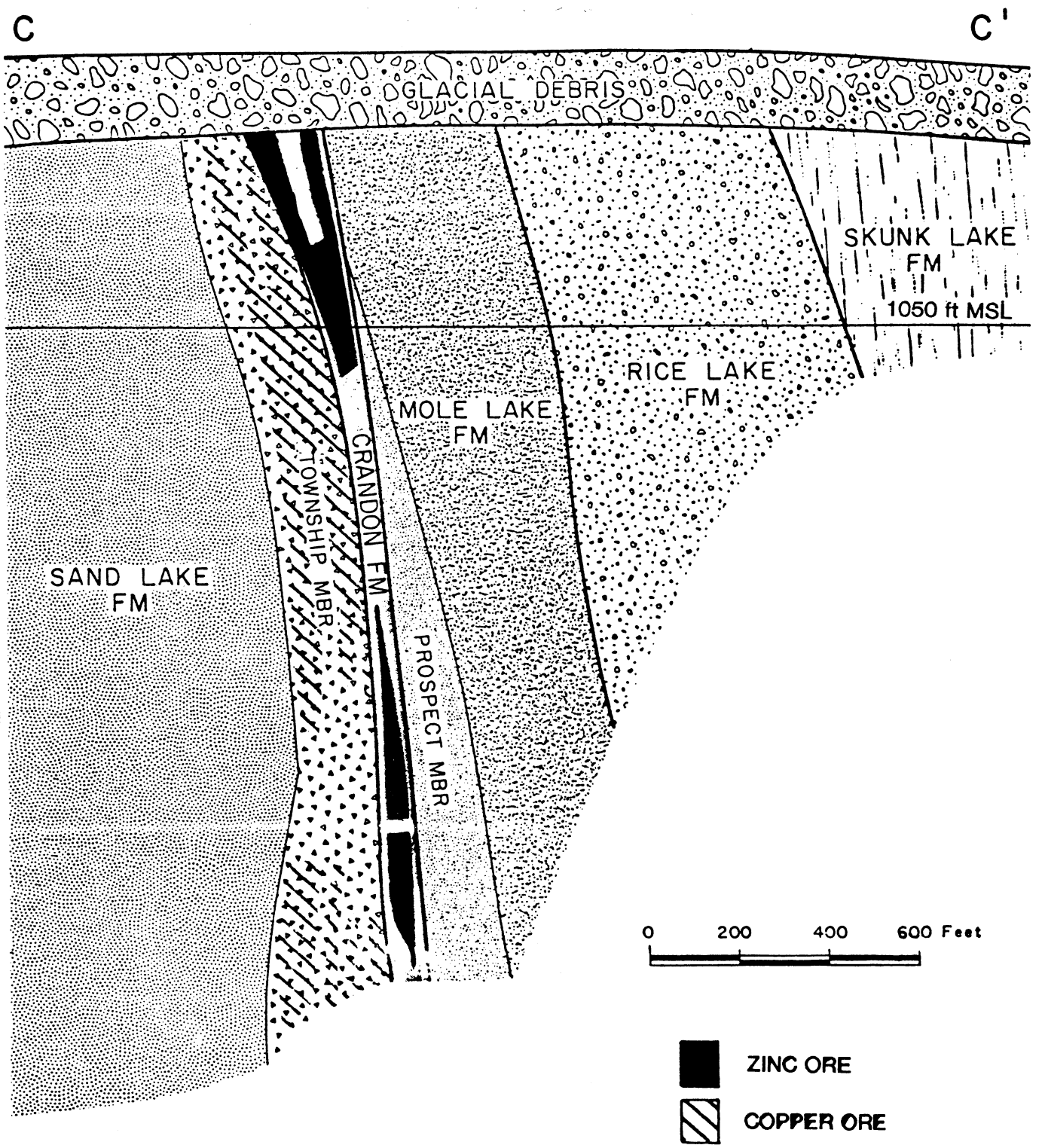
Crandon Mining Company

FIGURE 3.5-20
GENERALIZED ORE BODY
CROSS SECTION W-W'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

c:\cadwork\4c33fig.dgn

93C049



SOURCE:
CRANDON MINING COMPANY

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE:	MAY'95
APPROVED BY:	SVDI		DATE:	MAY'95
APPROVED BY:	GWS		DATE:	MAY'95

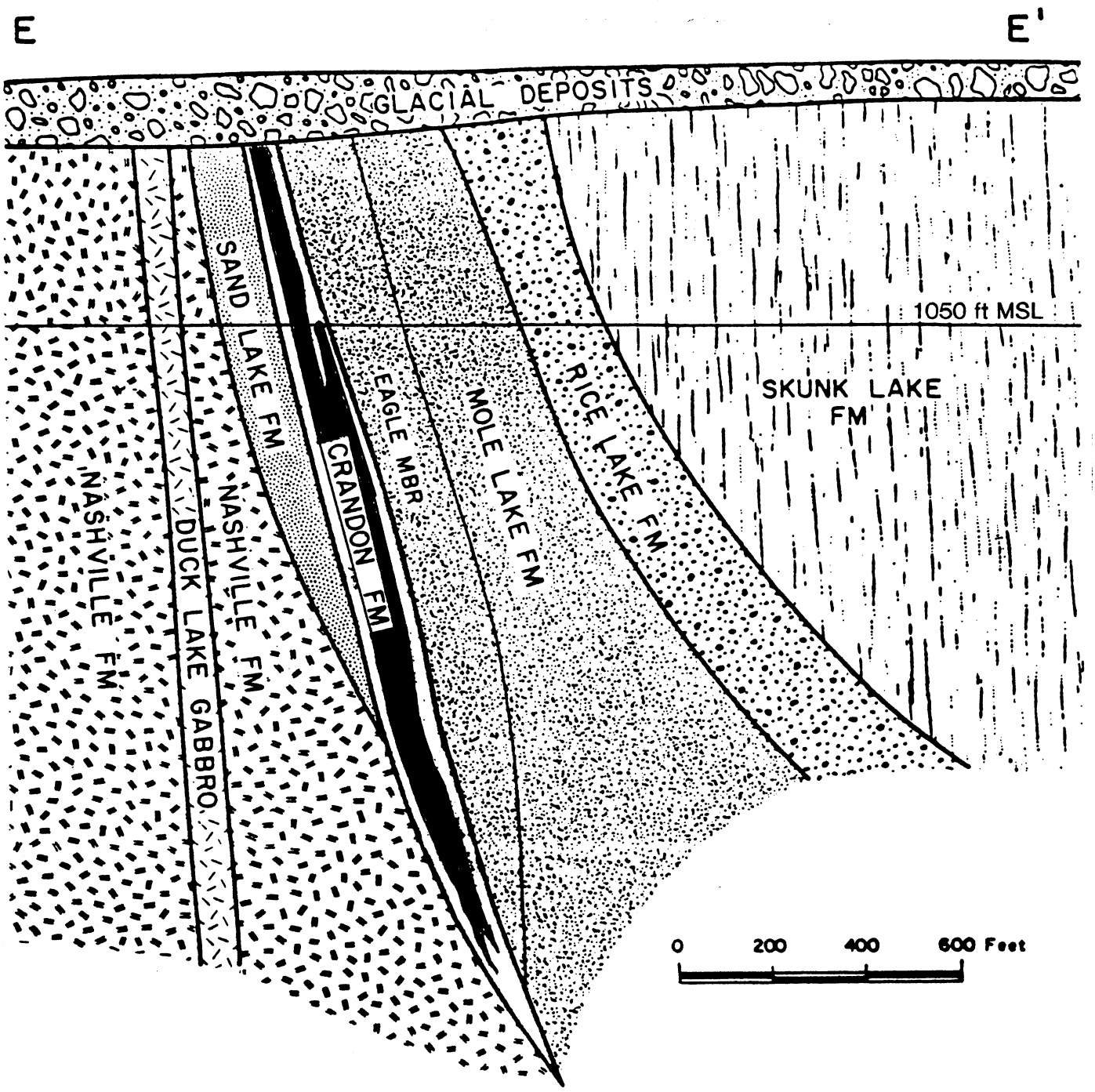
Crandon Mining Company

FIGURE 3.5-21
GENERALIZED ORE BODY
CROSS SECTION C-C'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

c:\cadwork\4c33fig.dgn

93C049



ZINC ORE

SOURCE:
CRANDON MINING COMPANY

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

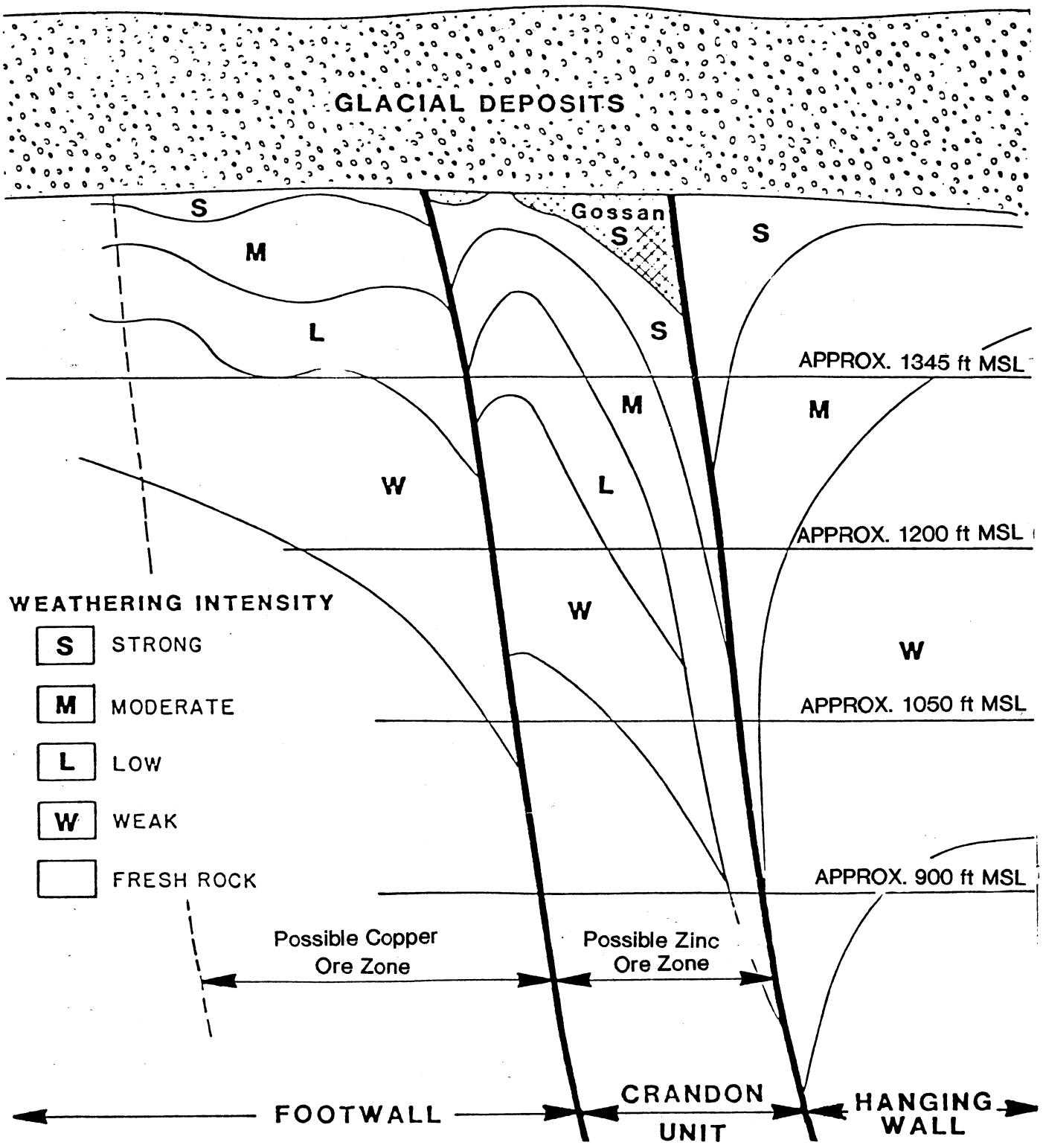
Crandon Mining Company

FIGURE 3.5-22
GENERALIZED ORE BODY
CROSS SECTION E-E'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

c:\cadwork\4c33flg.dgn

93C049



SOURCE:
ROWE, 1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

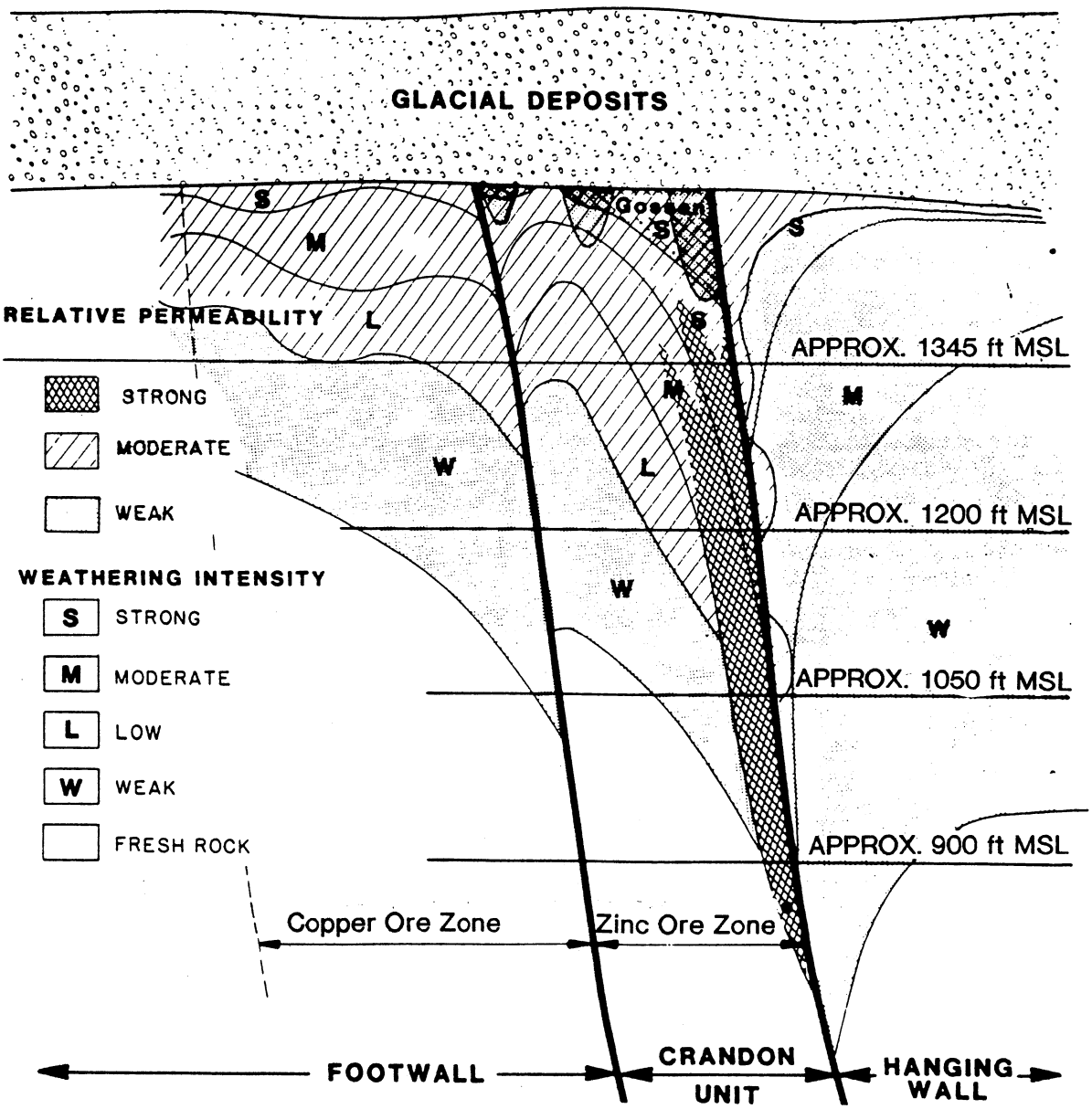
Crandon Mining Company

FIGURE 3.5-23
GENERALIZED WEATHERING PROFILE
OF CRANDON ORE DEPOSIT ROCK

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

/d3/dl/users/jpr1/4c33fig.dgn

93C049



SOURCE:
ROWE, 1984

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE:	MAY'95
APPROVED BY:	SVDI		DATE:	MAY'95
APPROVED BY:	GWS		DATE:	MAY'95

Crandon Mining Company

FIGURE 3.5-24
GENERALIZED PERMEABILITY PROFILE
OF CRANDON DEPOSIT ROCKS

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

/d3/d1/users/jpr1/4c33fig.dgn

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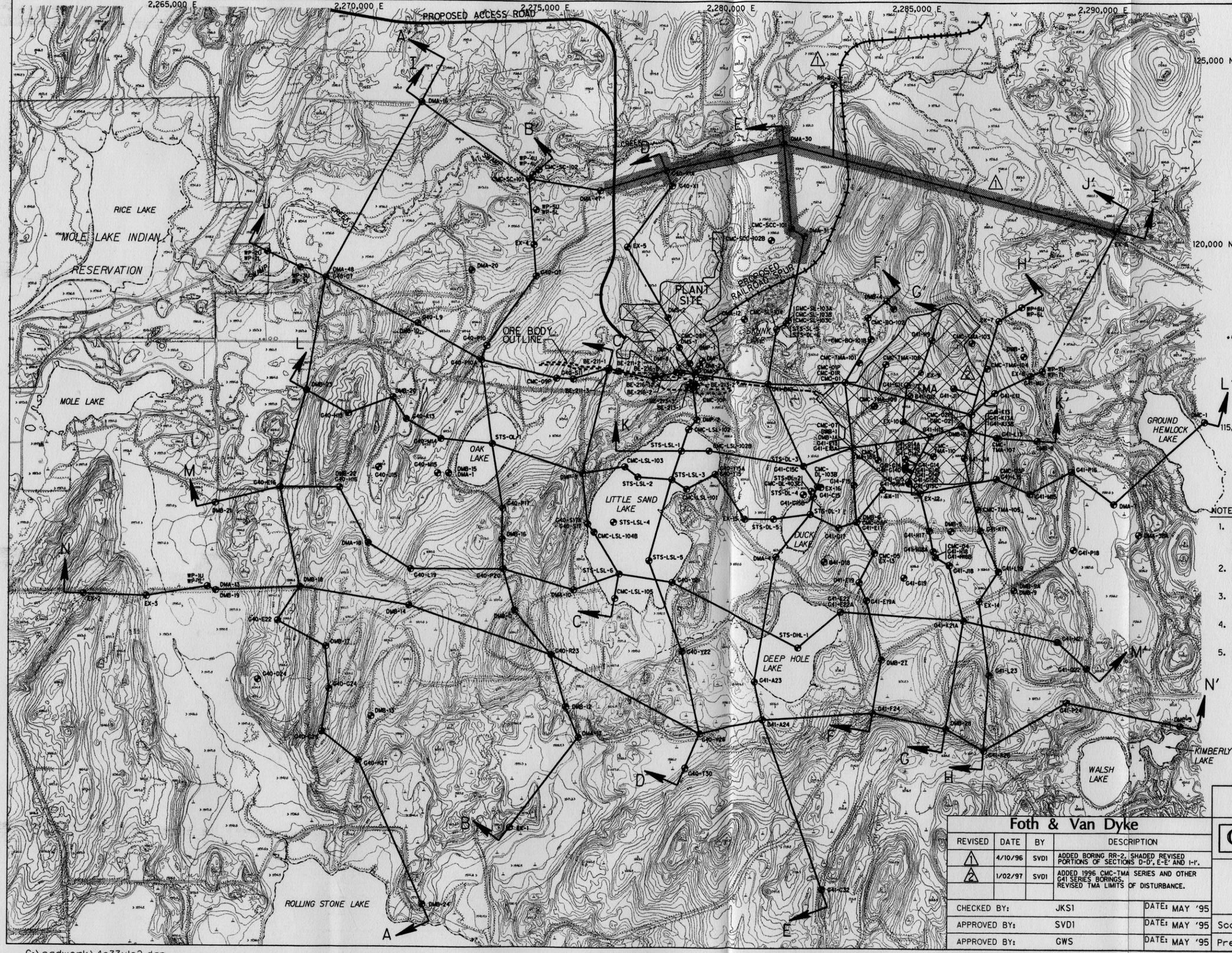

LEGEND

- 1600 — EXISTING CONTOUR
- TREES/BRUSH
- x 1677.0 — SPOT ELEVATION
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- CREEK/LAKE/WATERWAY
- DMB-20 — BORINGS CONSIDERED IN DRAFTING GEOLOGIC CROSS SECTIONS
- A ——— A' — GEOLOGIC CROSS SECTION LOCATION
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- AREA OF REVISED GEOLOGIC CROSS SECTION

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1250' 2500'
SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	4/10/96	SVD1	ADDED BORING RR-2. SHADED REVISED PORTIONS OF SECTIONS D-D', E-E' AND I-I'.
2	1/02/97	SVD1	ADDED 1996 CMC-TMA SERIES AND OTHER G41 SERIES BORINGS. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-25
GLACIAL OVERBURDEN
CROSS SECTION LOCATION MAP

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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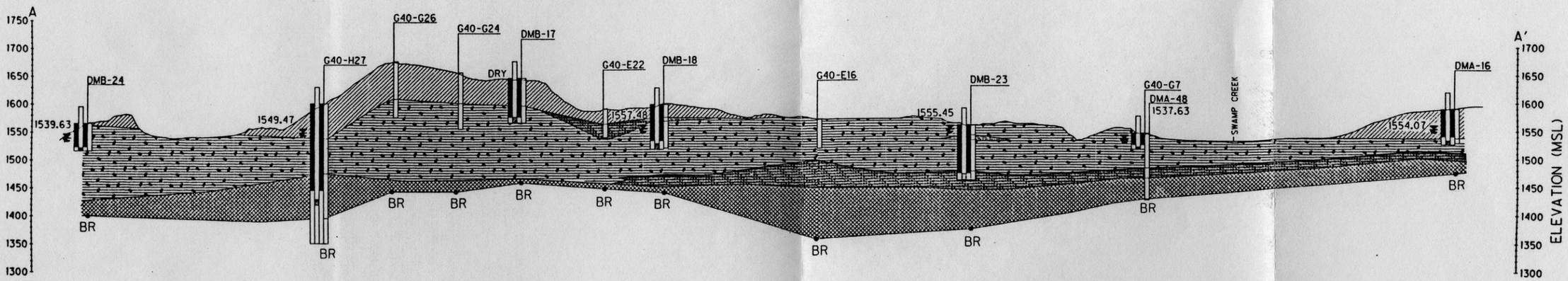
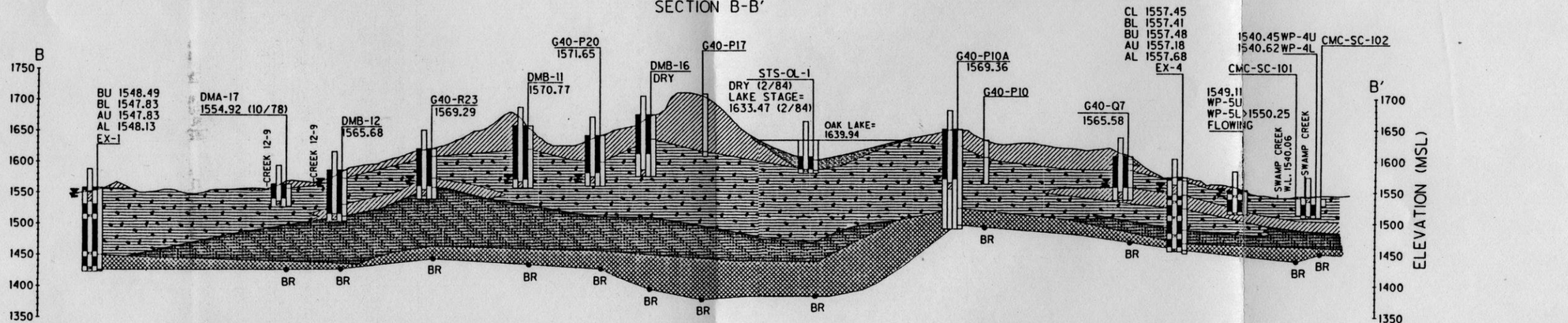
93C049

SECTION A-A'

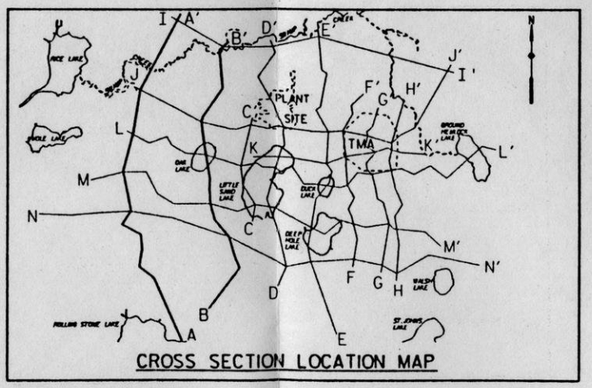


SECTION B-B'



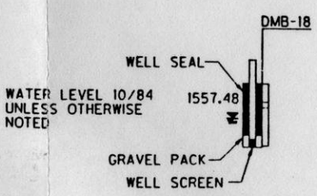
LEGEND

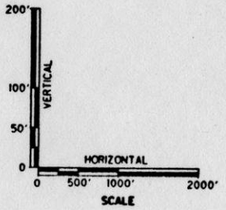
- Qtl UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
- Qowf FINE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND SILT OF WISCONSINAN AGE
- Qowl COARSE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND GRAVEL OF WISCONSINAN AGE
- INFERRED GEOLOGIC CONTACT
- Ql LACUSTRINE DEPOSITS — GLACIO-LACUSTRINE, RHYMETRICALLY BEDDED, SILT AND CLAY WITH MINOR AMOUNTS OF SAND OF WISCONSINAN, HOLOCENC AND RECENT AGE.
- Qhlc ICE-CONTACT DEPOSITS — ABLATION TILL, FLOW TILL, GLACIO-FLUVIAL SILT, CLAY AND SAND OF WISCONSINAN AGE
- Ms MASSIVE SAPROLITE — UNSTRUCTURED CLAY, SILT AND SAND. HIGHLY WEATHERED BEDROCK
- Ss STRUCTURED SAPROLITE BEDROCK — CLAY, SILT AND SAND WITH RELIC BEDROCK STRUCTURES, PARTLY WEATHERED BEDROCK
- PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM





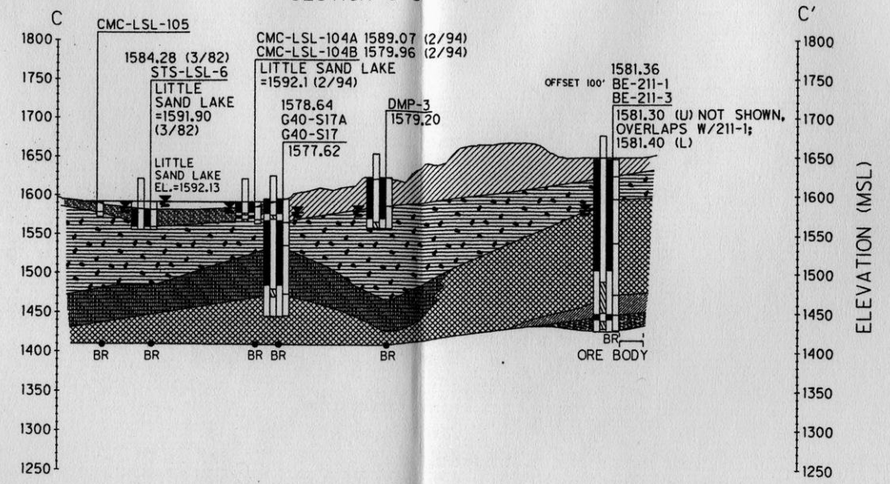
Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY:		JKSI	DATE: MAY '95
APPROVED BY:		SVDI	DATE: MAY '95
APPROVED BY:		GWS	DATE: MAY '95

Crandon Mining Company

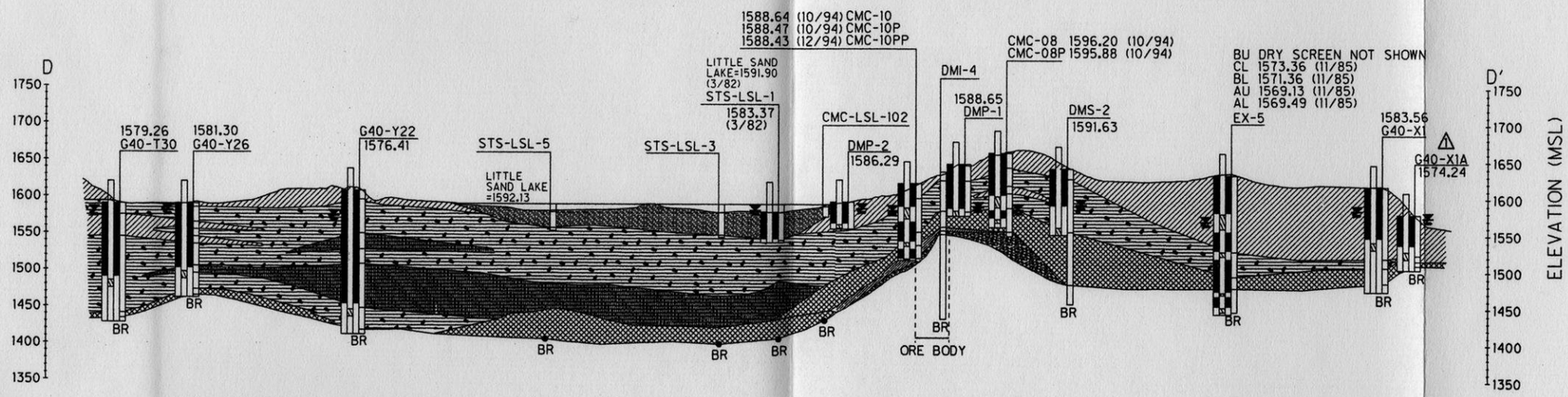
FIGURE 3.5-26
GEOLOGIC CROSS SECTIONS
A-A' AND B-B'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

SECTION C-C'



SECTION D-D'



LEGEND

- Qtl UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
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- Qowl COARSE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND GRAVEL OF WISCONSINAN AGE
- INFERRED GEOLOGIC CONTACT
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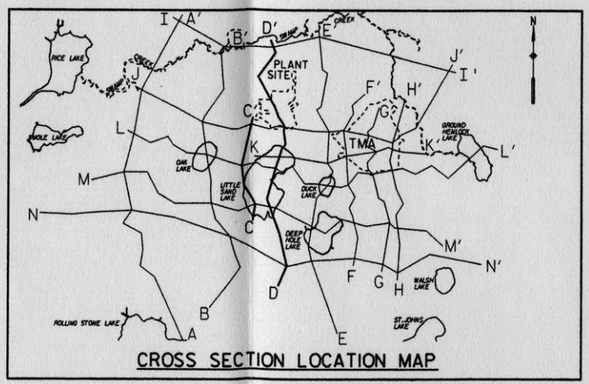
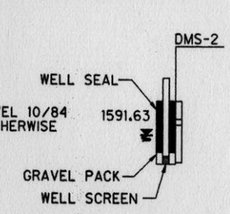
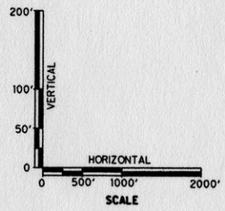
- BR PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- BR INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM





Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
⚠	4/19/96	SVD1	REVISED SECTION D-D' @ G40-X1A REVISED CORRELATIONS

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-27
GEOLOGIC CROSS SECTIONS
C-C' AND D-D'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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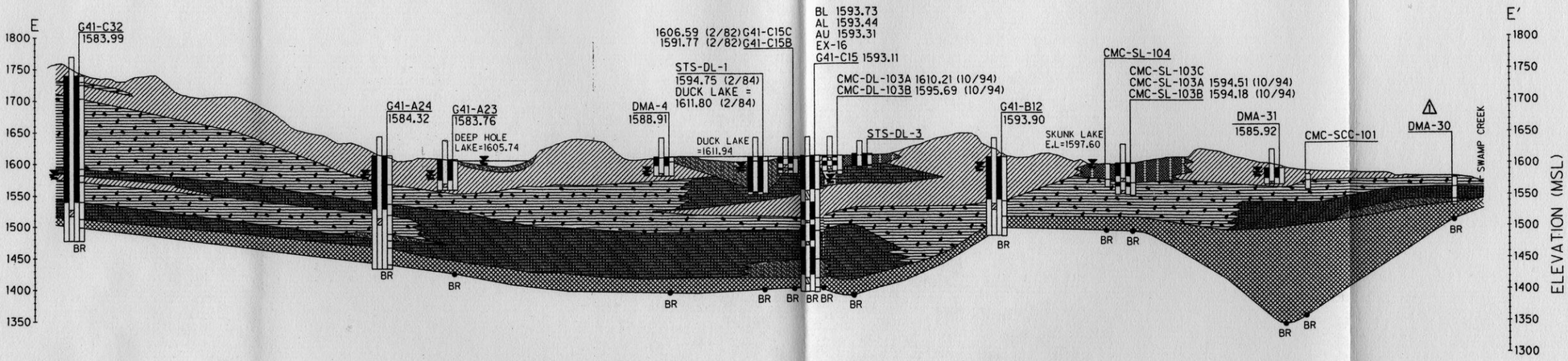
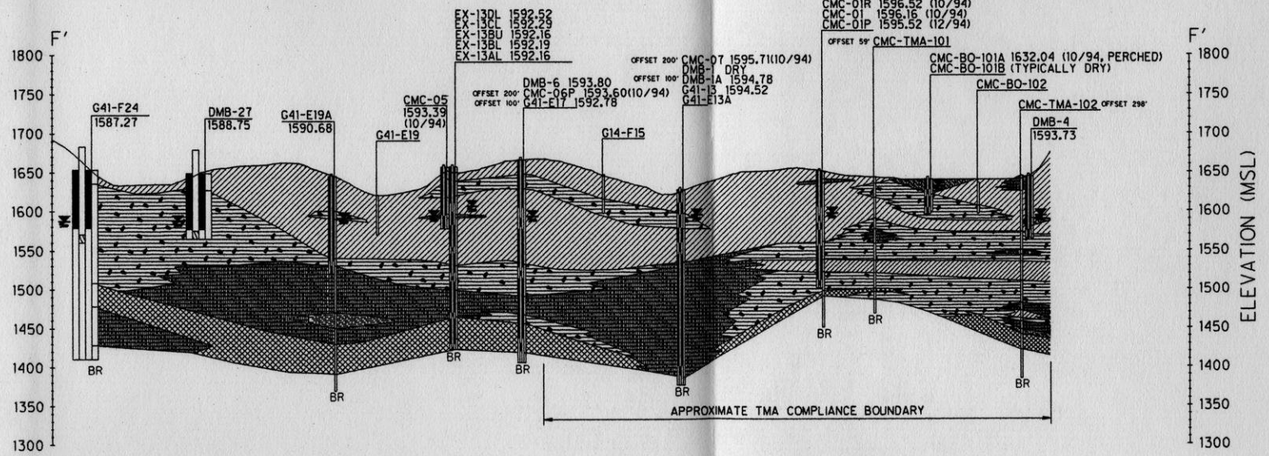
SECTION E-E'



SECTION F-F' ⚠2



LEGEND

- Qtl UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
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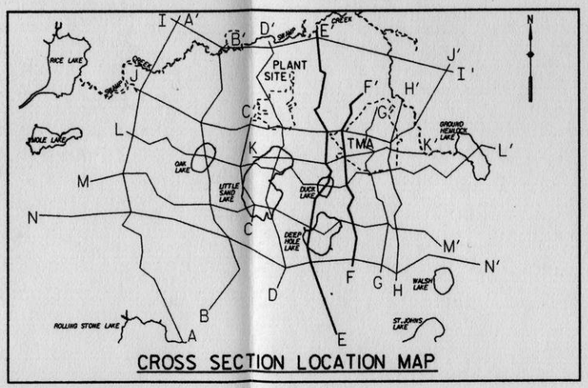
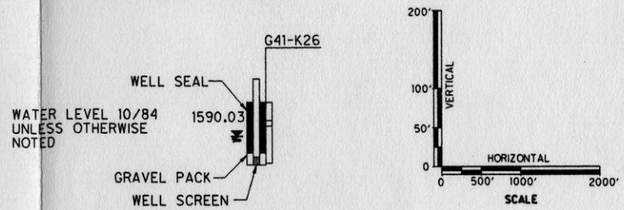
- BR PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- BR INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
⚠1	4/19/96	SVD1	REVISED SECTION F-F' & DMA-30, REVISED CORRELATION
⚠2	1/02/97	SVD1	ADDED 1996 CMC-TMA SERIES BORINGS TO SECTION F-F'

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-28
GEOLOGIC CROSS SECTIONS
E-E' AND F-F'

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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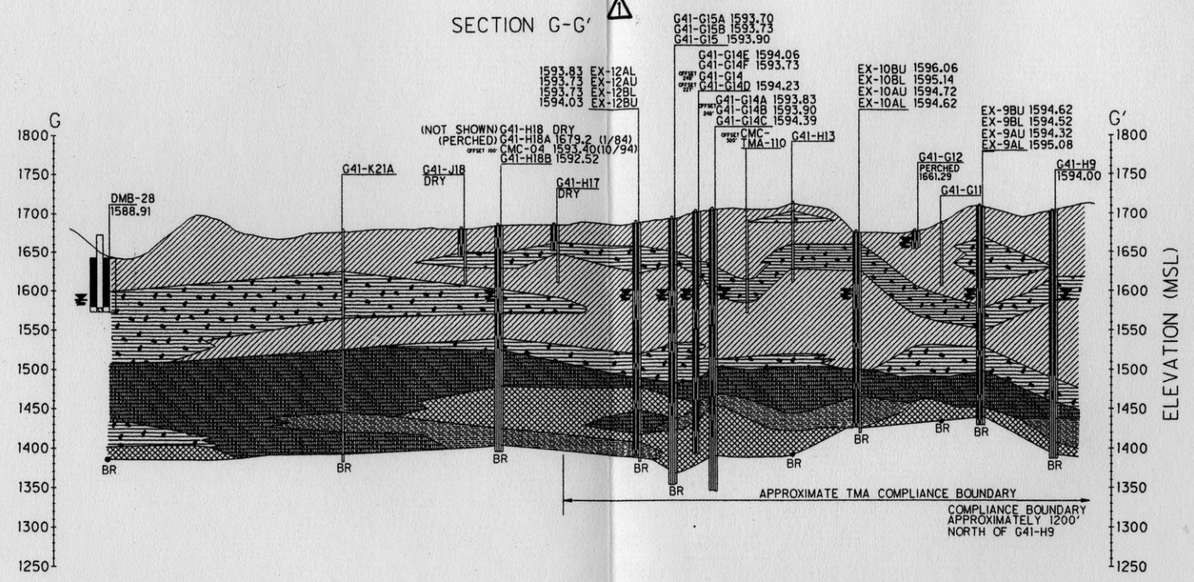
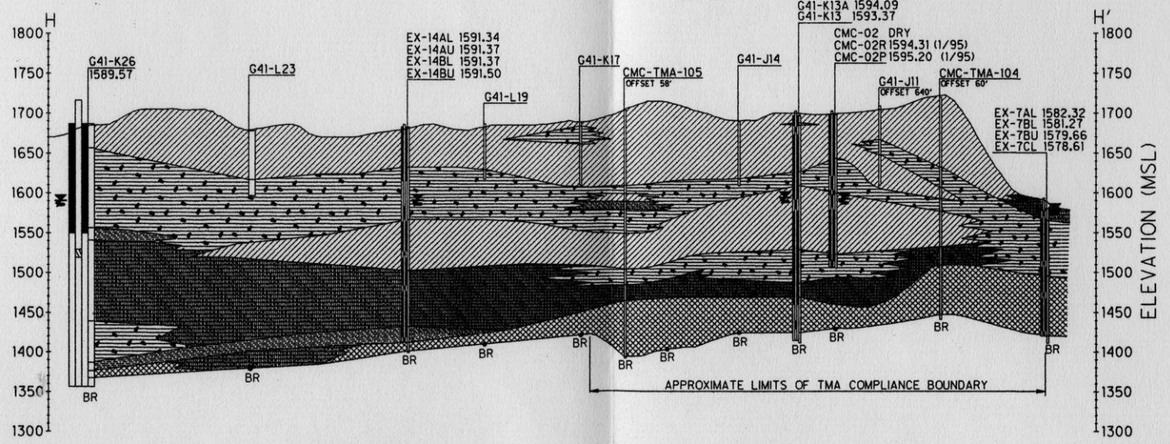
SECTION G-G'



SECTION H-H'



LEGEND

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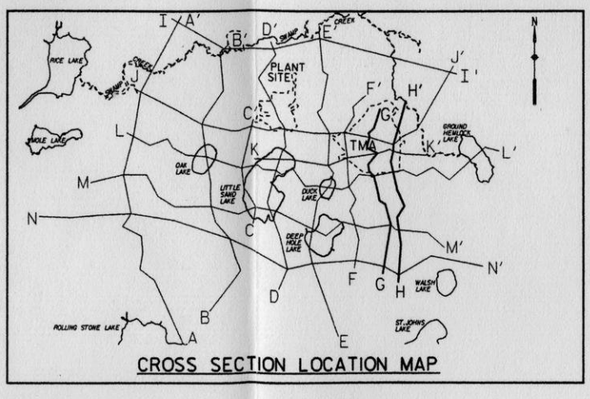
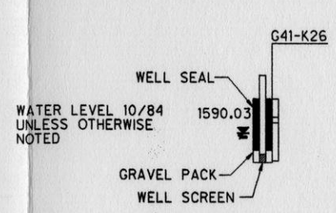


CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	1/02/97	SVD1	ADDED 1996 CMC-TMA AND G41-G14, G41-G12 SERIES BORINGS AND G41-J11
CHECKED BY:		JKS1	DATE: MAY '95
APPROVED BY:		SVD1	DATE: MAY '95
APPROVED BY:		GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-29
GEOLOGIC CROSS SECTIONS
G-G' AND H-H'

Scale: AS SHOWN	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: BSH

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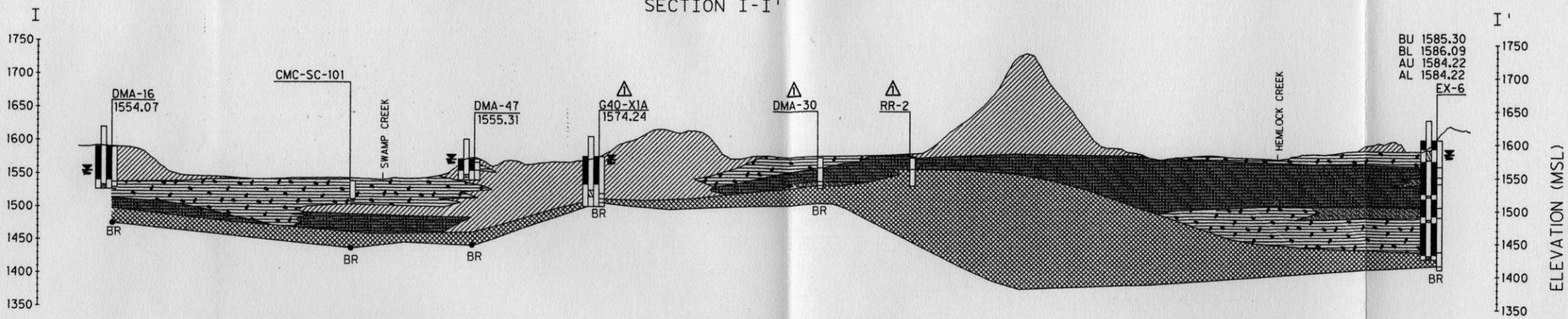
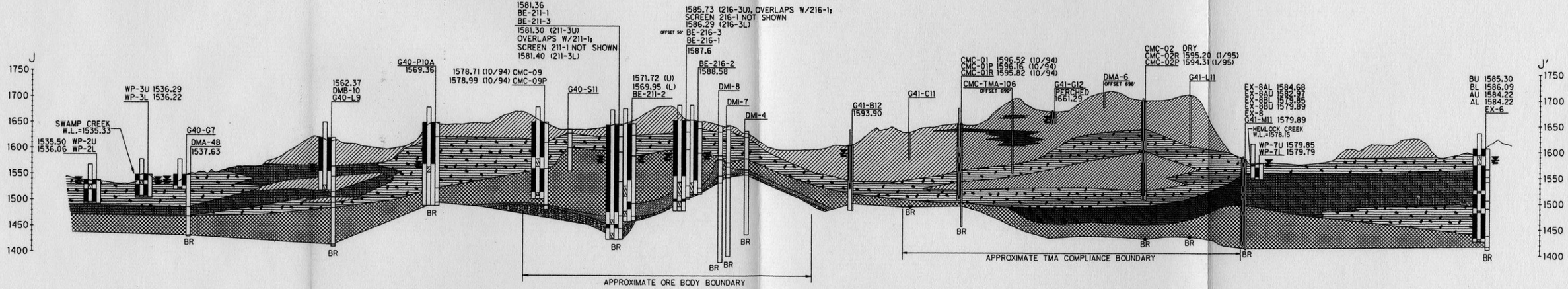
93C049

SECTION I-I'

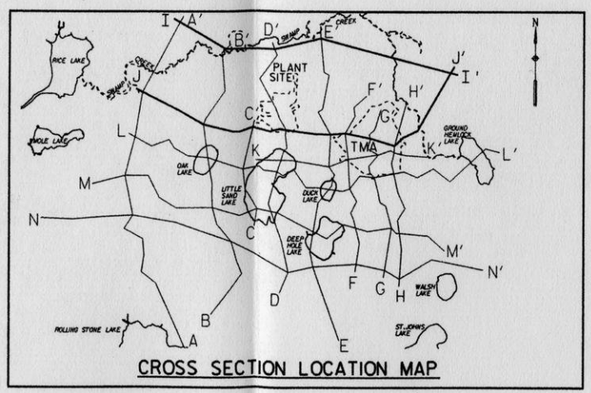


SECTION J-J'



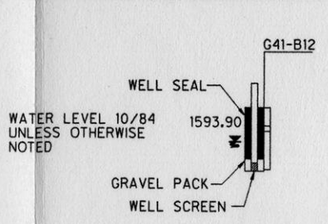
LEGEND

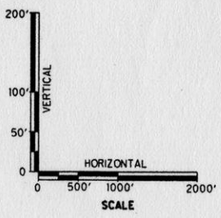
- Qtl UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
- Qowf FINE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND SILT OF WISCONSINAN AGE
- Qowl COARSE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND GRAVEL OF WISCONSINAN AGE
- INFERRED GEOLOGIC CONTACT
- Ql LACUSTRINE DEPOSITS — GLACIO-LACUSTRINE, RHYMETRICALLY BEDDED, SILT AND CLAY WITH MINOR AMOUNTS OF SAND OF WISCONSINAN, HOLOCENC AND RECENT AGE.
- Qhlc ICE-CONTACT DEPOSITS — ABLATION TILL, FLOW TILL, GLACIO-FLUVIAL SILT, CLAY AND SAND OF WISCONSINAN AGE
- Ms MASSIVE SAPROLITE — UNSTRUCTURED CLAY, SILT AND SAND, HIGHLY WEATHERED BEDROCK
- Ss STRUCTURED SAPROLITE BEDROCK — CLAY, SILT AND SAND WITH RELIC BEDROCK STRUCTURES, PARTLY WEATHERED BEDROCK
- BR PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- BR INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM





Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	4/10/96	SVD1	REVISED SECTION I-I' AT DMA-30, G40-X1A, ADDED RR-2, REVISED CORRELATION, CORRECTED WATER LEVELS AT BE-211-2U, -2L
2	1/02/97	SVD1	ADDED 1996 CMC-TMA SERIES BORINGS, G41-G12 AND DMA-6 TO J-J'
CHECKED BY:		JKS1	DATE: APR. '96
APPROVED BY:		SVD1	DATE: APR. '96
APPROVED BY:		GWS	DATE: APR. '96

Crandon Mining Company

FIGURE 3.5-30
GEOLOGIC CROSS SECTIONS
I-I' AND J-J'

Scale: AS SHOWN | Date: APRIL, 1996
Prepared By: Foth & Van Dyke | By: JOW

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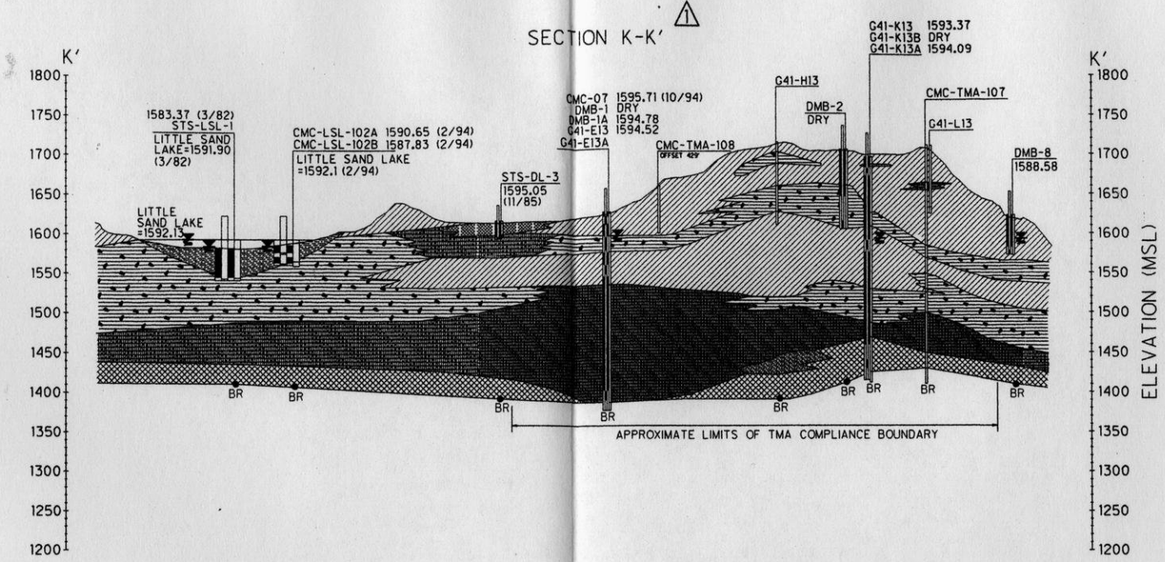
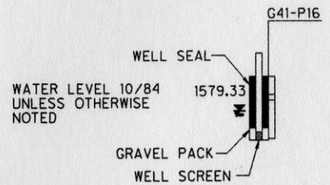
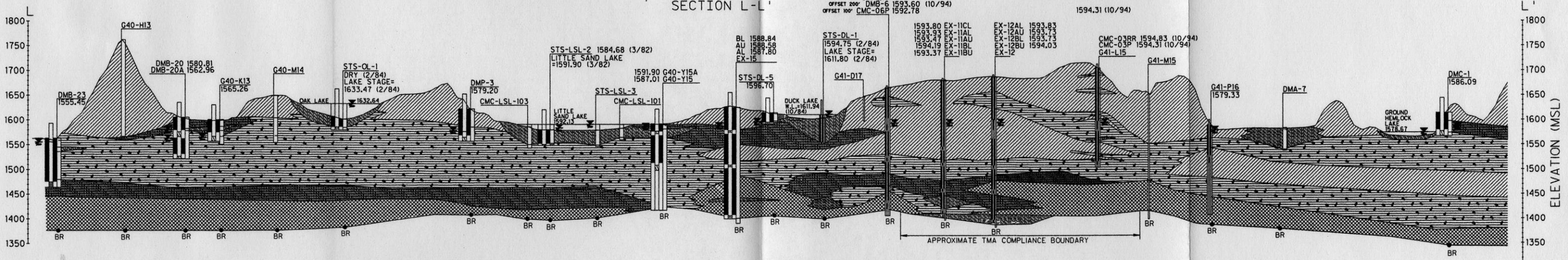
SECTION K-K'



WELL CONSTRUCTION DIAGRAM

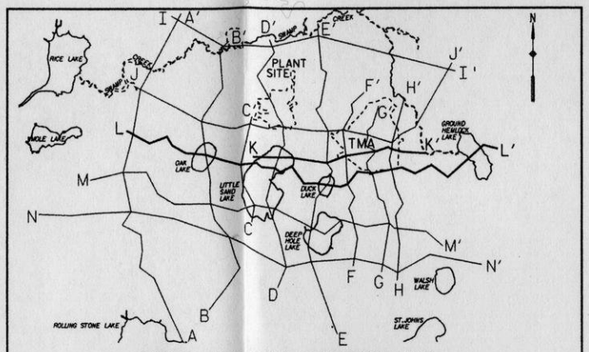


SECTION L-L'

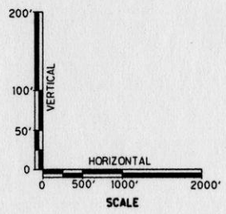


LEGEND

- Qtl UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
- Qowf FINE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND SILT OF WISCONSINAN AGE
- Qowl COARSE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND GRAVEL OF WISCONSINAN AGE
- INFERRED GEOLOGIC CONTACT
- Ql LACUSTRINE DEPOSITS — GLACIO-LACUSTRINE, RHYMETRICALLY BEDDED, SILT AND CLAY WITH MINOR AMOUNTS OF SAND OF WISCONSINAN, HOLOCENC AND RECENT AGE.
- Qhlc ICE-CONTACT DEPOSITS — ABLATION TILL, FLOW TILL, GLACIO-FLUVIAL SILT, CLAY AND SAND OF WISCONSINAN AGE
- Ms MASSIVE SAPROLITE — UNSTRUCTURED CLAY, SILT AND SAND, HIGHLY WEATHERED BEDROCK
- Ss STRUCTURED SAPROLITE BEDROCK — CLAY, SILT AND SAND WITH RELIC BEDROCK STRUCTURES, PARTLY WEATHERED BEDROCK
- PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- BR — INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP



Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
1	1/02/97	SVD1	ADDED 1996 CMC-TMA SERIES BORINGS TO K-K'	
CHECKED BY:		JKS1		DATE: MAY '95
APPROVED BY:		SVD1		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-31
GEOLOGIC CROSS SECTIONS
K-K' AND L-L'

Scale: AS SHOWN | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: BSH

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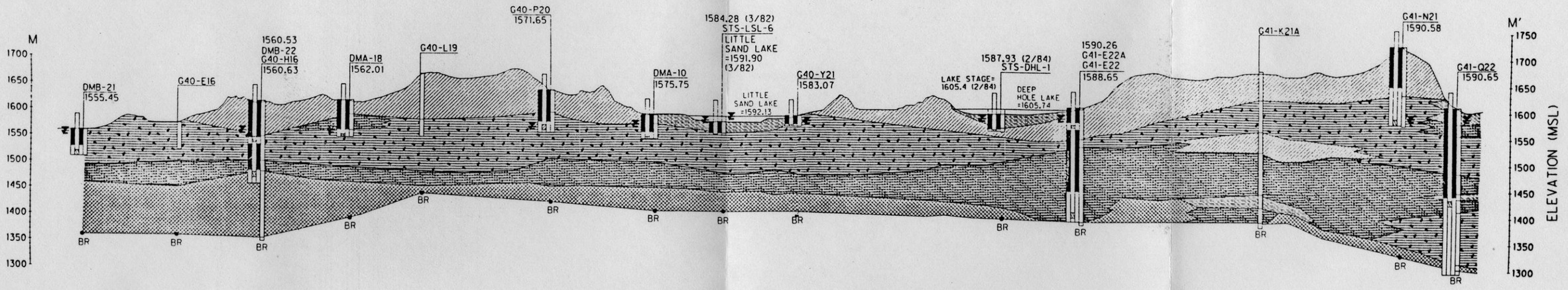
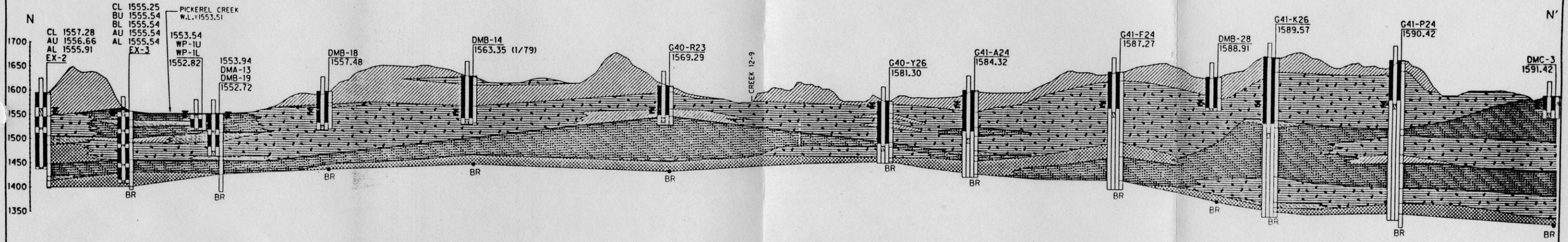
SECTION M-M'

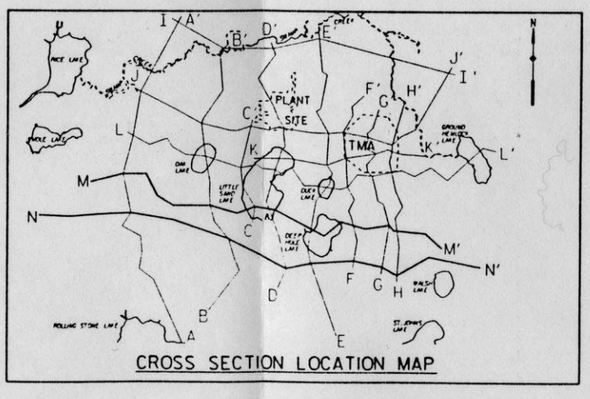


SECTION N-N'



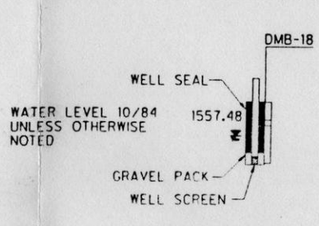
LEGEND

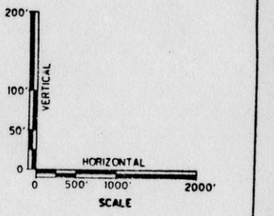
- Qt UNDIFFERENTIATED LATE WISCONSINAN TILL — NASHVILLE MEMBER, COPPER FALLS FORMATION AND THE MAPLEVILLE MEMBER, HORICON FORMATION
- Qte UNDIFFERENTIATED EARLY-WISCONSINAN-TILL AND PRE-WISCONSIN TILL — MARATHON AND LINCOLN FORMATIONS, MAY INCLUDE MASSIVE SAPROLITE
- Qowf FINE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND SILT OF WISCONSINAN AGE
- Qowl COARSE-GRAINED OUTWASH DEPOSITS — GLACIAL FLUVIAL STRATIFIED SAND AND GRAVEL OF WISCONSINAN AGE
- INFERRED GEOLOGIC CONTACT
- Ql LACUSTRINE DEPOSITS — GLACIO-LACUSTRINE, RHYMETRICALLY BEDDED, SILT AND CLAY WITH MINOR AMOUNTS OF SAND OF WISCONSINAN, HOLOCENC AND RECENT AGE.
- Qhlc ICE-CONTACT DEPOSITS — ABLATION TILL, FLOW TILL, GLACIO-FLUVIAL SILT, CLAY AND SAND OF WISCONSINAN AGE
- Ms MASSIVE SAPROLITE — UNSTRUCTURED CLAY, SILT AND SAND, HIGHLY WEATHERED BEDROCK
- Ss STRUCTURED SAPROLITE BEDROCK — CLAY, SILT AND SAND WITH RELIC BEDROCK STRUCTURES, PARTLY WEATHERED BEDROCK
- PCu UNDIFFERENTIATED BEDROCK — PRECAMBRIAN METAVOLCANIC BEDROCK, MAY INCLUDE STRUCTURED SAPROLITE
- BR INFERRED UNDIFFERENTIATED BEDROCK ELEVATION BASED UPON STS 1984 BEDROCK ELEVATION MAP



CROSS SECTION LOCATION MAP

WELL CONSTRUCTION DIAGRAM





Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY:	JKS1	DATE: MAY '95	
APPROVED BY:	SVD1	DATE: MAY '95	
APPROVED BY:	GWS	DATE: MAY '95	

Crandon Mining Company

FIGURE 3.5-32
GEOLOGIC CROSS SECTIONS
M-M' AND N-N'

Scale: AS SHOWN	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: BSH

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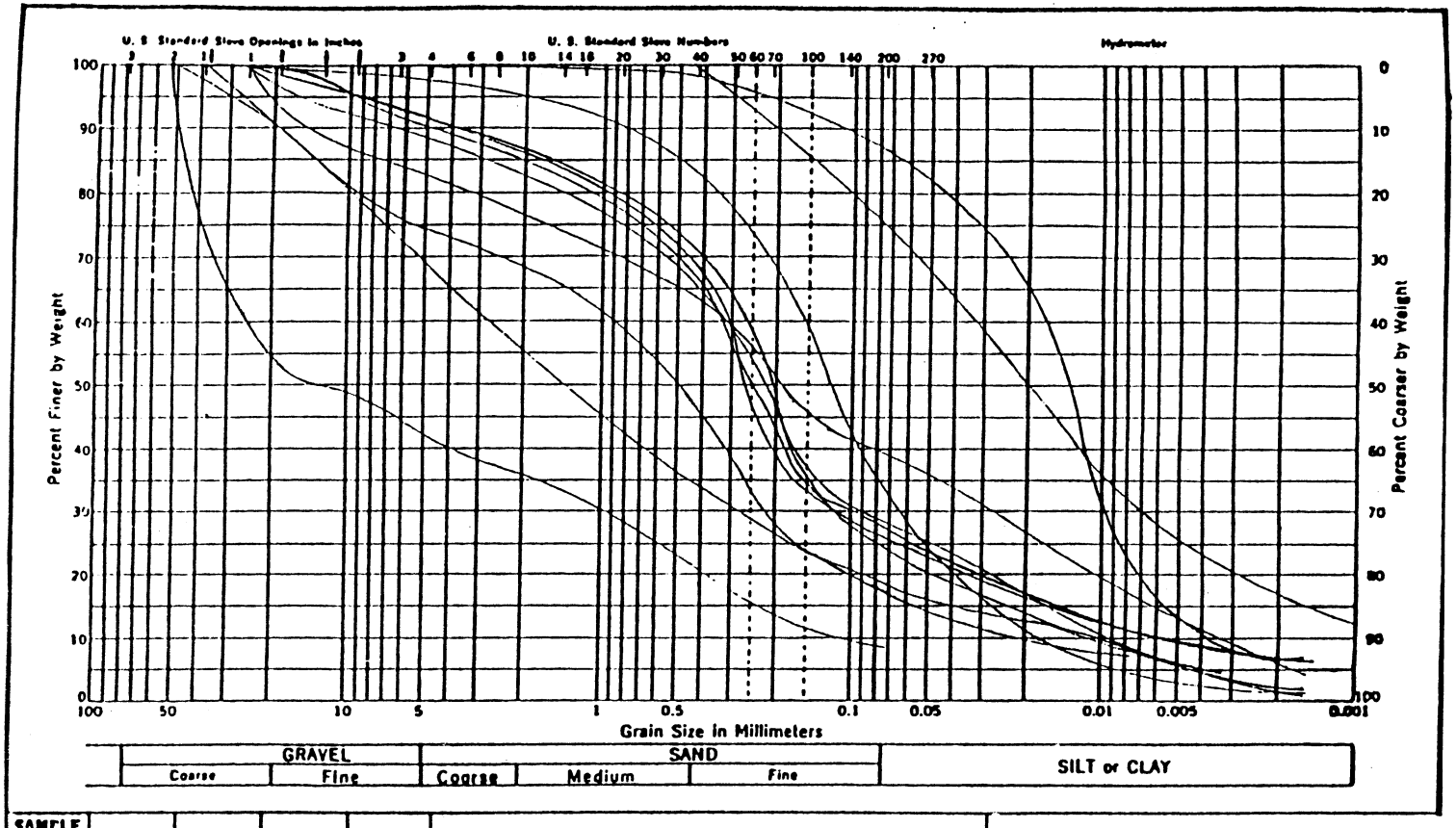
UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					PRE- TO EARLY WISCONSINAN TILL

REFERENCE: STS-1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-33

REPRESENTATIVE GRAIN SIZE CURVES
PRE-TO EARLY WISCONSINAN TILL

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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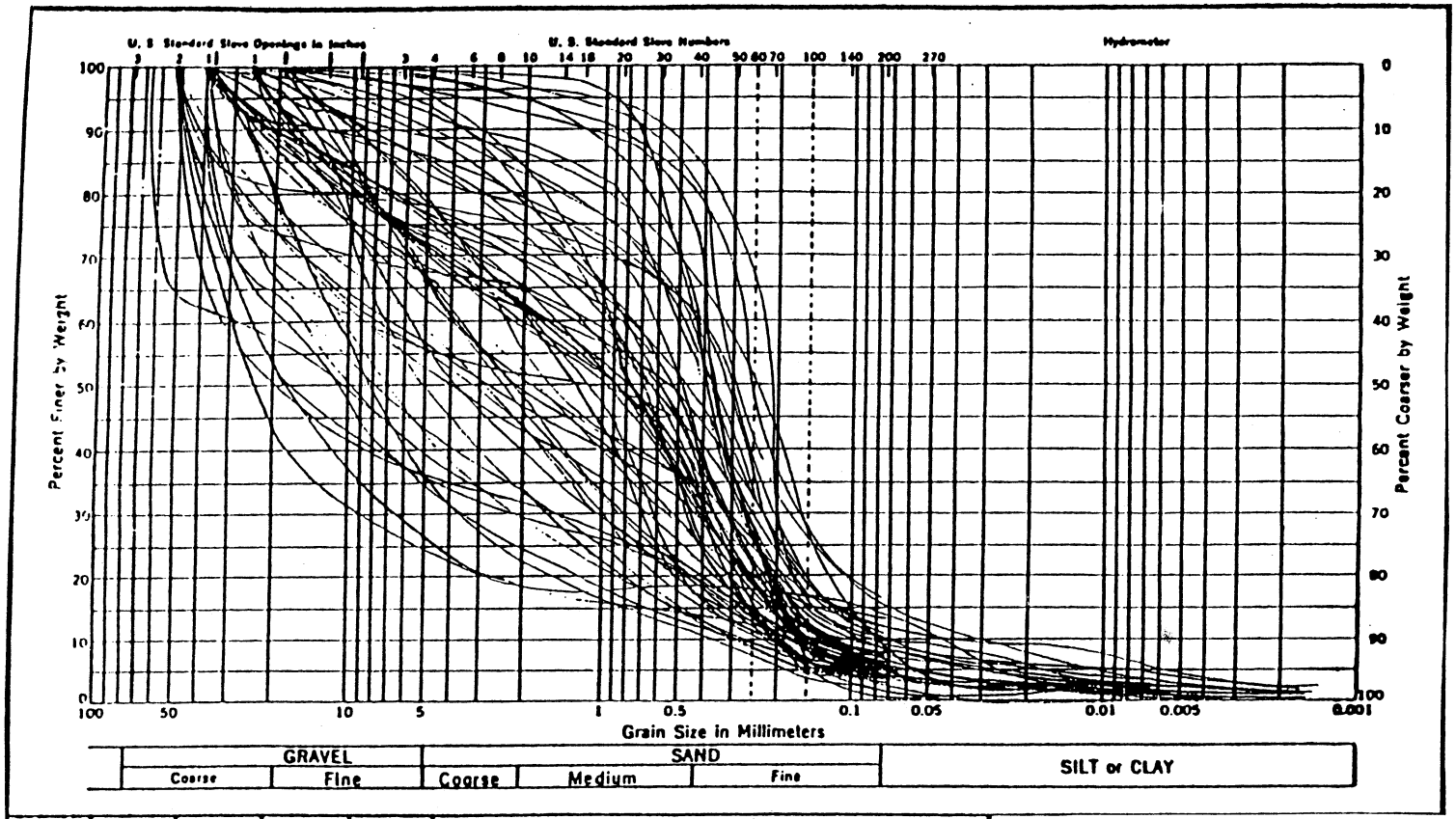
UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					COARSE GRAINED OUTWASH
					SP, SW, SM-SP, SM, GP-GM, GP, GW, GM

REFERENCE: STS-1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-34

REPRESENTATIVE GRAIN SIZE CURVES OF COARSE GRAINED OUTWASH DEPOSITS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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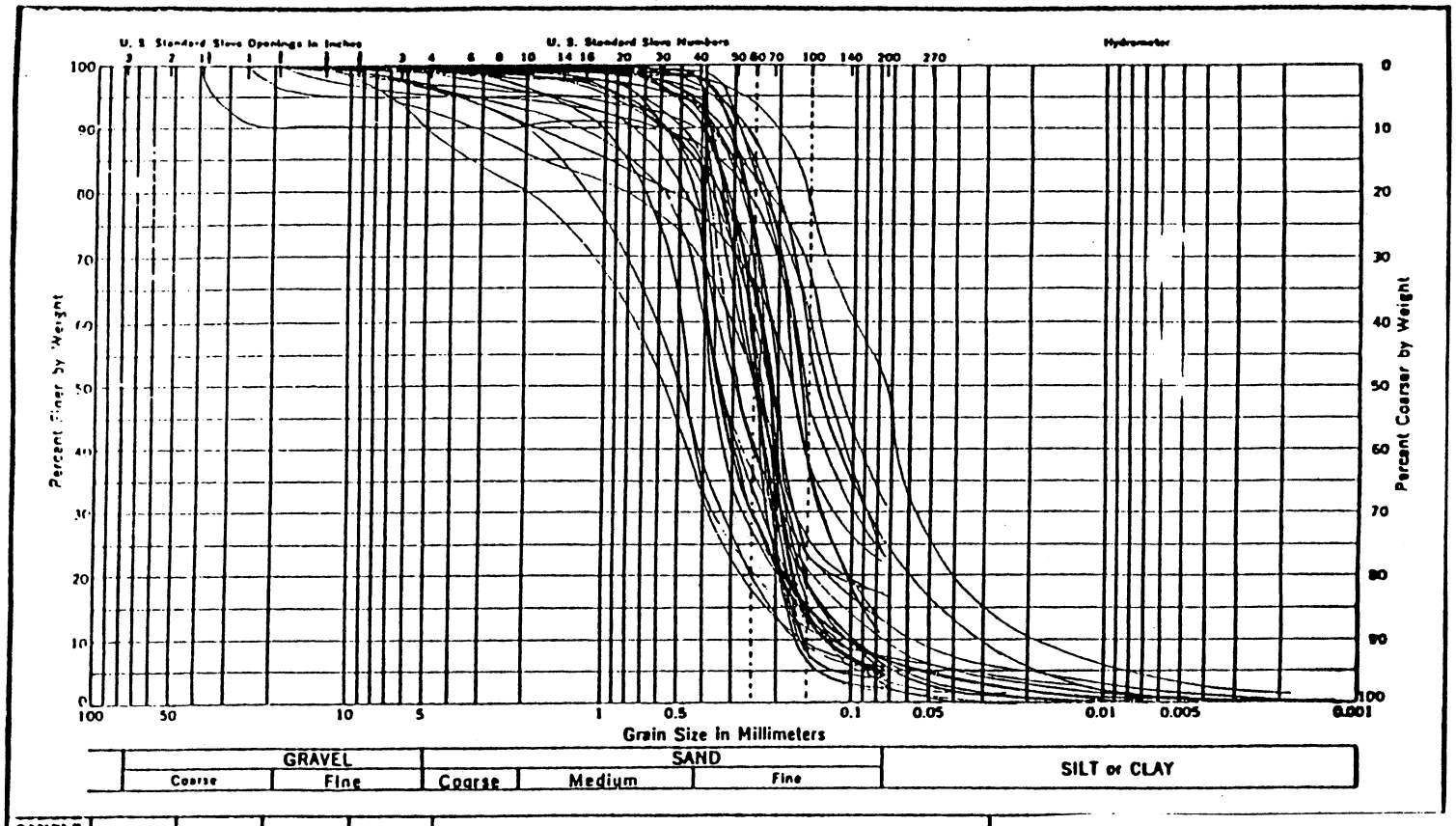
UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					FINE GRAINED OUTWASH
					SP, SM-SP, SM, ML

REFERENCE: STS-1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-35

REPRESENTATIVE GRAIN SIZE CURVES OF FINE GRAINED OUTWASH DEPOSITS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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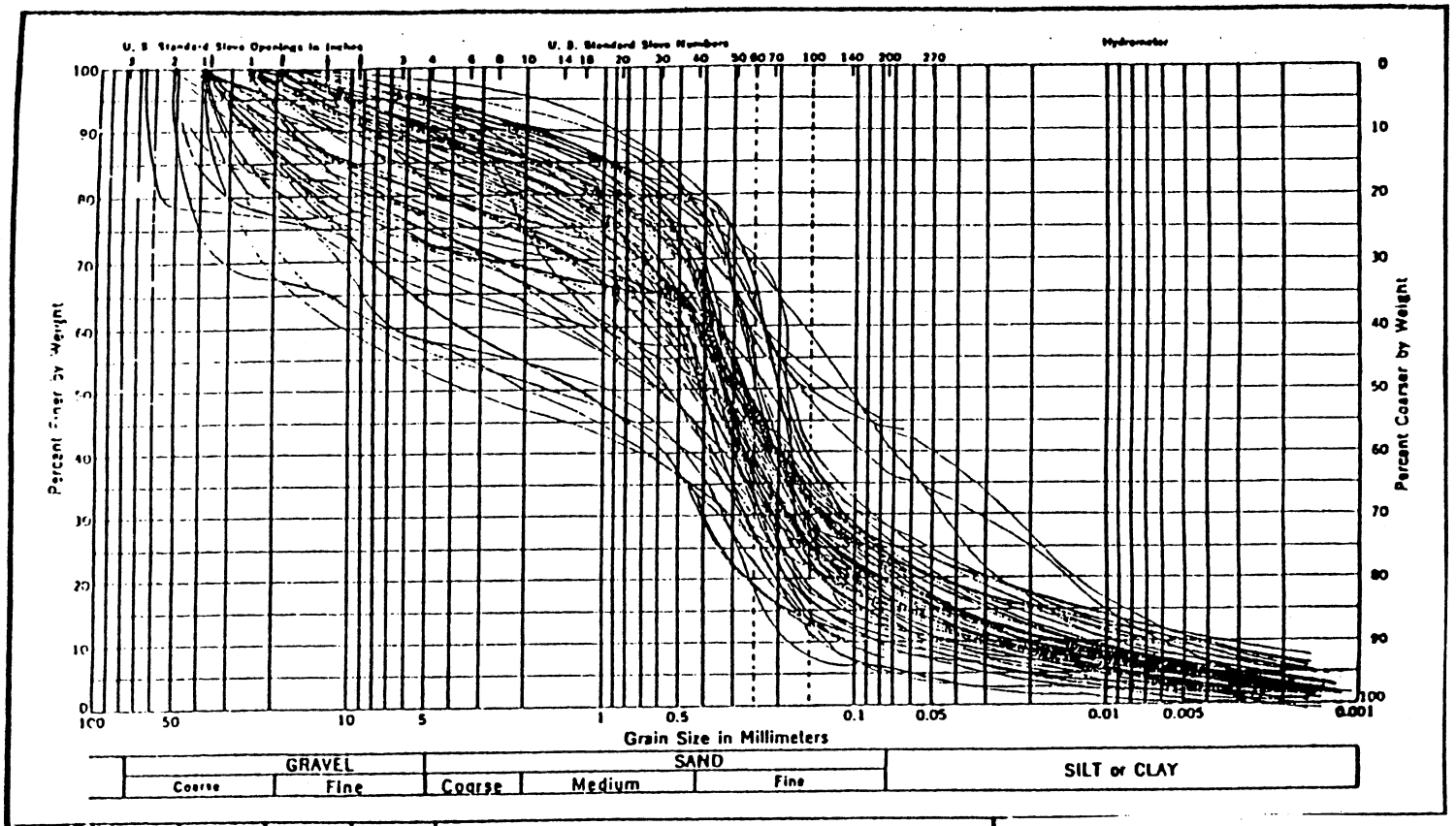
UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					LATE WISCONSINAN TILL

REFERENCE: STS-1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-36

REPRESENTATIVE GRAIN SIZE CURVES OF LATE WISCONSINAN TILL

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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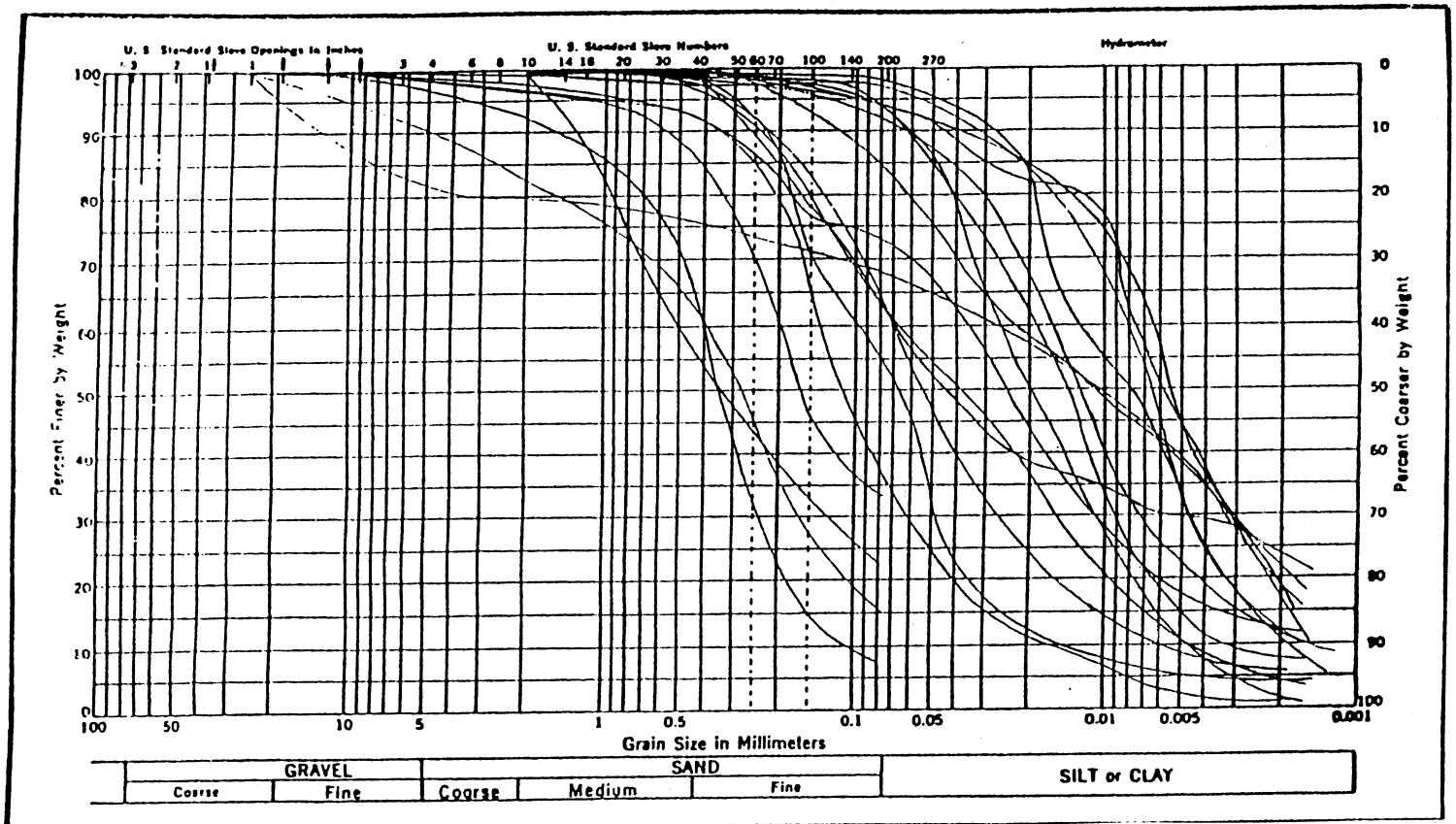
UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Lacustrine SM-SP, SM, ML, CL
					Note: Gradation Curves Represent
					Composite Samples and Not Individual
					Varves

REFERENCE: STS-1984

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-37

REPRESENTATIVE GRAIN SIZE CURVES OF LACUSTRINE DEPOSITS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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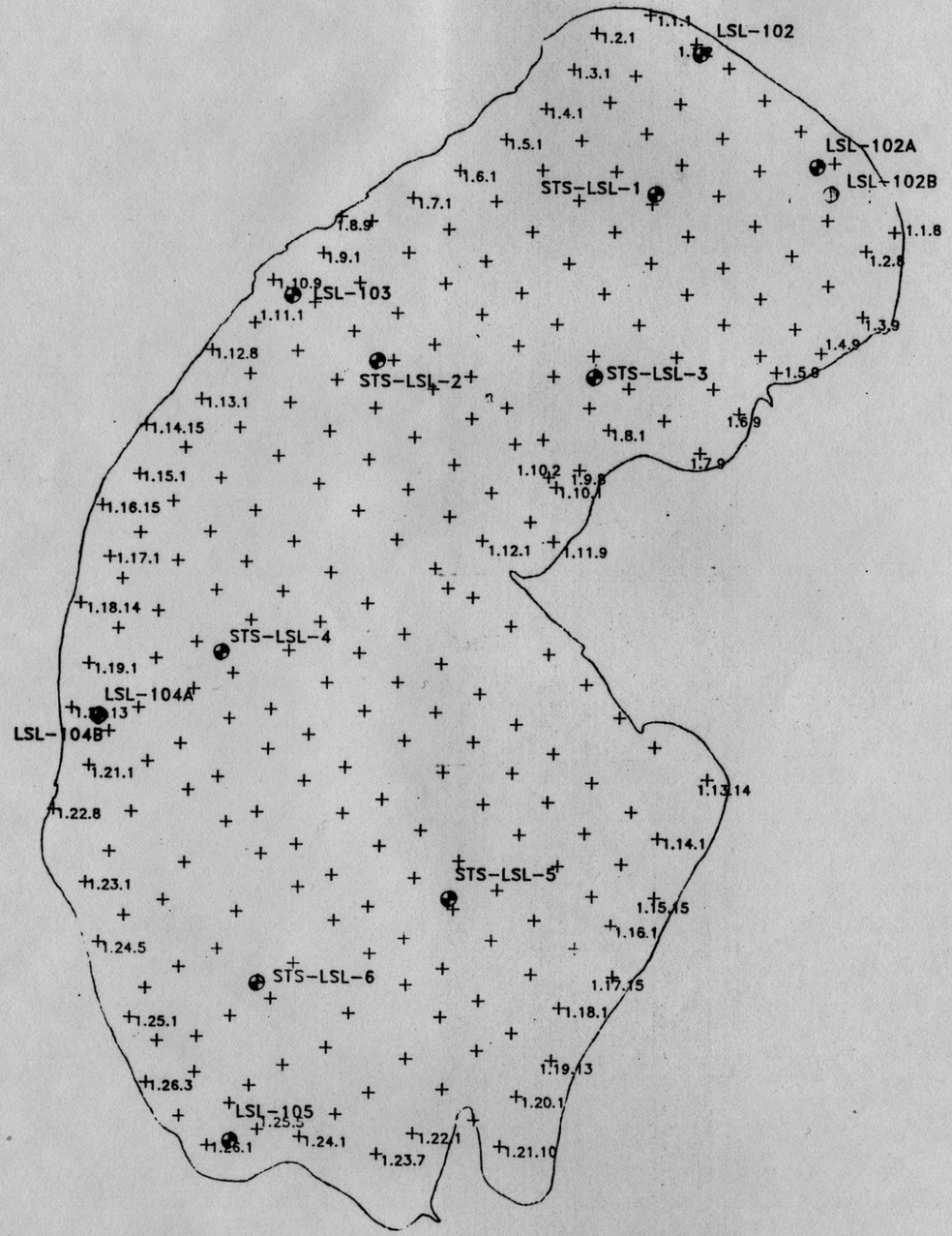

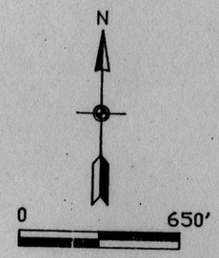

EXPLANATION

+ TDEM SURVEY STATION (DESIGNATIONS INDICATED AT START AND END OF EACH SURVEY LINE)

● LOCATION AND DESIGNATION OF SOIL BORINGS

SOURCE: SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED, 1994.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95	
APPROVED BY:	SVDI	DATE: MAY '95	
APPROVED BY:	GWS	DATE: MAY '95	

Crandon Mining Company

FIGURE 3.5-38

SITE PLAN SHOWING LOCATION OF TDEM SURVEY STATIONS - LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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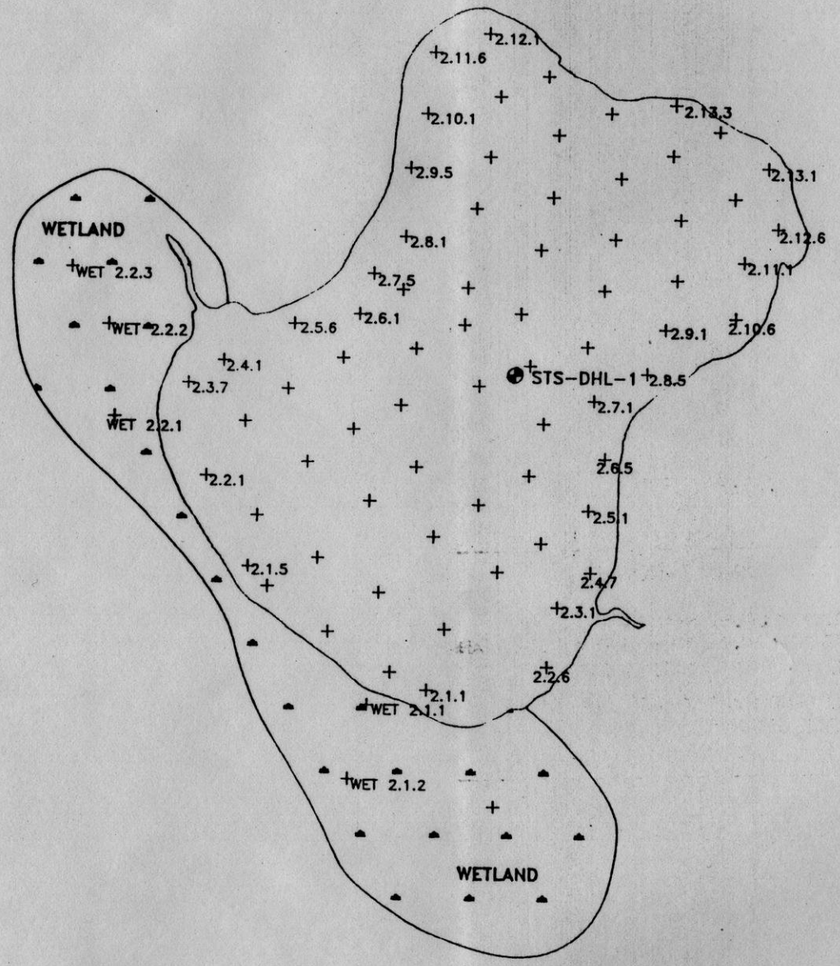

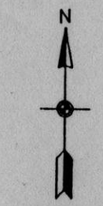

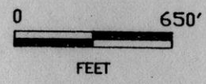

EXPLANATION

+ TDEM SURVEY STATION (DESIGNATIONS INDICATED AT START AND END OF EACH SURVEY LINE)

LOCATION AND DESIGNATION OF SOIL BORINGS

SOURCE: SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED, 1994.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-39

SITE MAP SHOWING LOCATION OF TDEM SURVEY STATIONS - DEEP HOLE LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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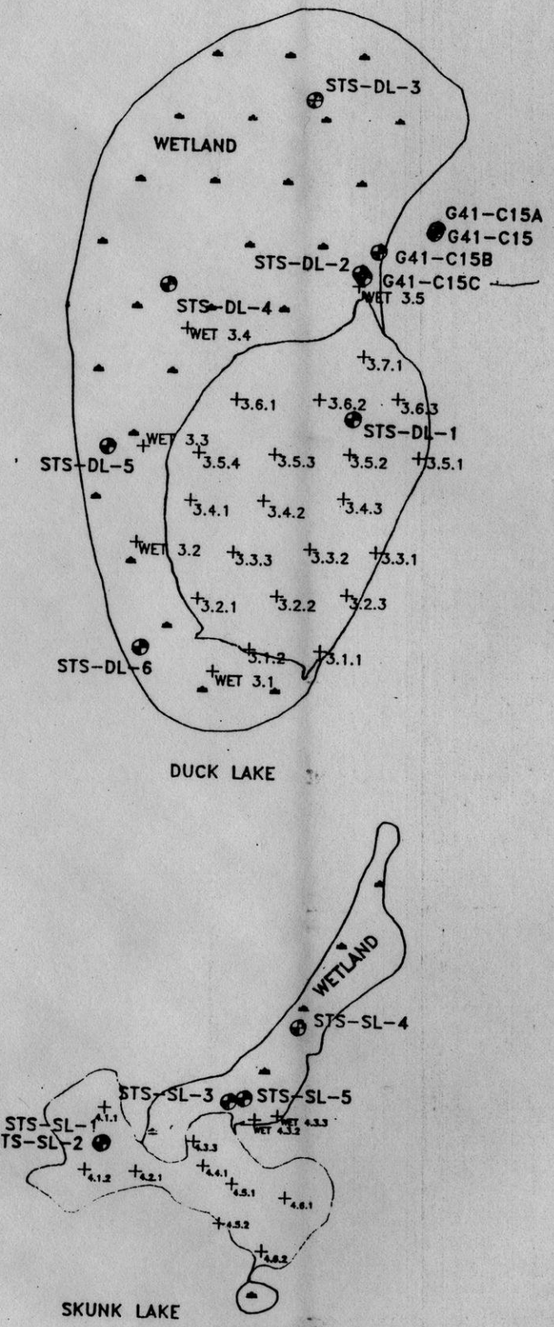
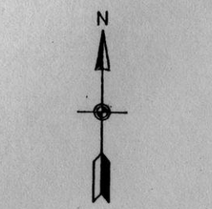
93C049





0 650'

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EXPLANATION

+ TDEM SURVEY STATION (DESIGNATIONS INDICATED AT START AND END OF EACH SURVEY LINE)

LOCATION AND DESIGNATION OF SOIL BORINGS

SOURCE: SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED, 1994.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-40
SITE MAP SHOWING LOCATION OF TDEM SURVEY STATIONS DUCK AND SKUNK LAKES

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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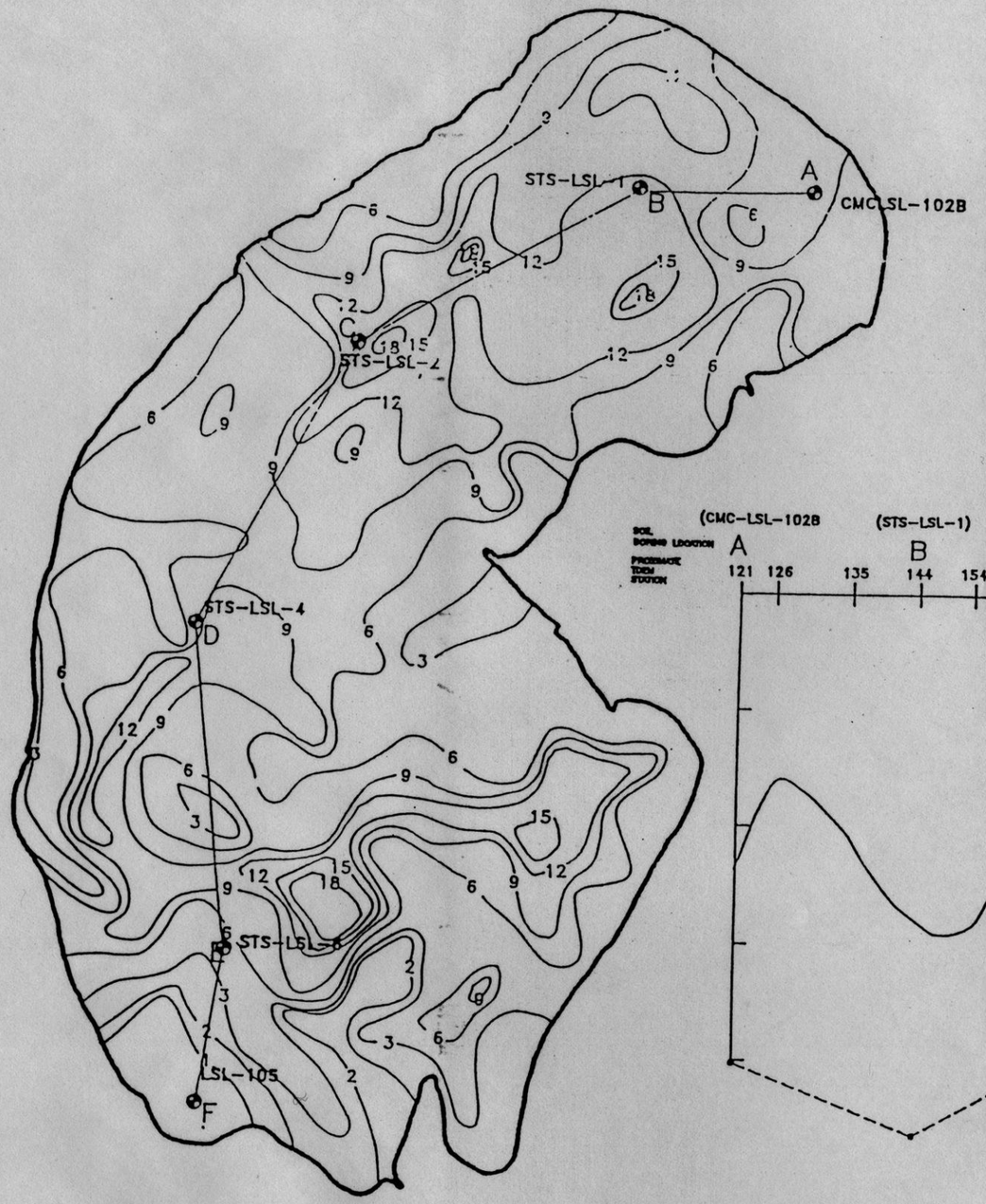
93C049

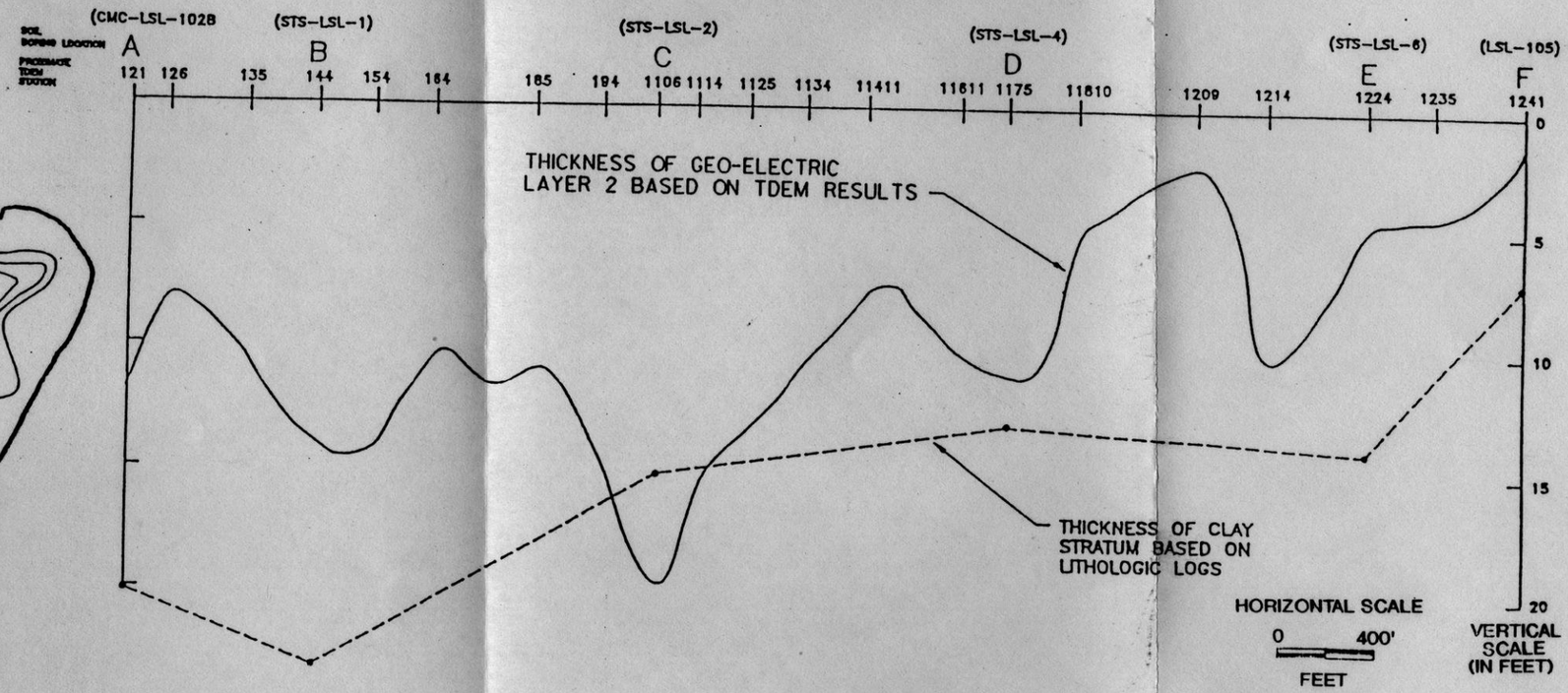


EXPLANATION

- 6 — ISOPACH LINE SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)
- LOCATION OF GEOLOGICAL CROSS-SECTION
- LOCATION AND DESIGNATION OF SOIL BORINGS

N

CROSS-SECTIONAL PERSPECTIVE OF GEO-ELECTRIC LAYER 2 THICKNESS LITTLE SAND LAKE



SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 9
MAY, 1994 REPORT.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-41
ORIGINAL ISOPACH MAP AND CROSS SECTION SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (SILTY CLAY) - LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049

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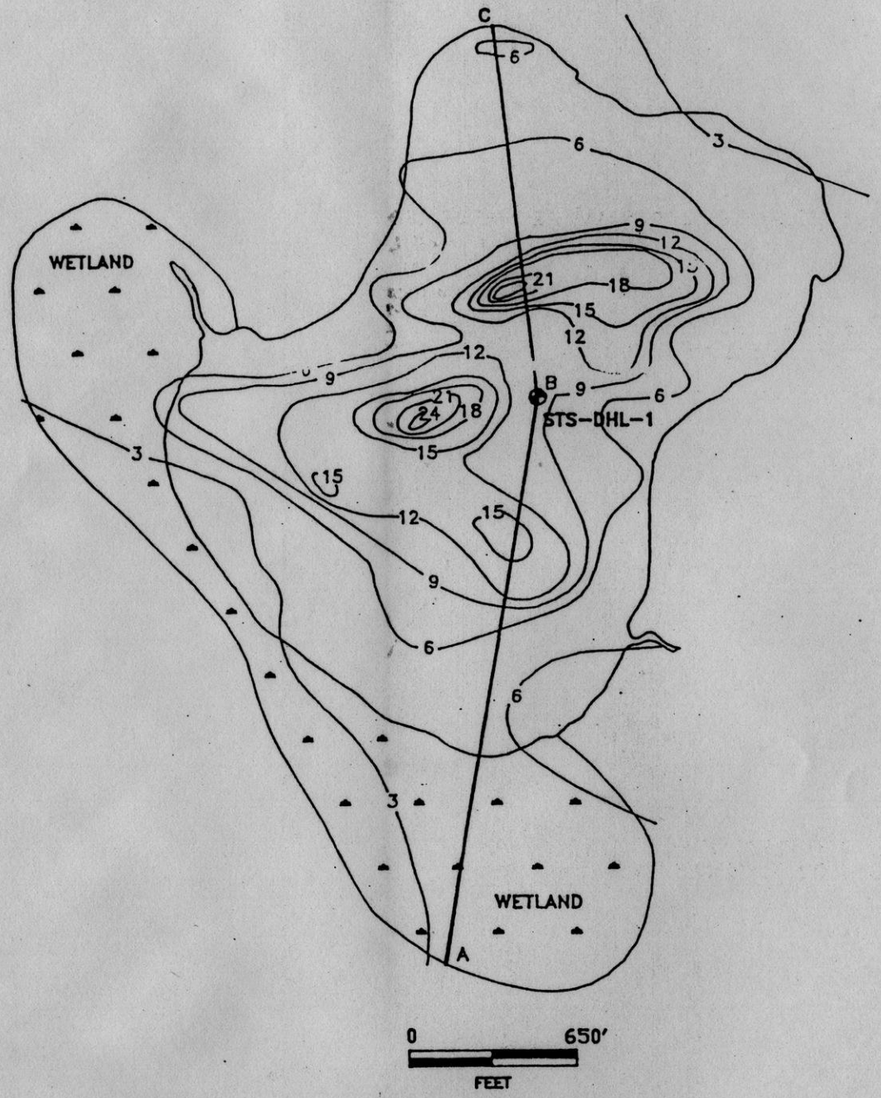
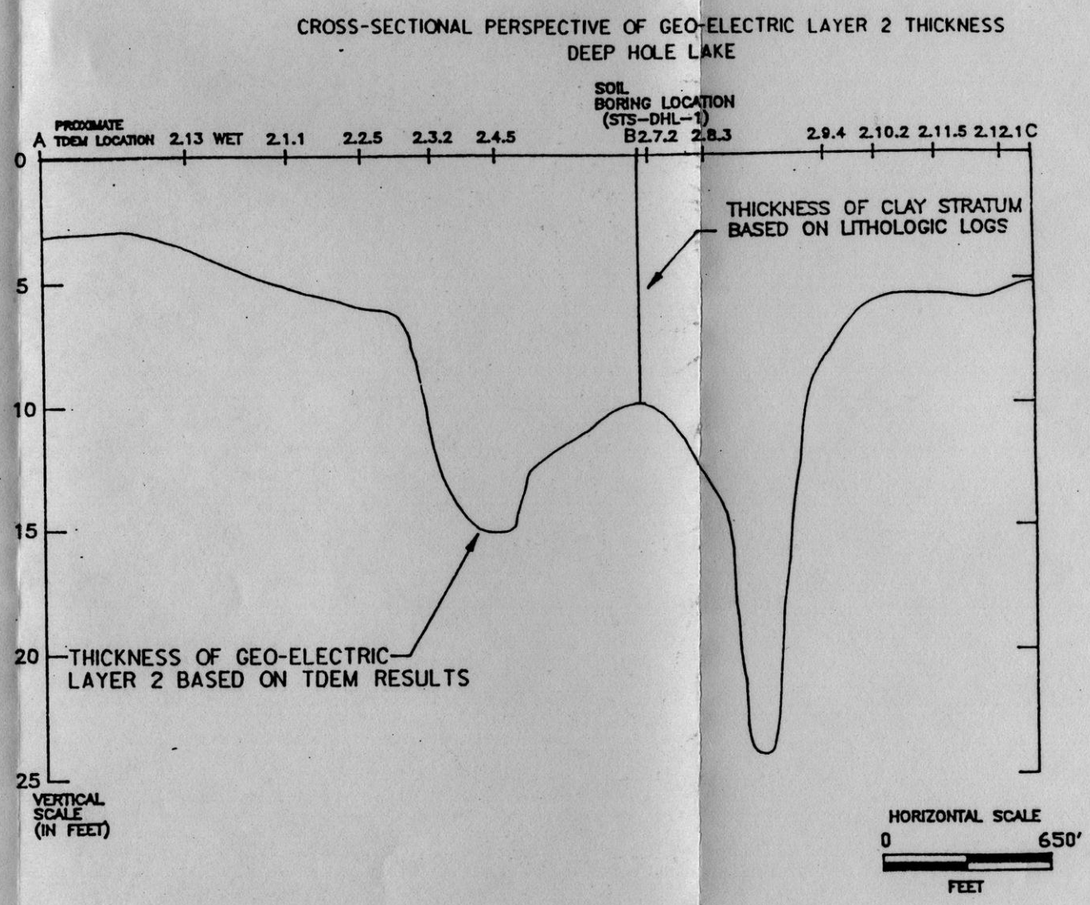


EXPLANATION

- 6 — ISOPACH LINE SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)
- ——— LOCATION OF GEOLOGICAL CROSS-SECTION
- ⊕ LOCATION AND DESIGNATION OF SOIL BORINGS



SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 11
MAY, 1994 REPORT.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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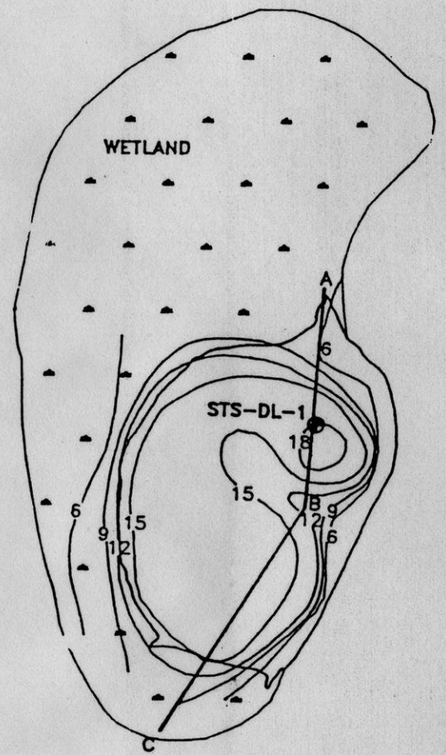
FIGURE 3.5-42
REVISED ISOPACH AND CROSS SECTION OF GEO-ELECTRIC LAYER 2 (SILT LAYER) DEEP HOLE LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

c:\cadwork\4c33fig.dgn

93C049



DUCK LAKE

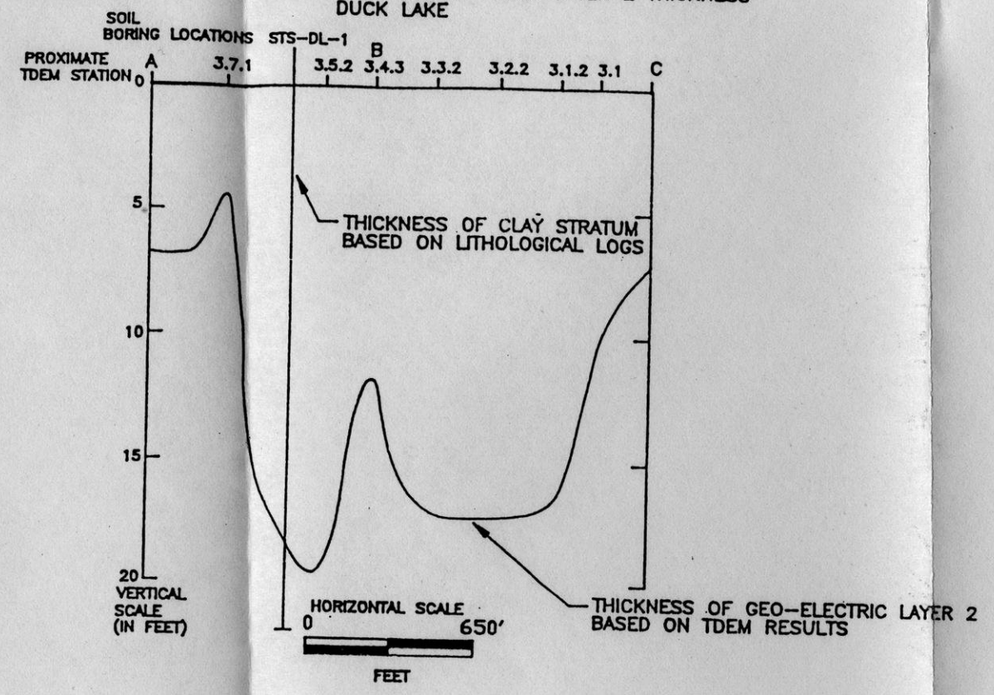
EXPLANATION

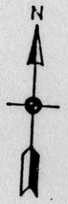
6 — ISOPACH LINE SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)

—— LOCATION OF GEOLOGICAL CROSS-SECTION

● LOCATION AND DESIGNATION OF SOIL BORINGS

CROSS-SECTIONAL PERSPECTIVE OF GEO-ELECTRIC LAYER 2 THICKNESS
DUCK LAKE





SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 13
MAY, 1994 REPORT

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-43
ORIGINAL ISOPACH OF GEO-ELECTRIC LAYER 2 (SILTY CLAY)
DUCK LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049

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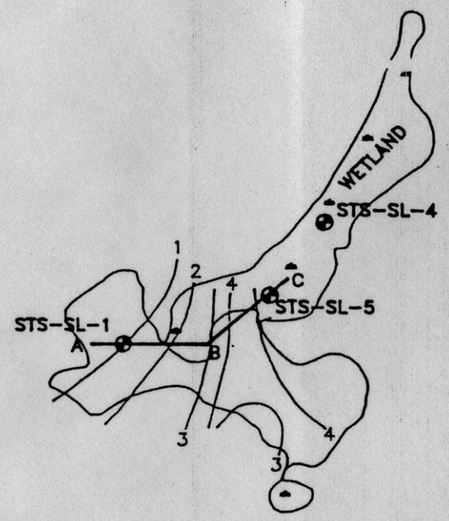
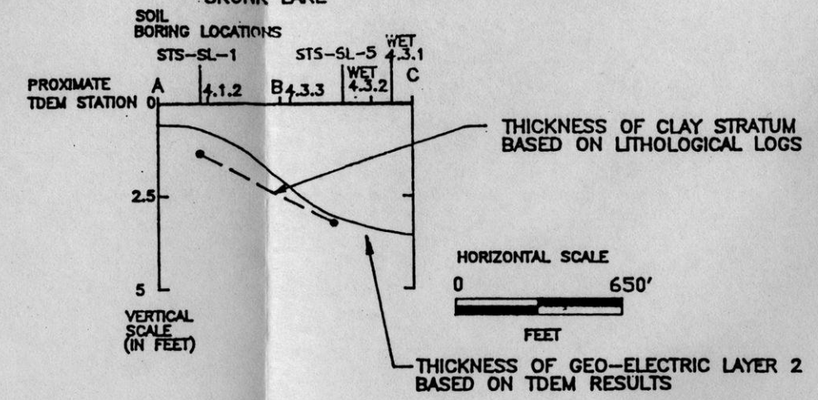


SKUNK LAKE

CROSS-SECTIONAL PERSPECTIVE OF GEO-ELECTRIC LAYER 2 THICKNESS
SKUNK LAKE



EXPLANATION

- 6 — ISOPACH LINE SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)
- LOCATION OF GEOLOGICAL CROSS-SECTION
- LOCATION AND DESIGNATION OF SOIL BORINGS

SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 13
MAY, 1994 REPORT

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

Crandon Mining Company

FIGURE 3.5-44
REVISED ISOPACH AND CROSS SECTION OF GEO-ELECTRIC LAYER 2 (SILTY CLAY) SKUNK LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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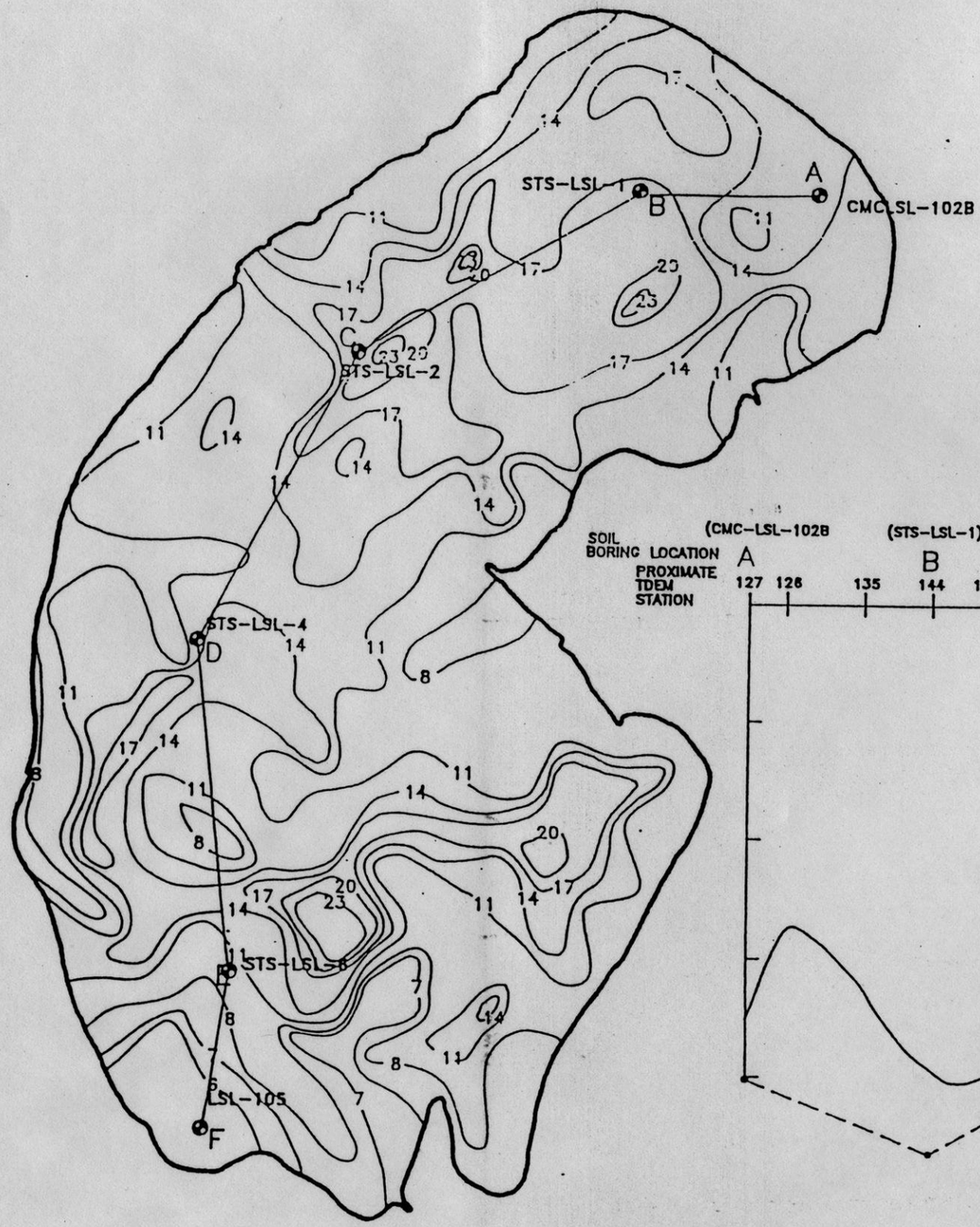
93C049



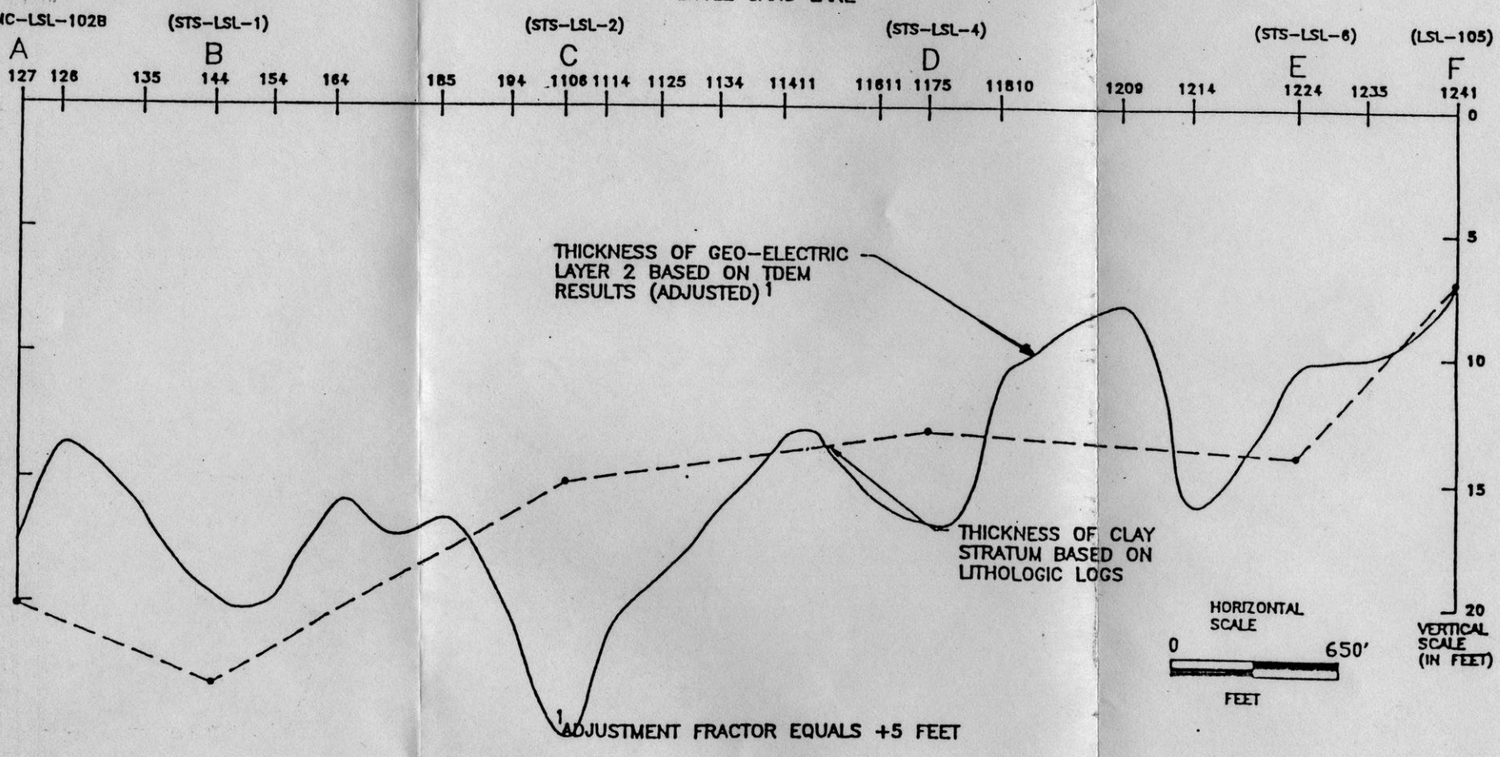
EXPLANATION

- ISOPACH LINE SHOWING ESTIMATED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)
- LOCATION OF GEOLOGICAL CROSS-SECTION
- LOCATION AND DESIGNATION OF SOIL BORINGS

N

CROSS-SECTIONAL PERSPECTIVE OF GEO-ELECTRIC LAYER 2, (ADJUSTED)

LITTLE SAND LAKE



SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 9
MAY, 1994 REPORT,
ADJUSTED BY 5 FT.

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-45

ISOPACH MAP AND CROSS SECTION SHOWING ADJUSTED THICKNESS OF GEO-ELECTRIC LAYER 2 (SILTY CLAY) - LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

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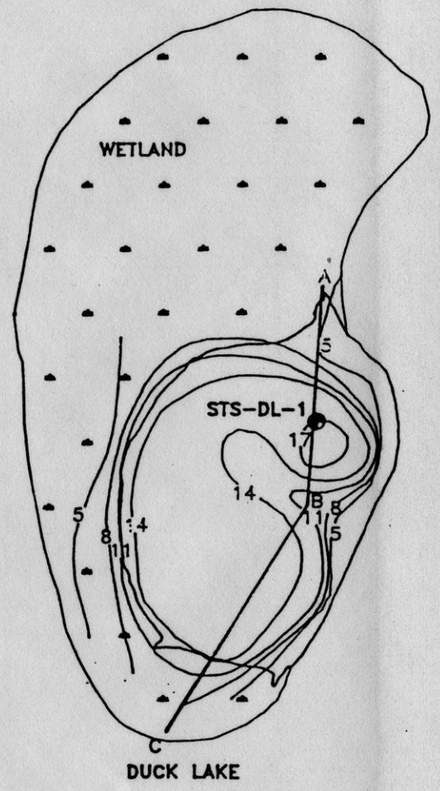
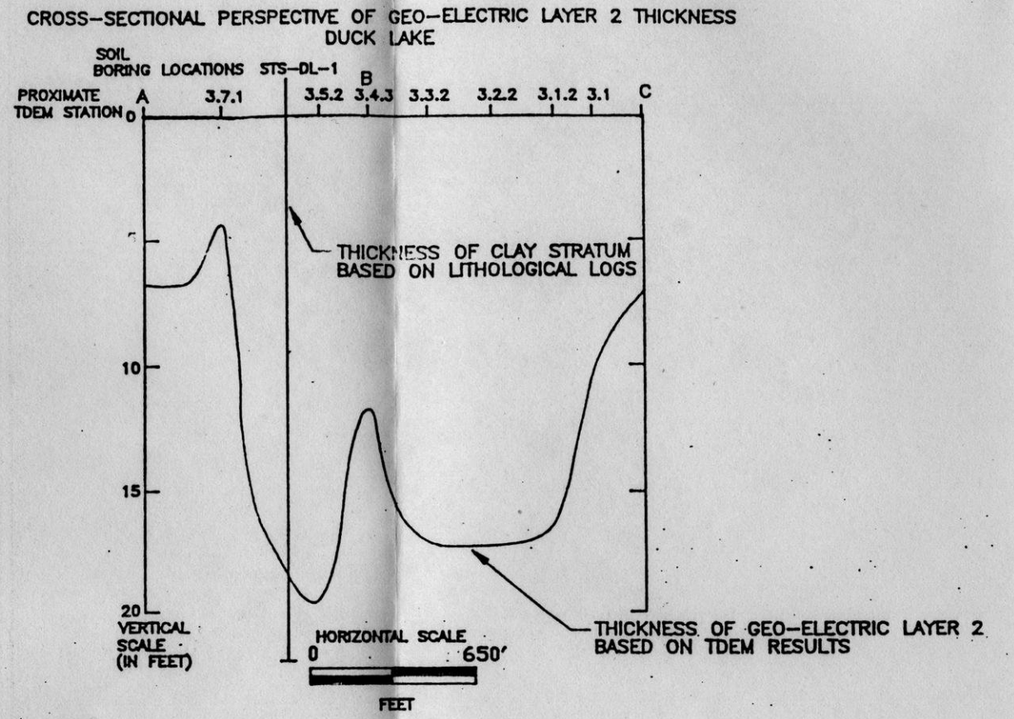
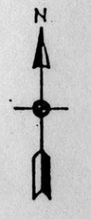
93C049







EXPLANATION

6 — ISOPACH LINE SHOWING ESTIMATED ADJUSTED THICKNESS OF GEO-ELECTRIC LAYER 2 (IN FEET)

——— LOCATION OF GEOLOGICAL CROSS-SECTION

LOCATION AND DESIGNATION OF SOIL BORINGS

SOURCE:
SUBSURFACE DETECTIONS INVESTIGATIONS, INC.
FROM FIGURE 13
MAY, 1994 REPORT,
ADJUSTED BY -1 FT.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JSKI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-46
ISOPACH AND CROSS SECTION OF ADJUSTED THICKNESS OF GEO-ELECTRIC LAYER 2 (SILTY CLAY) - DUCK LAKE

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049

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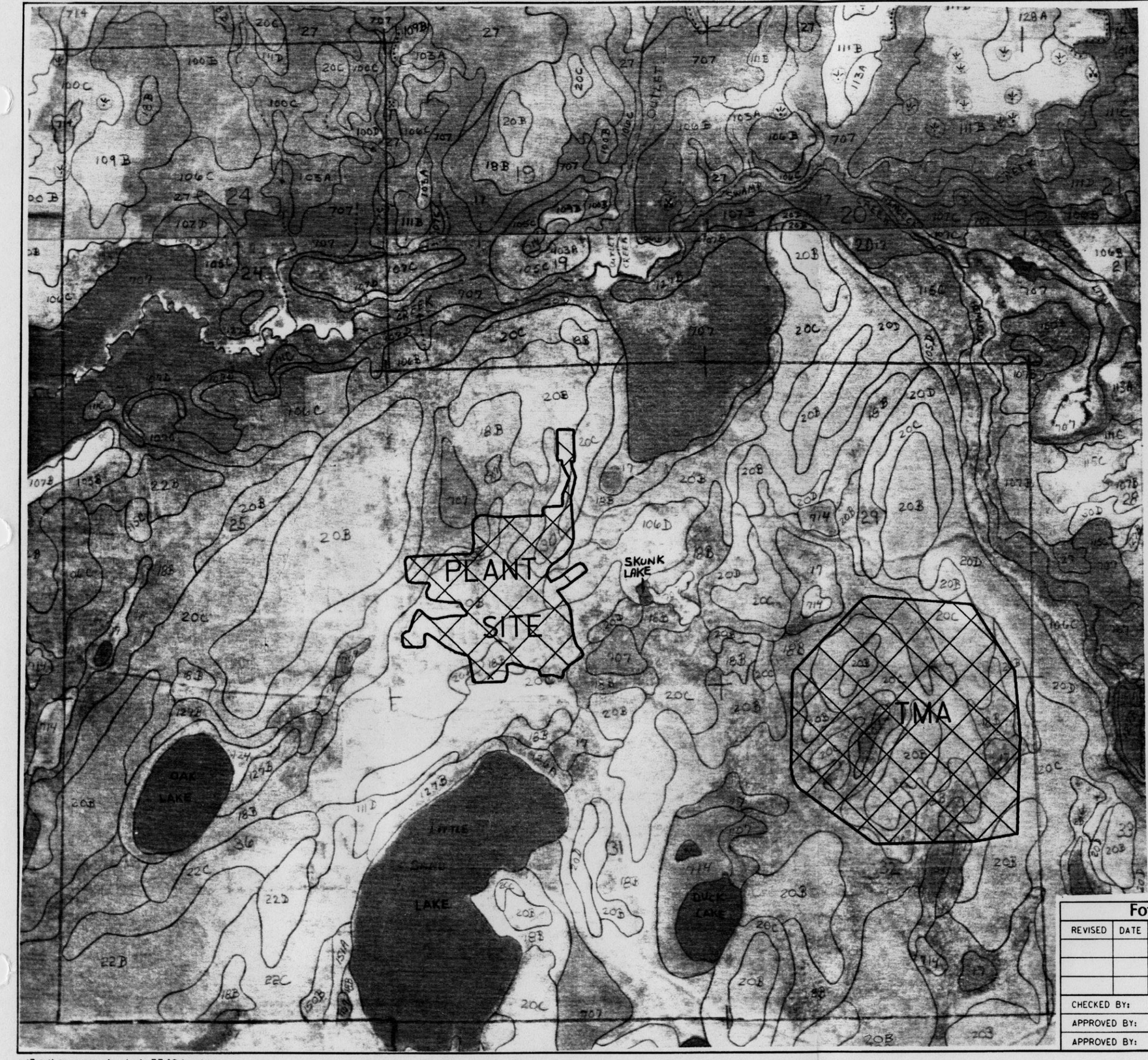

LEGEND

PROPOSED FACILITIES

20B SOIL UNIT NUMBER

N

REFERENCE TABLE 3.5-11 OR DESCRIPTION OF SOIL UNIT NUMBERS AS DISPLAYED ON MAP.

SOURCE: U.S. DEPARTMENT OF AGRICULTURE
SOIL CONVERVATION SERVICE
SOIL SURVEY FIELD SHEET
FOREST COUNTY, WISCONSIN
ADVANCE COPY SUBJECT TO CHANGE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.5-47
SOIL SURVEY MAP

Scale:	APPROX. 1"=1667'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

/d3/dl/users/jprl/4c33f94a.dgn

93C049

2,270,000 E

2,275,000 E

2,280,000 E

2,285,000 E

125,000 N

120,000 N

115,000 N

110,000 N

AIRPORT RD

ARK RD

RAILROAD

KEITH SIDING RD

SHERMAN LN

SWAMP LN

OUTLET

CREEK

SWAMP

CREEK

HEMLOCK

CREEK

CREEK

SWAMP

FVD-AR-1
FVD-AR-2
FVD-AR-3
FVD-AR-4
FVD-AR-5
FVD-AR-6
FVD-AR-7
FVD-AR-8
FVD-AR-9
FVD-AR-10
FVD-AR-11
FVD-AR-12
FVD-AR-13
FVD-AR-14
FVD-AR-15
FVD-AR-16
FVD-AR-17
FVD-AR-18
FVD-AR-19
FVD-AR-20
FVD-AR-21
AR-1
AR-2
FVD-AR-22
FVD-AR-23
FVD-AR-24
FVD-AR-25
FVD-AR-26
FVD-AR-27
FVD-AR-28
FVD-AR-29
FVD-AR-30
FVD-AR-31

FVD-RR-1
FVD-RR-2
FVD-RR-3
FVD-RR-4
FVD-RR-5
FVD-RR-6
FVD-RR-7
FVD-RR-8
FVD-RR-9
FVD-RR-10
FVD-RR-11
FVD-RR-12
FVD-RR-13
FVD-RR-14
FVD-RR-15
FVD-RR-16
FVD-RR-17
FVD-RR-18
FVD-RR-19
FVD-RR-20
FVD-RR-21
RR-1
RR-2
FVD-RR-22
FVD-RR-23
FVD-RR-24
FVD-RR-25
FVD-RR-26
FVD-RR-27
FVD-RR-28
FVD-RR-29
FVD-RR-30
FVD-RR-31
FVD-RR-32
FVD-RR-33
FVD-RR-34
FVD-RR-35

PLANT

DMS-1
DMS-2
CMC-SB-08A
CMC-SB-10P
DMI-1
DMI-2
DMI-3
STS-TP-80-1
STS-TP-80-2
STS-TP-80-3
STS-TP-80-4
STS-TP-80-5
STS-TP-80-6
STS-TP-80-7
STS-TP-80-8
STS-TP-80-9
STS-TP-80-10
STS-TP-80-11
STS-TP-80-12
STS-TP-80-13
STS-TP-80-14
STS-SAF-6
STS-SAF-7
STS-SAF-8
STS-FVS
CMC-TOPP
STS-SAF-16

SKUNK LAKE

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

LITTLE SAND LAKE RD

BEECH LN

TIMBER LN

VALICAN SHORES LN

SAND LAKE RD

DEEP HOLE LAKE RD

BERRY LN

HEMLOCK

DEEP HOLE L

TP-4

G41-C11
G41-E11
CMC-01P
G41-G11
TP-85-2
TP-85-5
TP-85-4
TP-7
G41-J11
TP-2
TP-85-17
TP-85-16
TP-85-10
TP-85-9
TP-85-8
TP-85-15
TP-85-7
TP-85-14
CMC-02P
TP-85-6
G41-H13
G41-K13
CMC-07
G41-E13
TP-3
G41-J14
TP-84-20
TP-84-21

N

LEGEND

- EXISTING ROAD
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- LAKES
- STREAMS
- FVD-RR-33 TOPSOIL THICKNESS LOCATION AND NUMBER

NOTES:

1. BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: JAN, '97
APPROVED BY:	EAS	DATE: JAN, '97
APPROVED BY:	GWS	DATE: JAN, '97

Crandon Mining Company

FIGURE 3.5-47A

BORINGS AND TEST PIT LOCATIONS USED FOR O AND A HORIZON THICKNESS EVALUATION

Scale: 0 1000' 2000' | Date: JANUARY, 1997

Prepared By: Foth & Van Dyke | By: JOW

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93C049

LEGEND

- EXISTING ROAD
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- X 1586.0 SPOT ELEVATION
- 1600 EXISTING CONTOUR
- LAKES
- STREAMS
- x 3.0 TOPSOIL THICKNESS (INCHES)

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: JAN, '97
APPROVED BY:	EAS	DATE: JAN, '97
APPROVED BY:	GWS	DATE: JAN, '97

Crandon Mining Company

FIGURE 3.5-47B

O AND A HORIZON THICKNESS
BASED ON SOIL GAS SURVEY DATA

Scale: 0 300' 600' Date: JANUARY, 1997

Prepared By: Foth & Van Dyke By: JOW

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93C049

2,270+000 E
2,275+000 E
2,280+000 E
2,285+000 E
2,290+000 E
125+000 N
120+000 N
115+000 N

AIRPORT RD
SWAMPY LN
OUTLET
RD
LROAD
KEITH SIDING RD
SHERMAN LN
SWAMP
CREEK
HEMLOCK
CREEK
SKUNK LAKE
PLANT SITE
TMA
OAK LAKE
LITTLE SAND LAKE RD
LITTLE SAND LAKE
DUCK LAKE
HEMLOCK CREEK
GROUND HEMLOC LAKE
EP HOLE LAKE RD

PROPOSED ACCESS ROAD CORRIDOR

PROPOSED RAILROAD CORRIDOR

PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE CORRIDOR

LEGEND

- EXISTING ROAD
- PROPOSED FACILITIES
- LAKES
- STREAMS

17	CAPITOLA MUCK
18	MUD LAKE SILT LOAM
20	WABENO-GOODMAN COMPLEX
27	MINOCQUA MUCK
100	STAMBAUGH SILT LOAM
106	PADUS-PENCE COMPLEX
107	PADUS VILAS COMPLEX
109	VANZILE SILT LOAM
111	PENCE SANDY LOAM
707	LUPTON, CATHRO, AND MARKEY MUCK
714	LOXLEY, BESEMAN AND DAWSON PEATS

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. AVERAGE CORRIDOR WIDTHS SHOWN AS FOLLOWS:
   - -SITE ACCESS ROAD = 100 FEET
   - -RAILROAD SPUR
     - MAINLINE = 60 FEET
     - W/ SIDELINE = 80 FEET
   - -TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE = 100 FEET

   IN SOME AREAS THE ACTUAL WIDTH WILL BE LESS THAN THE AVERAGE, AND IN OTHER AREAS IT WILL BE GREATER.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: JAN, '97
APPROVED BY:	EAS	DATE: JAN, '97
APPROVED BY:	GWS	DATE: JAN, '97

Crandon Mining Company

FIGURE 3.5-47C

SOIL SERIES WITHIN AREAS OF DISTURBANCE

Scale: 0 1000' 2000' | Date: JANUARY, 1997

Prepared By: Foth & Van Dyke | By: JOW

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93C049

2,270+000 E | 2,275+000 E | 2,280+000 E | 2,285+000 E | 2,290+000 E

125+000 N

120+000 N

115+000 N

PROPOSED RAILROAD CORRIDOR

PROPOSED ACCESS ROAD CORRIDOR

PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE CORRIDOR

PLANT SITE

TMA

SHERMAN LN.

SWAMP CREEK

SWAMPY LN

OUTLET

KEITH SIDING RD

HEMLOCK CREEK

DEEP HOLE LAKE RD

BEECH LN

LITTLE SAND LAKE RD

TIMBER LN

VALICAN SHORES LN

POPPLE POND

OAK LAKE

LITTLE SAND LAKE

SKUNK LAKE

DUCK LAKE

LEGEND

- EXISTING ROAD
- PROPOSED FACILITIES
- LAKES
- STREAMS

17	CAPITOLA MUCK
18	MUD LAKE SILT LOAM
20	WABENO-GOODMAN COMPLEX
27	MINOCQUA MUCK
100	STAMBAUGH SILT LOAM
106	PADUS-PENCE COMPLEX
107	PADUS VILAS COMPLEX
109	VANZILE SILT LOAM
111	PENCE SANDY LOAM
707	LUPTON, CATHRO, AND MARKEY MUCK
714	LOXLEY, BESEMAN AND DAWSON PEATS

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. AVERAGE CORRIDOR WIDTHS SHOWN AS FOLLOWS:
   - -SITE ACCESS ROAD = 100 FEET
   - -RAILROAD SPUR
     - MAINLINE = 60 FEET
     - W/ SIDELINE = 80 FEET
   - -TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE = 100 FEET

   IN SOME AREAS THE ACTUAL WIDTH WILL BE LESS THAN THE AVERAGE, AND IN OTHER AREAS IT WILL BE GREATER.

VEGETATION CLASSIFICATIONS

- B = BOGS
- C = SWAMP CONIFERS
- DW = DECIDUOUS FORESTED WETLANDS
- M = MARSHES
- S = SHRUB WETLANDS
- F = FIELDS AND UPLAND OPENINGS (INCLUDING TREES < 10' IN HEIGHT)
- A = AGRICULTURAL LANDS
- P = PINE PLANTATIONS
- N = NORTHERN HARDWOOD FORESTS (INCLUDING > 10' IN HEIGHT)

OTHER LAND CLASSIFICATIONS

- W = OPEN WATER
- U = URBAN, RESIDENTIAL OR DEVELOPED AREAS

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: JAN, '97
APPROVED BY:	EAS	DATE: JAN, '97
APPROVED BY:	GWS	DATE: JAN, '97

Crandon Mining Company

FIGURE 3.5-47D

SOIL SERIES AND VEGETATION TYPE

Scale: 0 1000' 2000' | Date: JANUARY, 1997

Prepared By: Foth & Van Dyke | By: JOW

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93C049

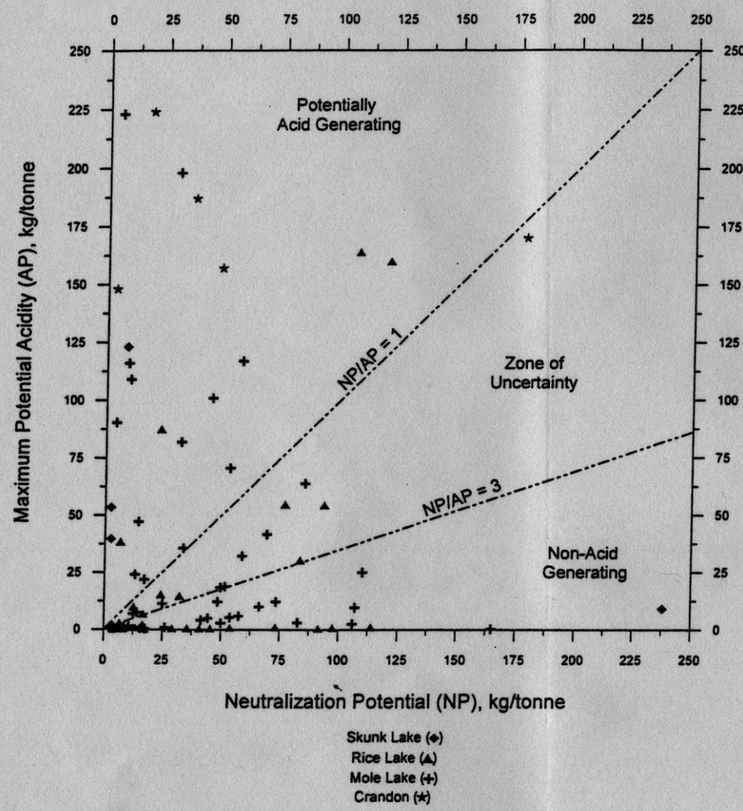

Figure 3.5-48a. Acid-Base Accounting Results of the Samples Used in the 1994 Evaluation the ABA Variability within the Hanging Wall and Ore Formations

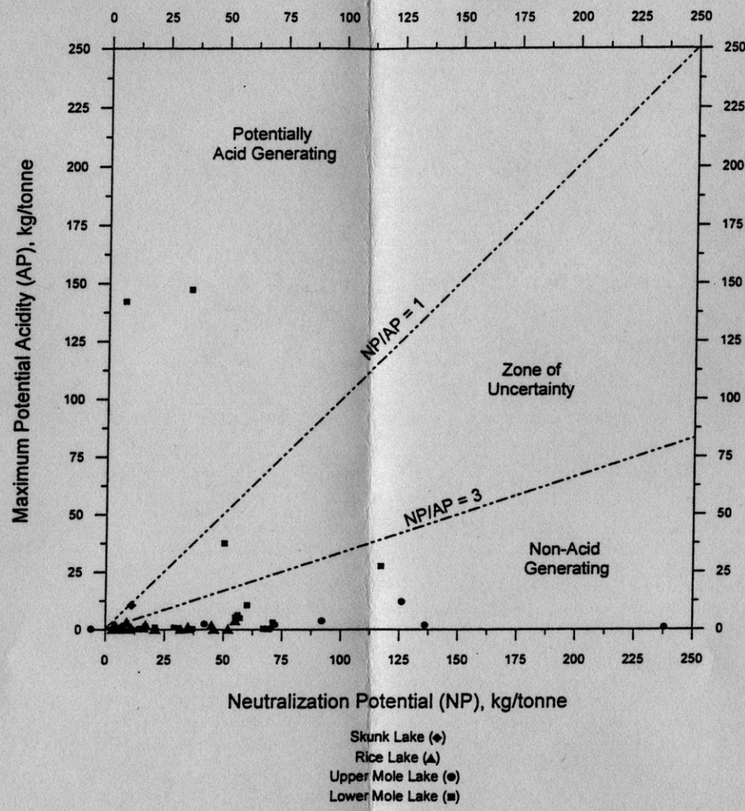

Figure 3.5-48b. Acid-Base Accounting Results of the Samples Used in the 1995 Evaluation the ABA Variability within the Four Master Waste Rock Composites

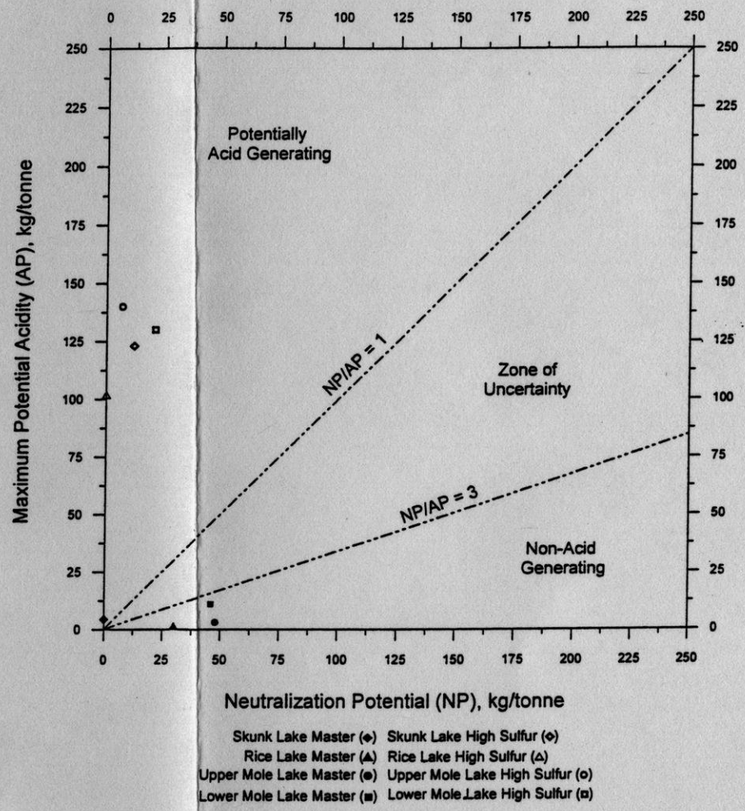

Figure 3.5-48c. Acid-Base Accounting Results for the Four Master, and the Four High Sulfur, Waste Rock Composites Used in the Waste Characterization Kinetic Tests

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	MLD2	DATE: JULY '97
APPROVED BY:	GWS	DATE: JULY '97
APPROVED BY:		DATE:

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FIGURE 3.5-48

RESULTS OF ABA TESTS IN TERMS OF CALCULATED NEUTRALIZATION POTENTIAL (NP) AND MAXIMUM POTENTIAL ACIDITY (AP)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JOW

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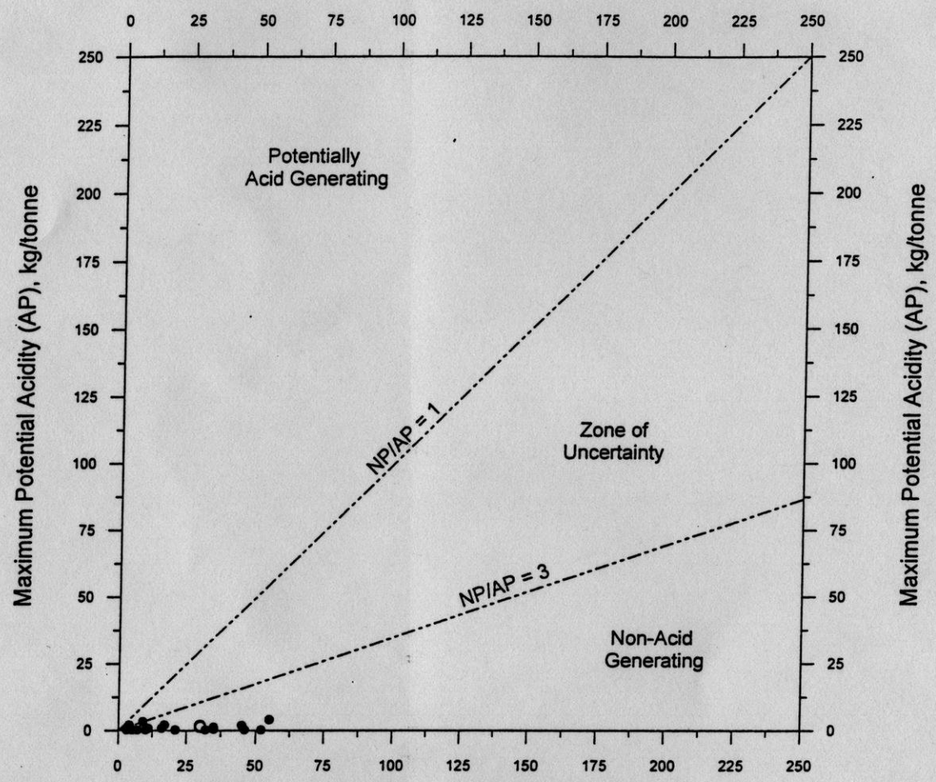
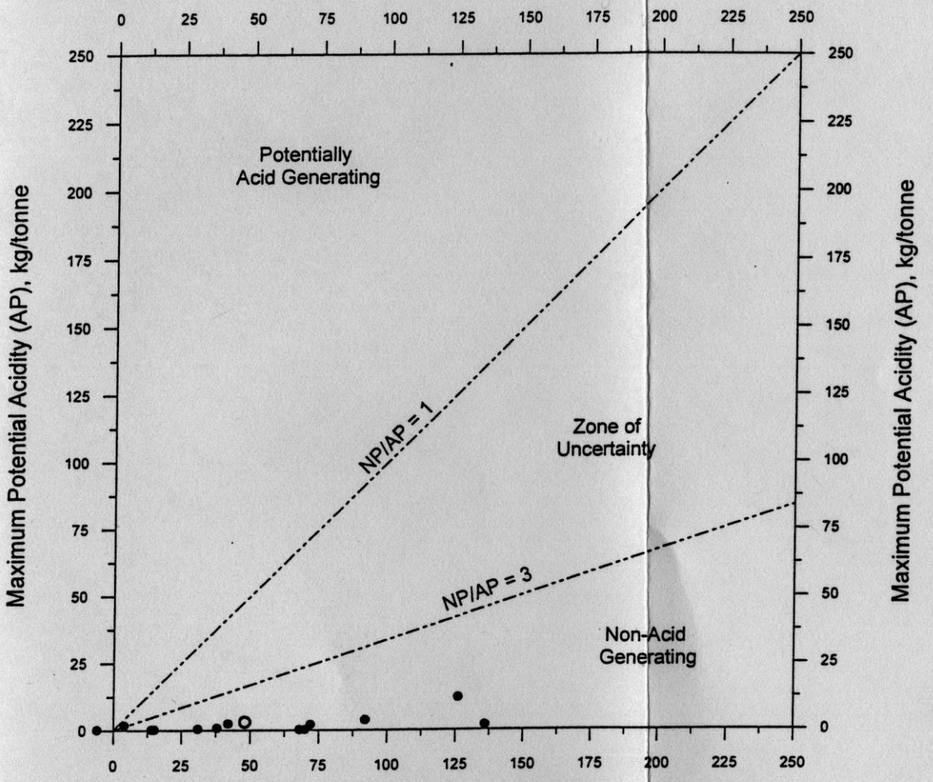


Rice Lake Master Composite (○)
Rice Lake Randomly Selected Intervals (●)

Figure 3.5-49a. Acid-Base Accounting Results for the Rice Lake Master Composite and the Randomly Selected Core Intervals Used to Evaluate the ABA Variability within the Master Composite



Upper Mole Lake Master Composite (○)
Upper Mole Lake Randomly Selected Intervals (●)

Figure 3.5-49b. Acid-Base Accounting Results for the Upper Mole Lake Master Composite and the Randomly Selected Core Intervals Used to Evaluate the ABA Variability within the Master Composite

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	MLD2	DATE: JULY '97
APPROVED BY:	GWS	DATE: JULY '97
APPROVED BY:		DATE:

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FIGURE 3.5-49
RESULTS OF ABA TESTS IN TERMS OF CALCULATED NEUTRALIZATION POTENTIAL (NP) AND MAXIMUM POTENTIAL ACIDITY (AP) FOR RICE LAKE AND UPPER MOLE LAKE RANDOM CORES

Scale:	AS SHOWN	Date:	JULY '97
Prepared By:	Foth & Van Dyke	By:	JOW

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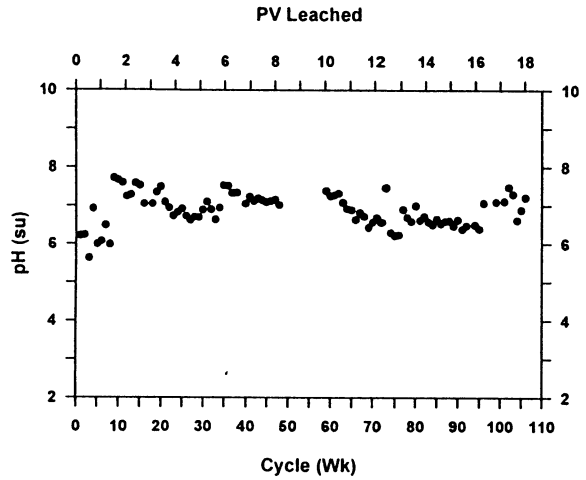

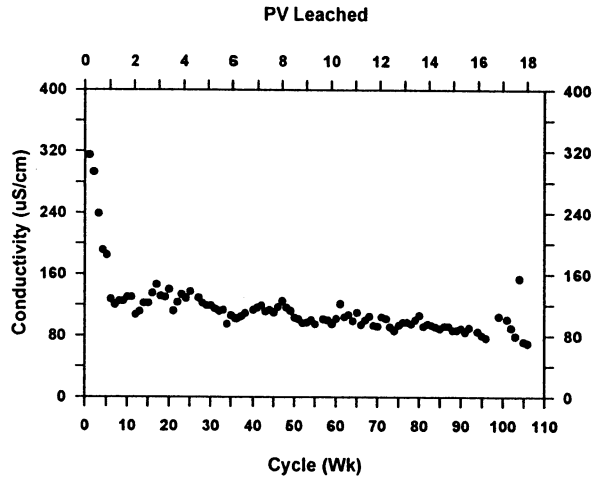

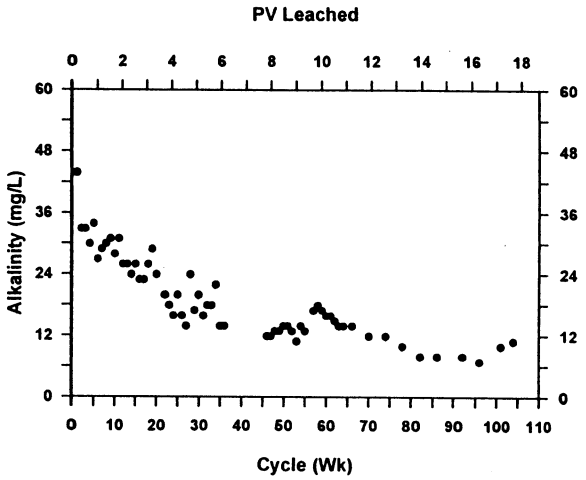

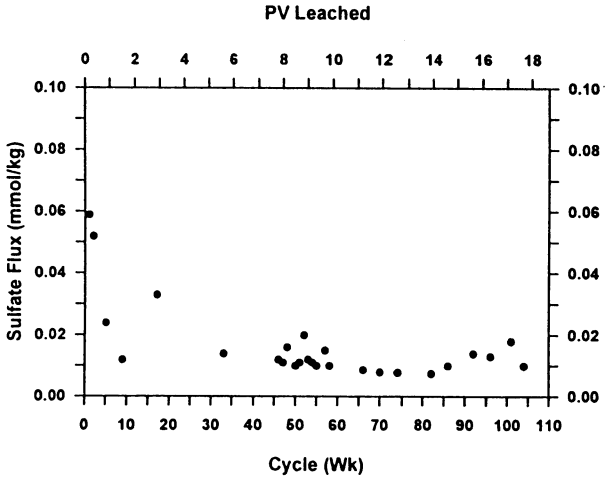

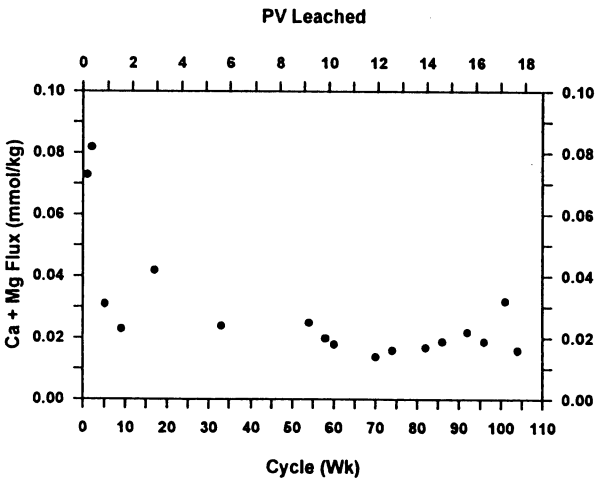

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FIGURE 3.5-50

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE SKUNK LAKE MASTER COMPOSITE (WD-05)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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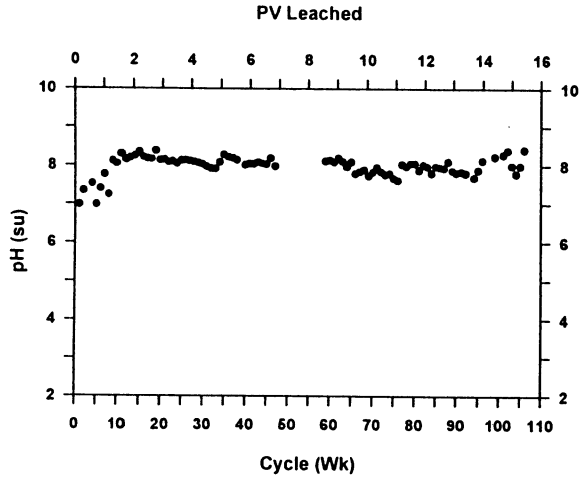

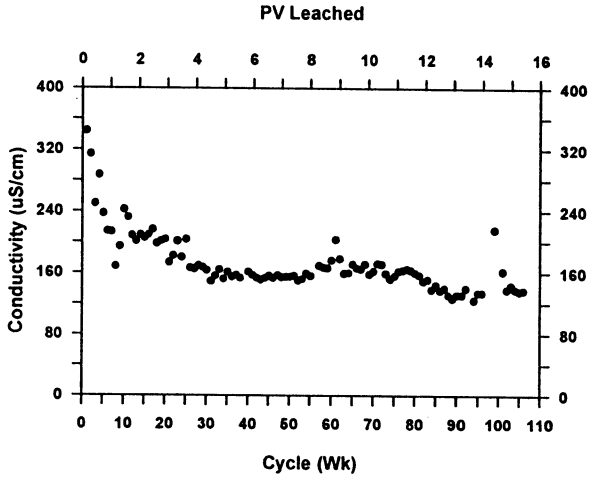

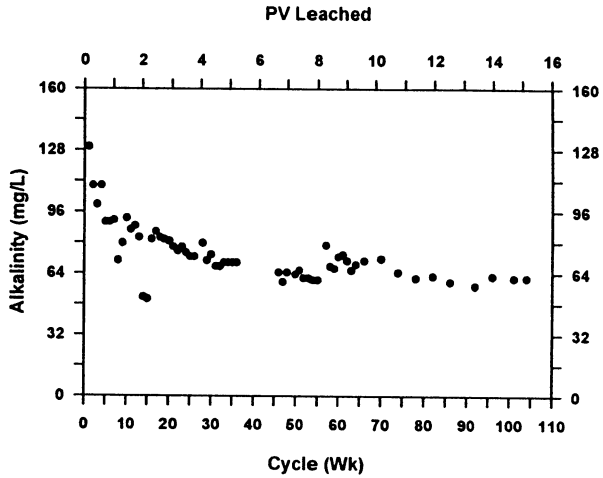

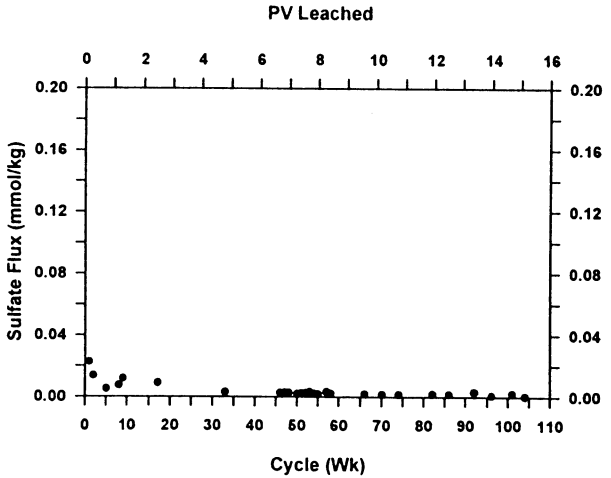

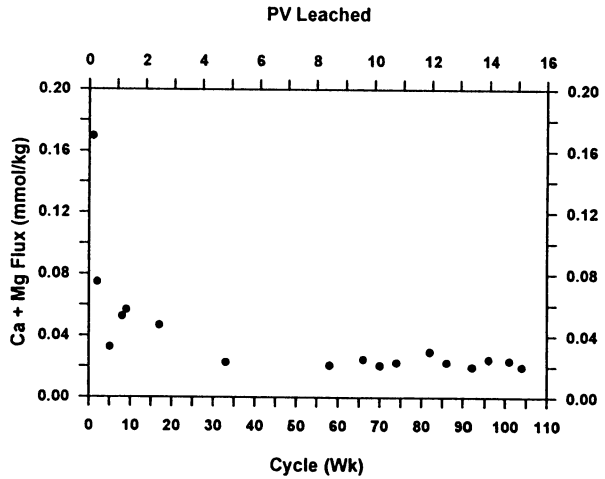

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FIGURE 3.5-51

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE RICE LAKE MASTER COMPOSITE (WD-06)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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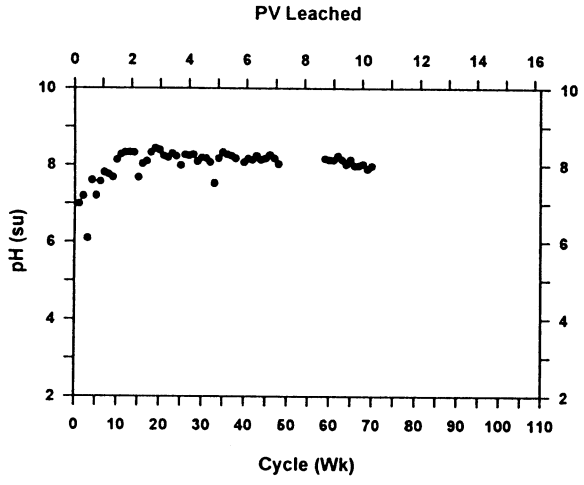

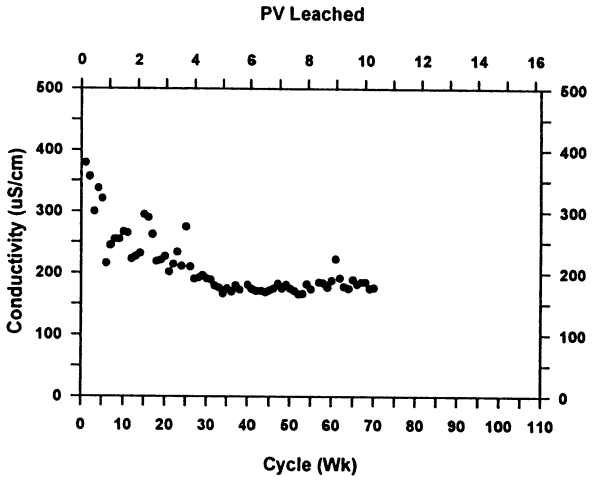

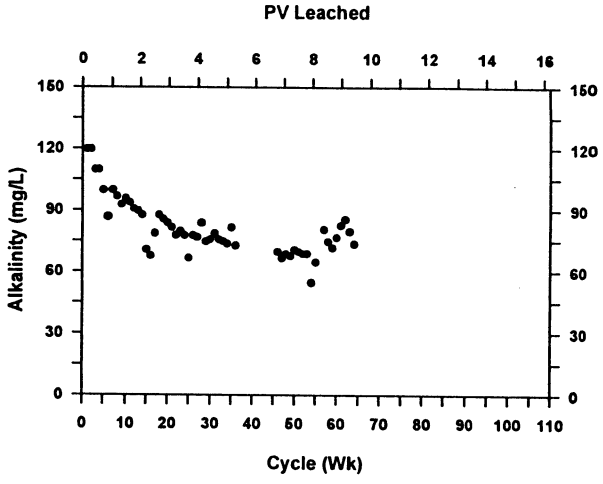

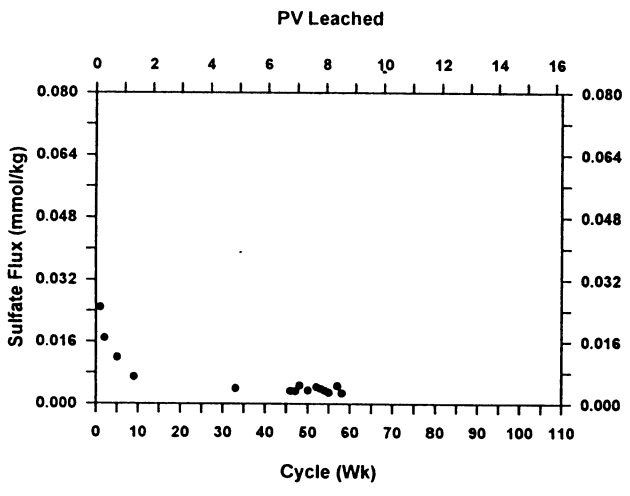

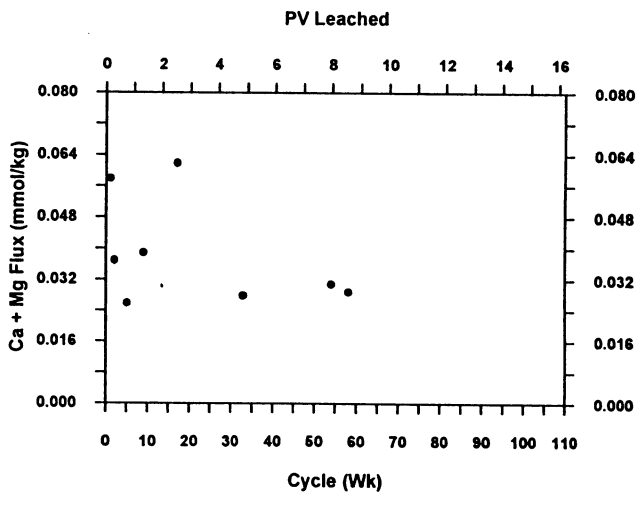

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FIGURE 3.5-52

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE UPPER MOLE LAKE MASTER COMPOSITE (WD-07)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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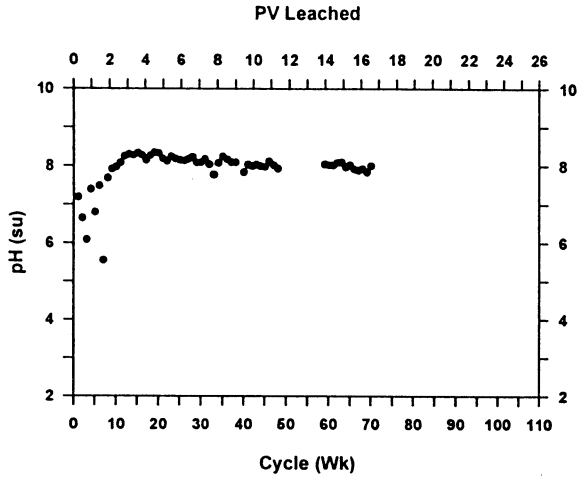

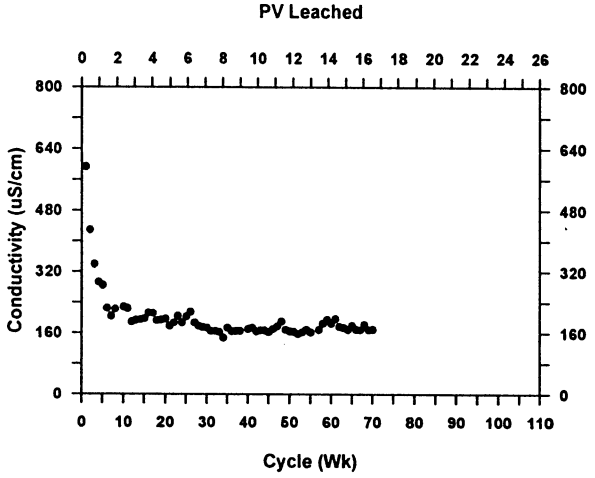

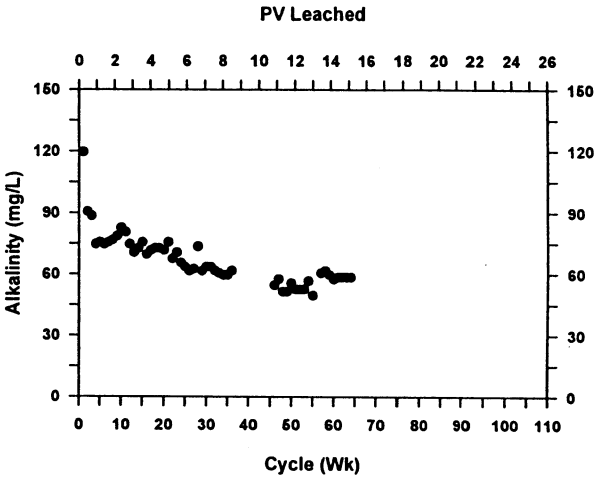

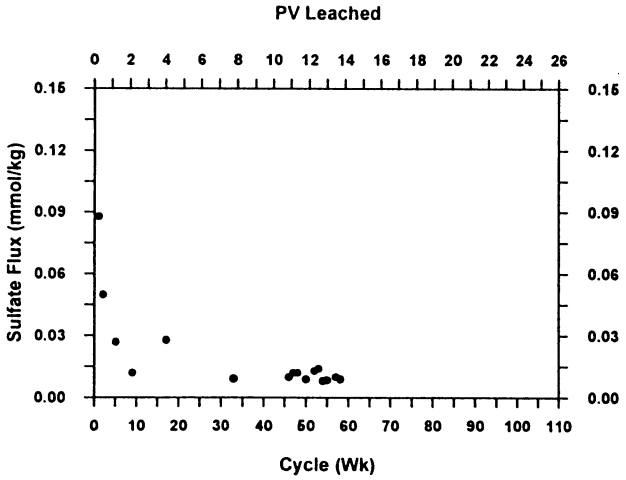

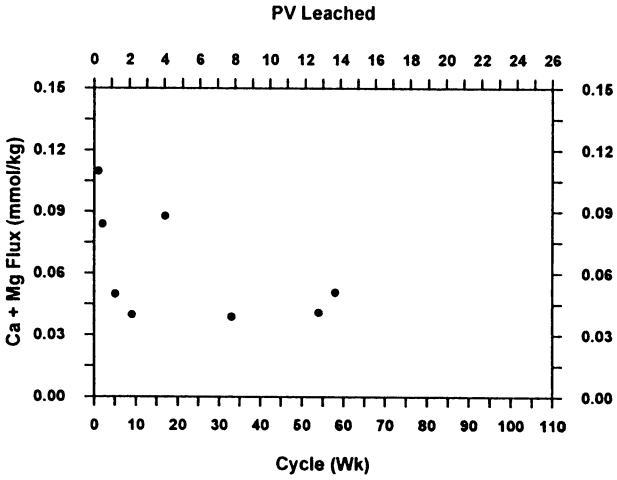

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FIGURE 3.5-53

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE LOWER MOLE LAKE MASTER COMPOSITE (WD-08)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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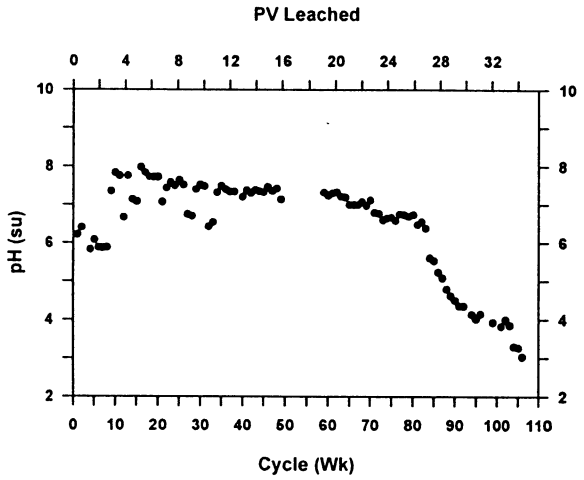

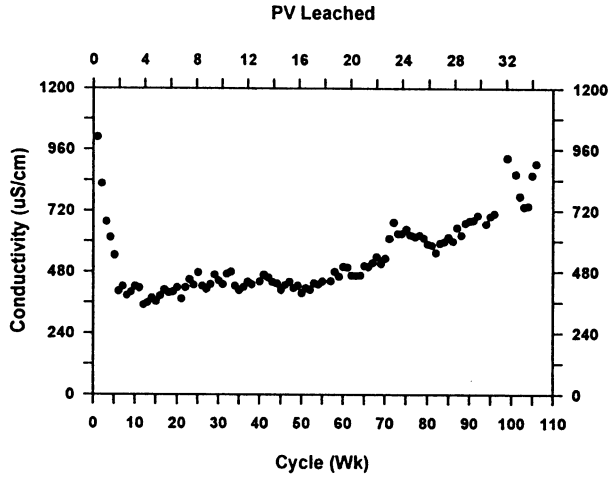

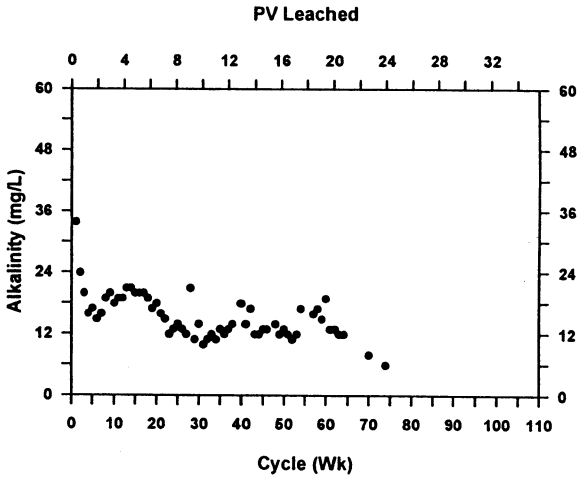

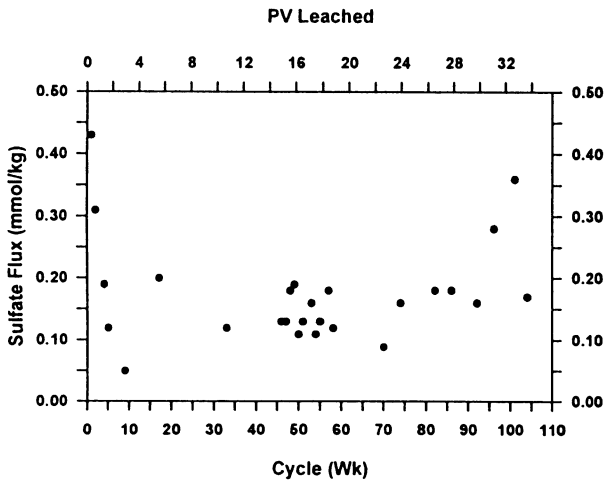

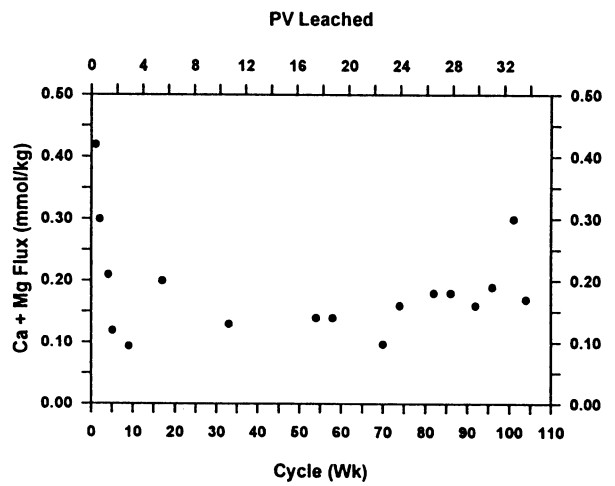

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FIGURE 3.5-54

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE SKUNK LAKE HIGH SULFUR COMPOSITE (WD-09)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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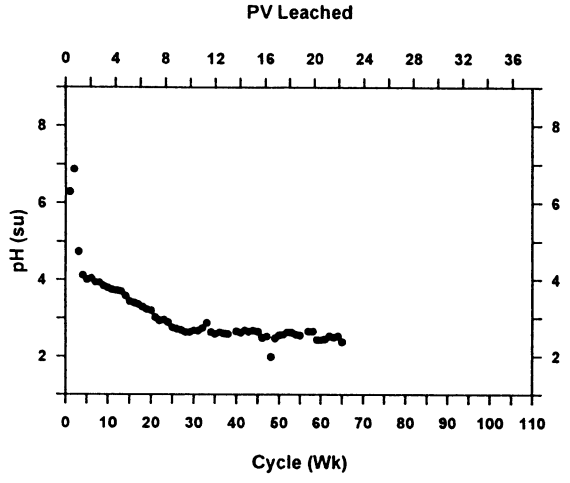

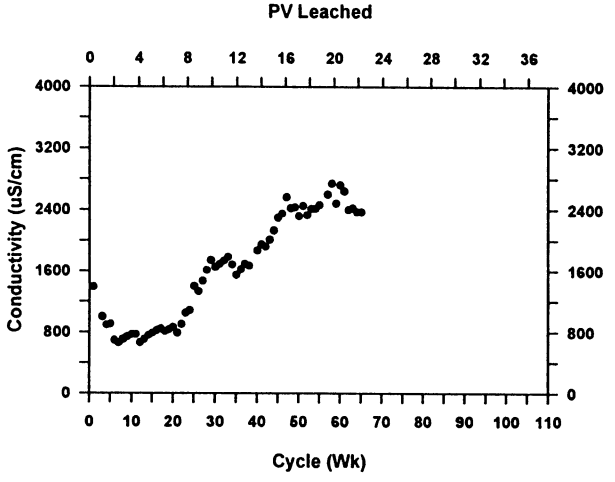

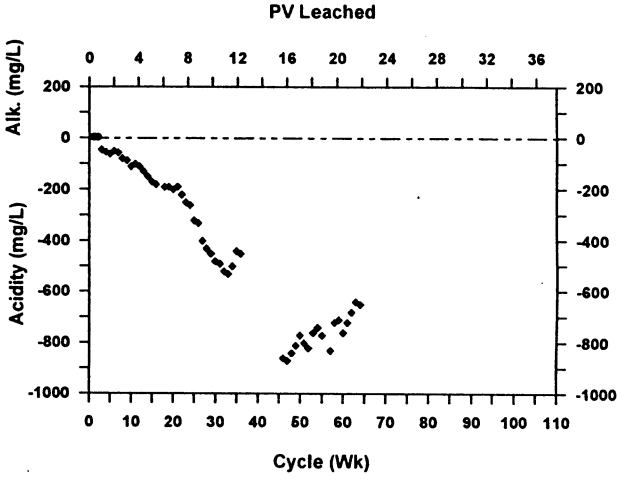

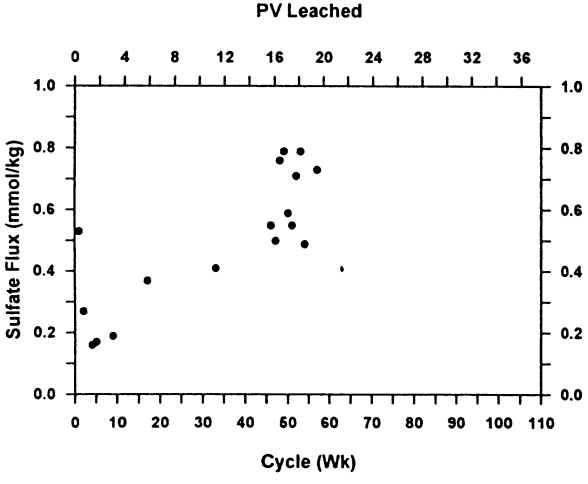

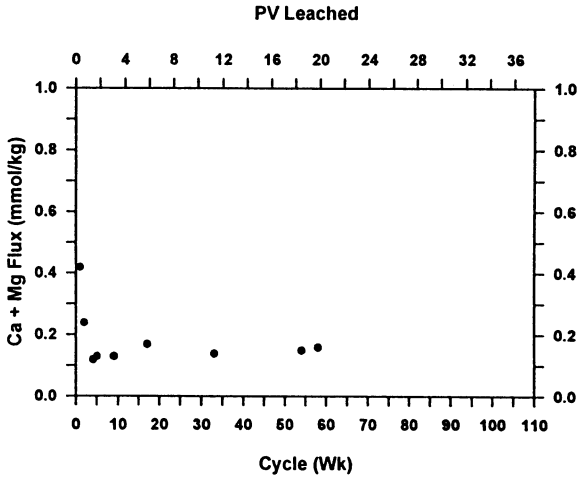

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FIGURE 3.5-55

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE RICE LAKE HIGH SULFUR COMPOSITE (WD-10)

Scale: AS SHOWN	Date: JULY, 1997
Prepared By: Foth & Van Dyke	By: JET

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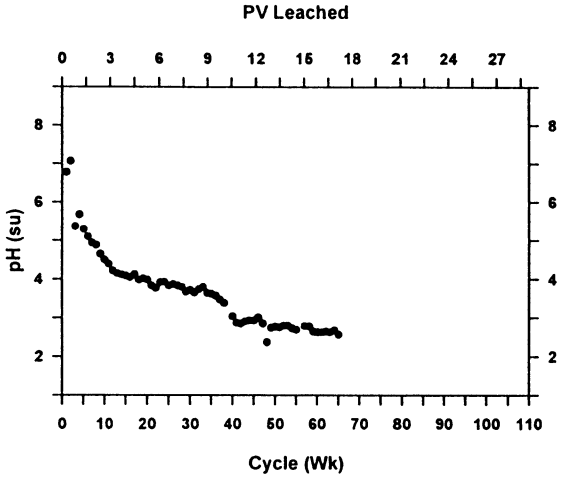

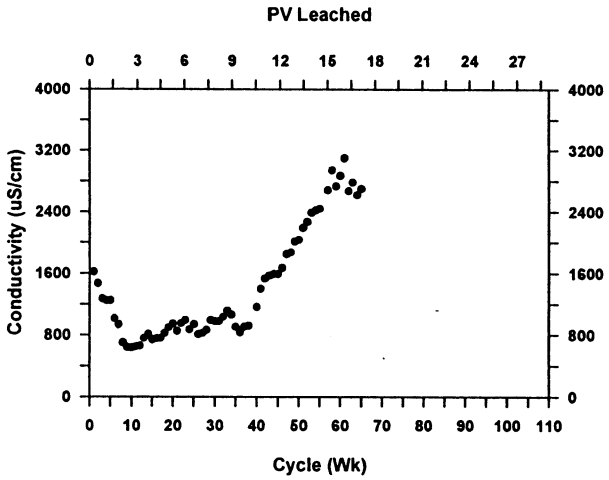

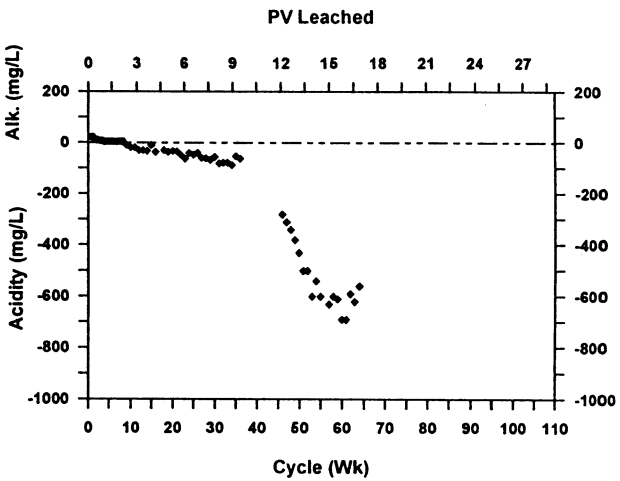

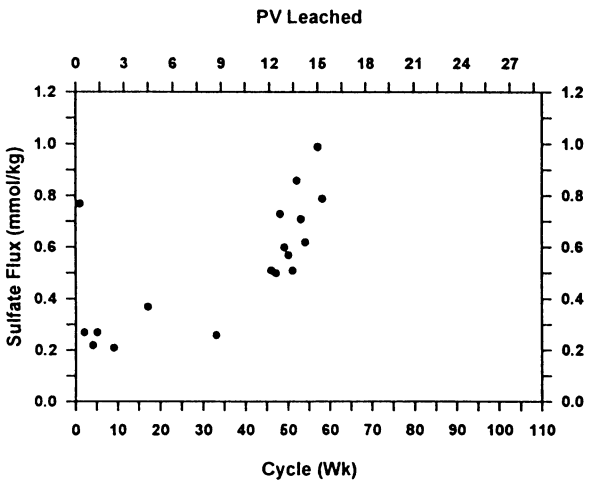

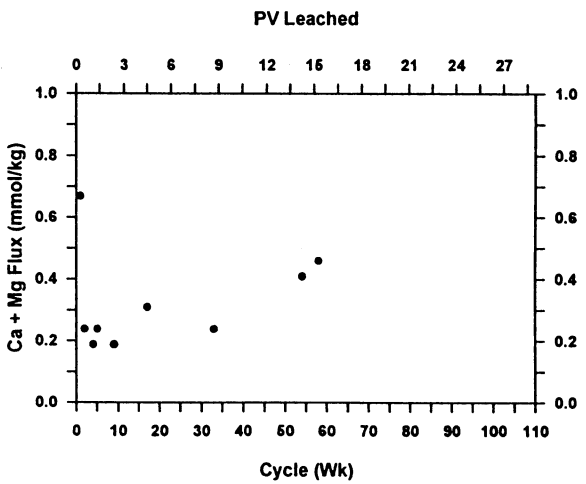

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FIGURE 3.5-56

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE UPPER MOLE LAKE HIGH SULFUR COMPOSITE (WD-11)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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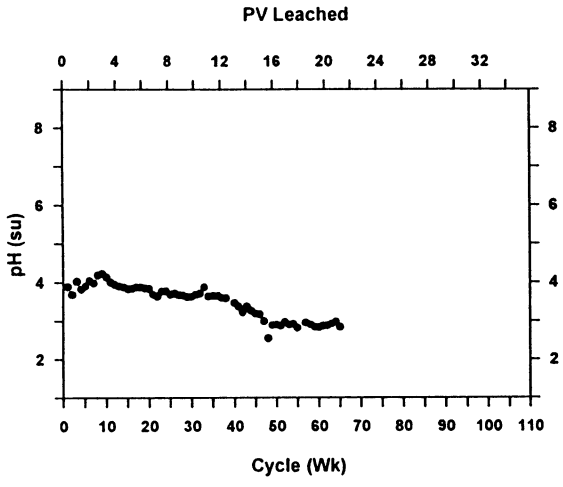

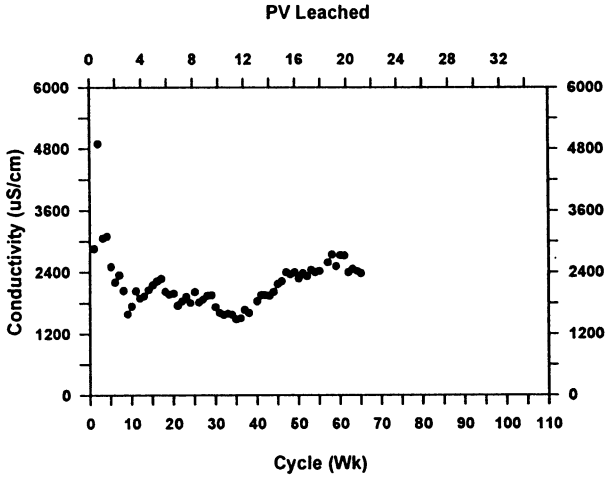

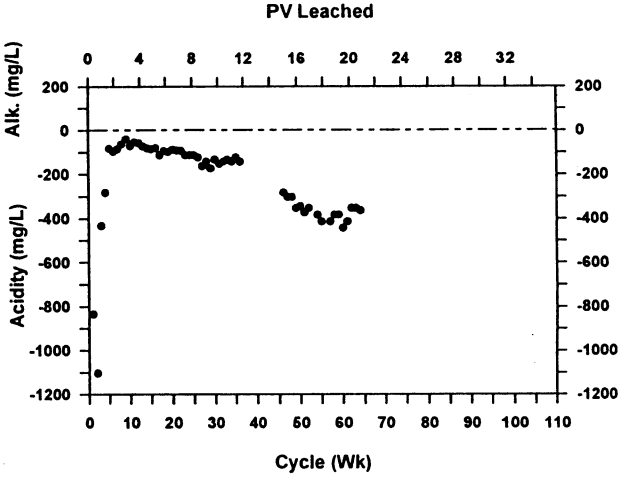

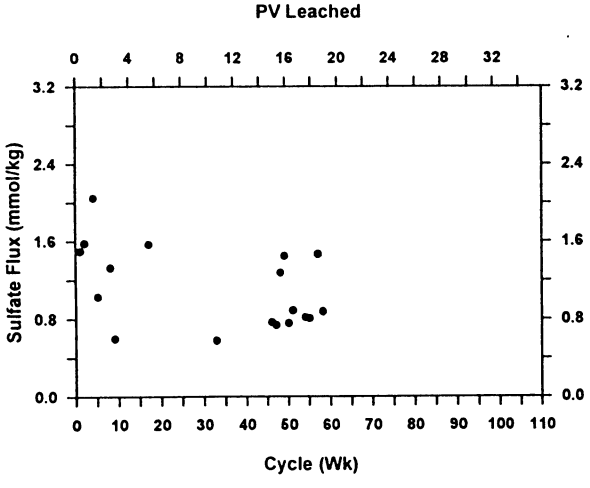

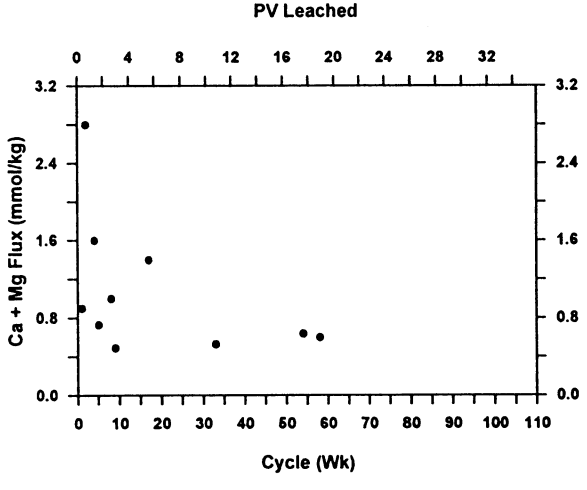

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FIGURE 3.5-57

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE LOWER MOLE LAKE HIGH SULFUR COMPOSITE (WD-12)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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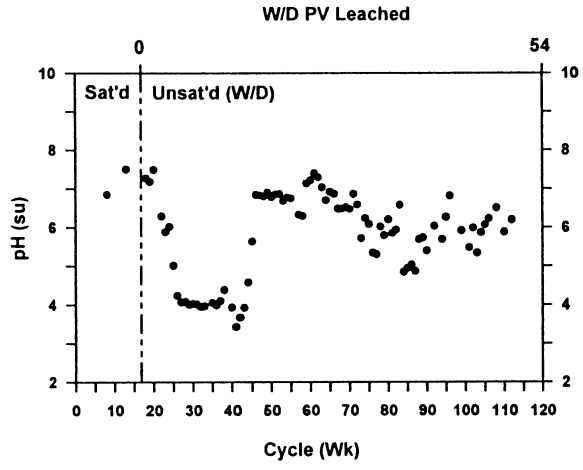

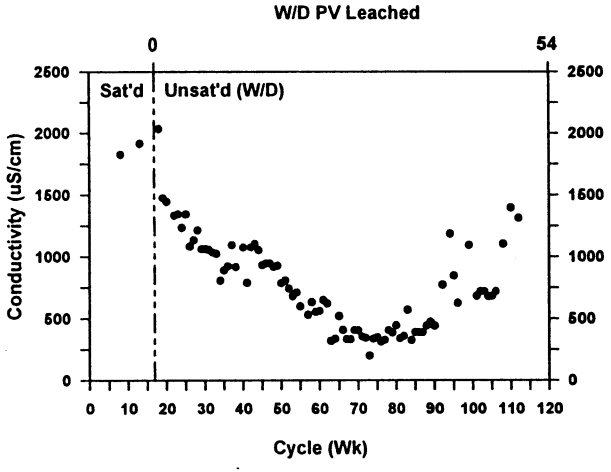

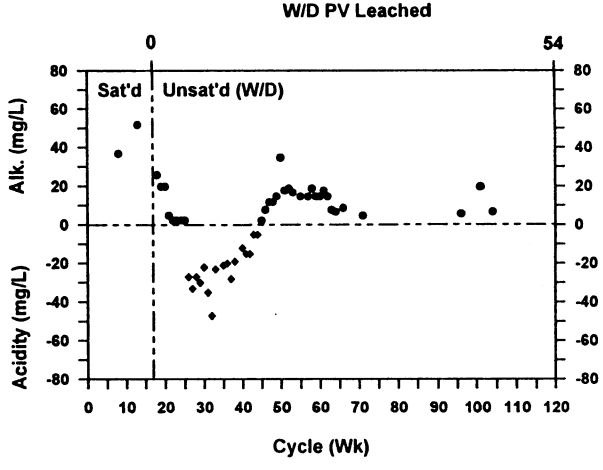

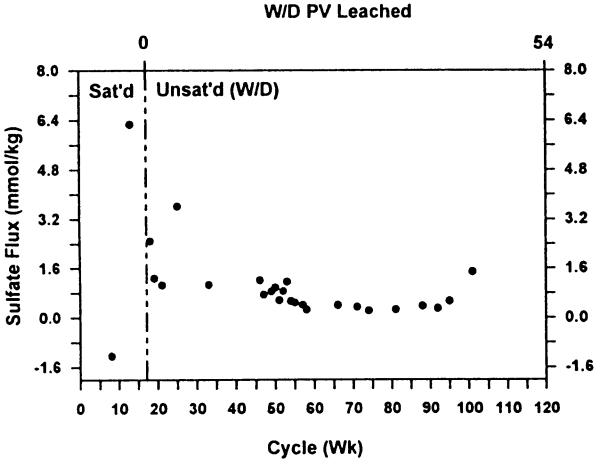

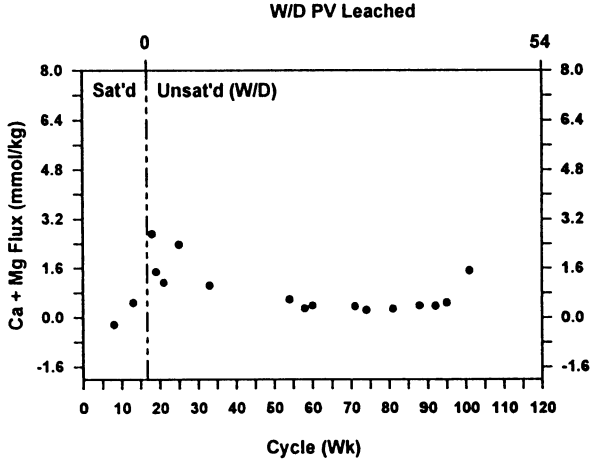

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FIGURE 3.5-58

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND W/D PORE VOLUMES LEACHED IN LEACHATE FROM THE TMA FINE TAILINGS COMPOSITE (RS-18)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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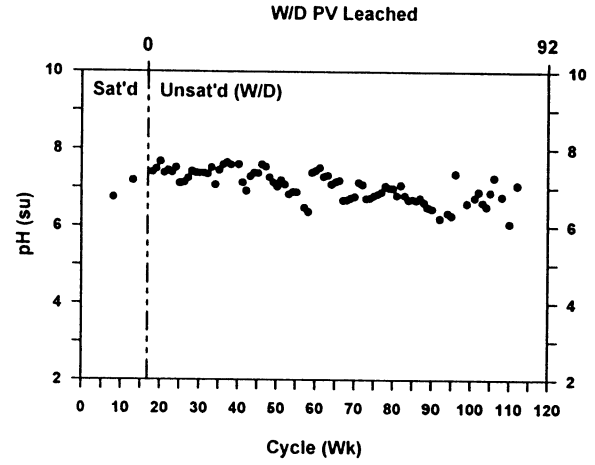

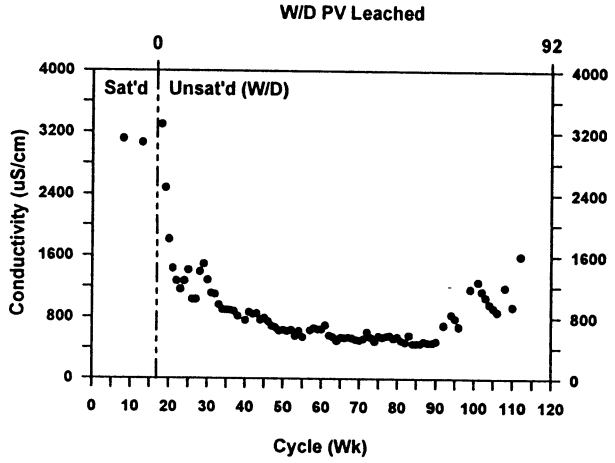

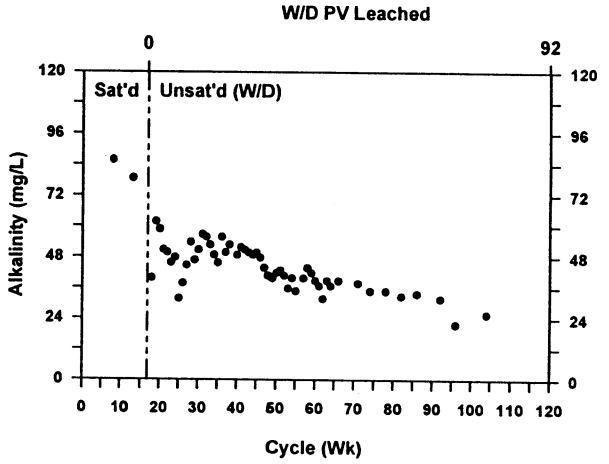

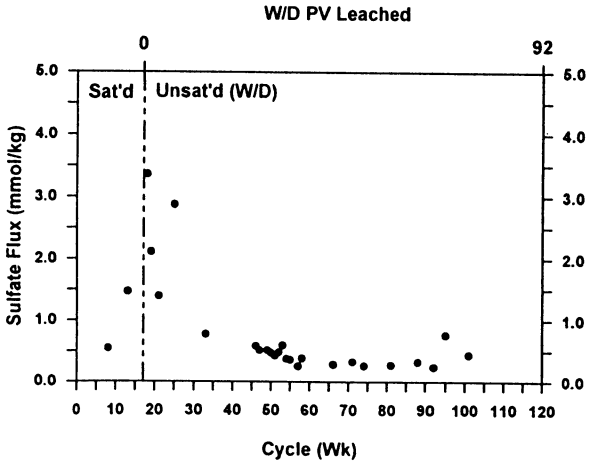

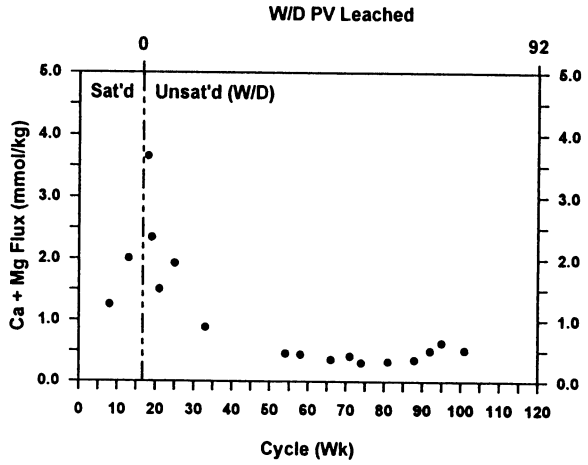

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FIGURE 3.5-59

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND W/D PORE VOLUMES LEACHED IN LEACHATE FROM THE TMA WHOLE TAILINGS COMPOSITE (RS-13)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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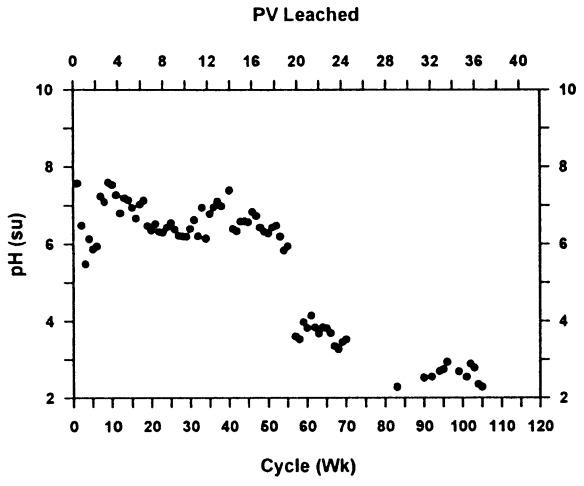

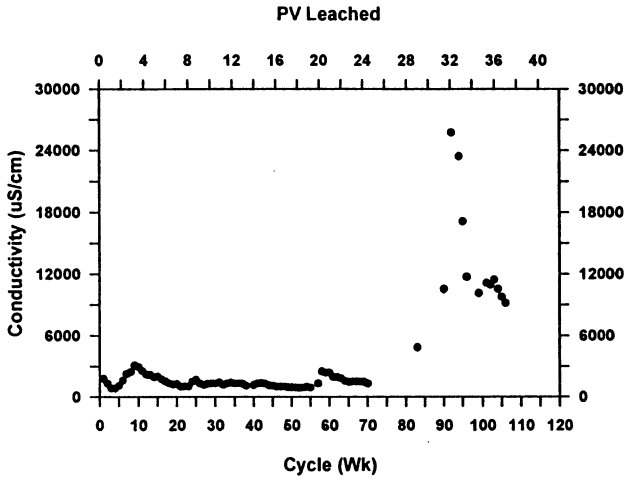

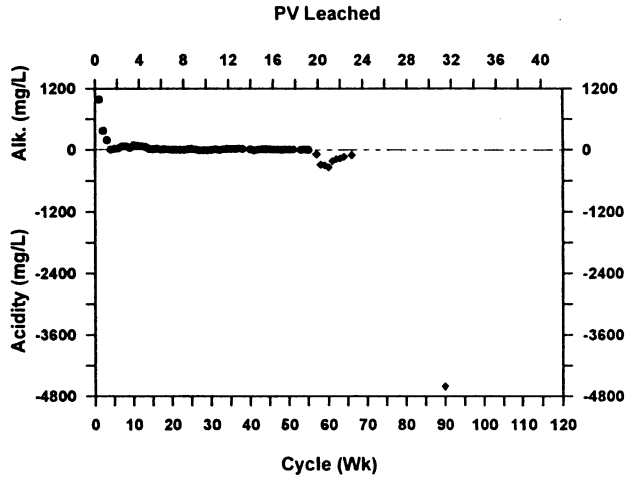

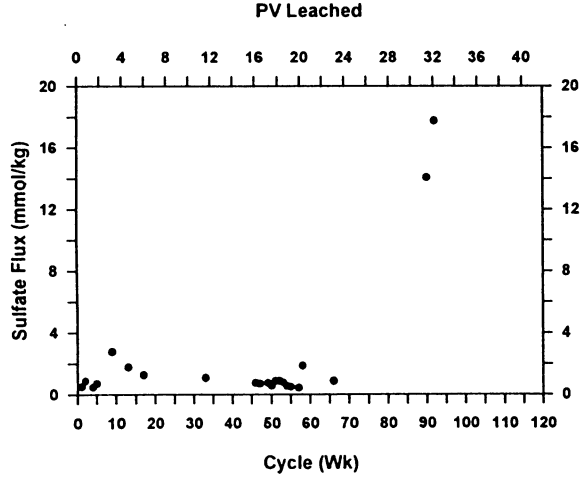

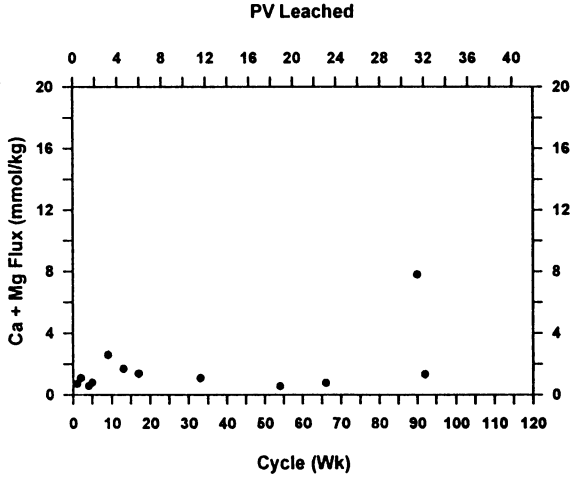

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FIGURE 3.5-60

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE WHOLE TAILINGS COMPOSITE (WD-13)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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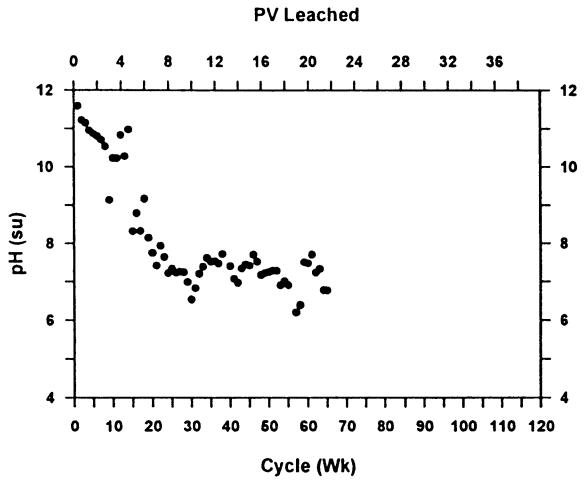

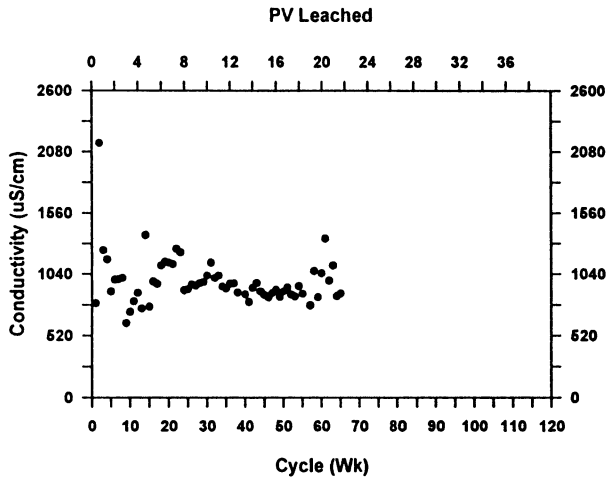

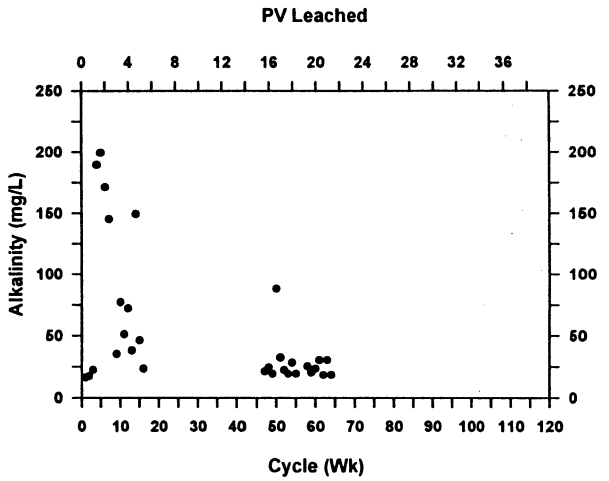

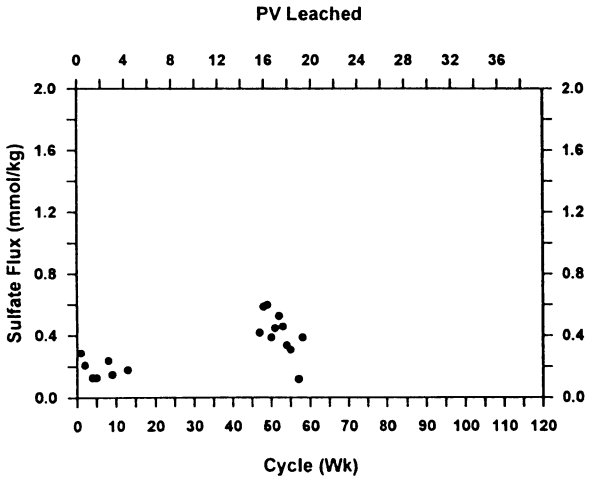

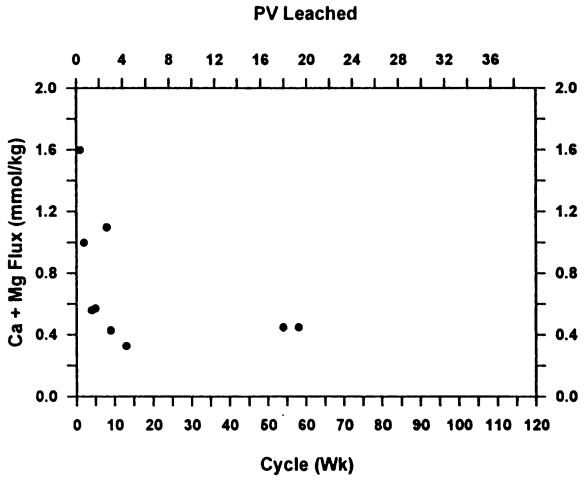

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FIGURE 3.5-61

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND PORE VOLUMES LEACHED IN LEACHATE FROM THE LIME AMENDED WHOLE TAILINGS COMPOSITE (WD-14)

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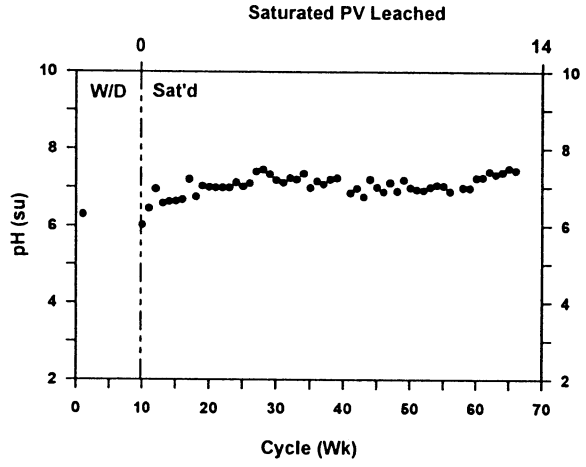

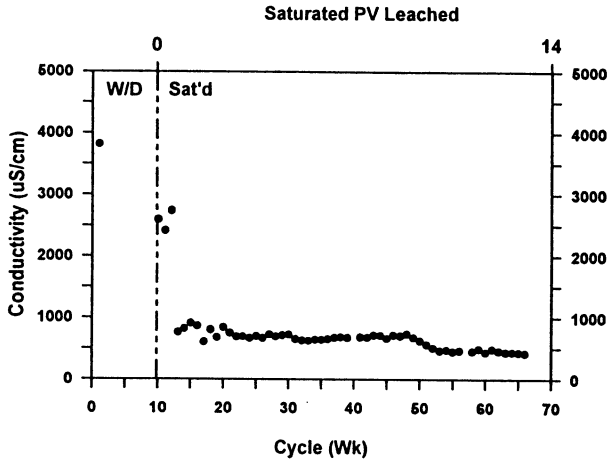

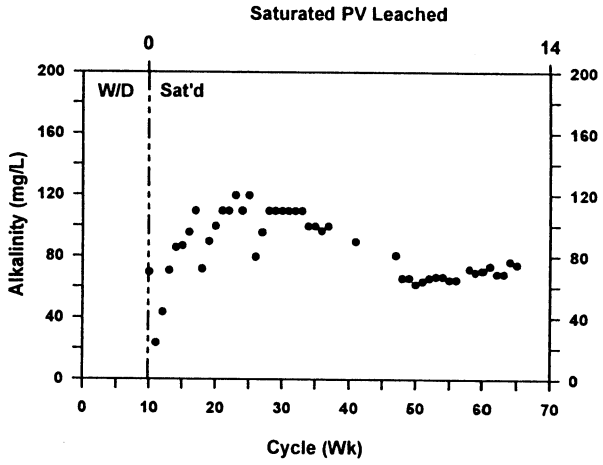

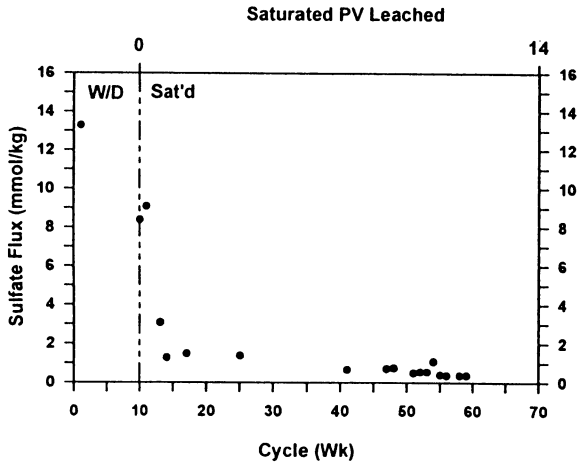

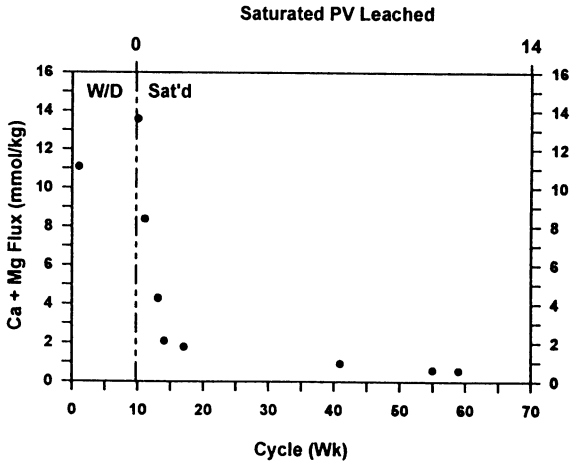

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FIGURE 3.5-62

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND SATURATED PORE VOLUMES LEACHED IN LEACHATE FROM THE BACKFILL COARSE TAILINGS (AL-15)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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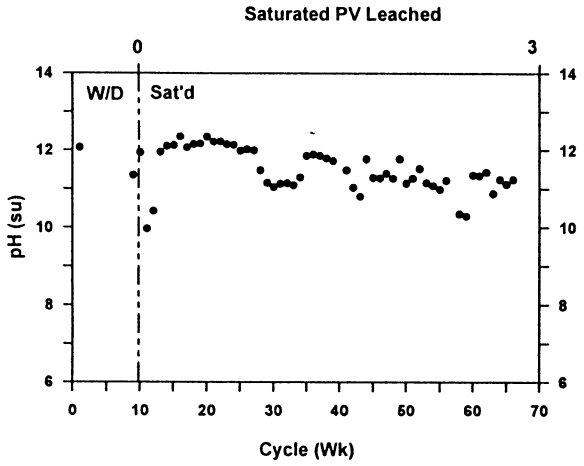

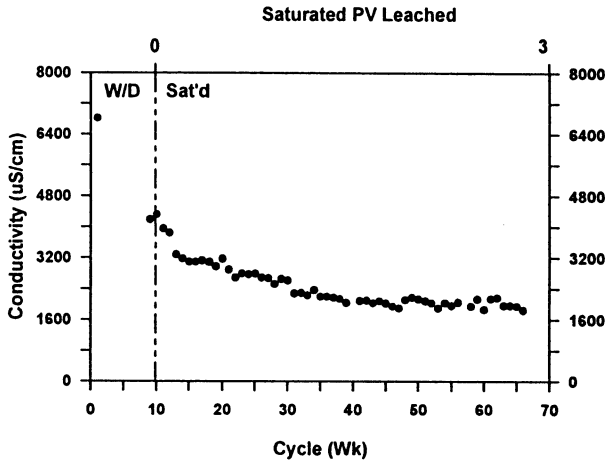

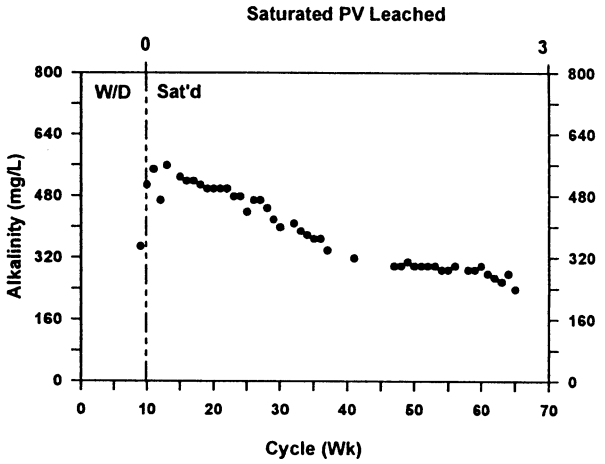

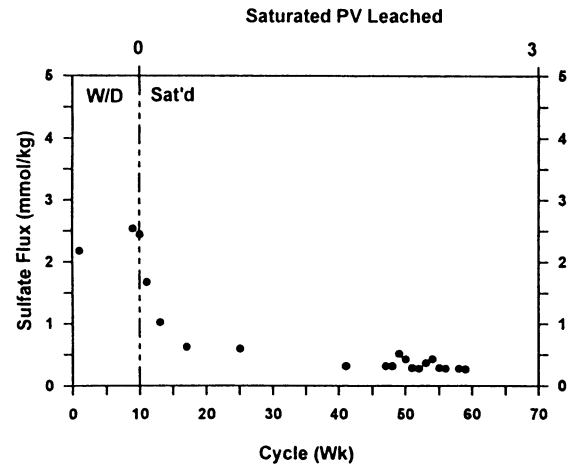

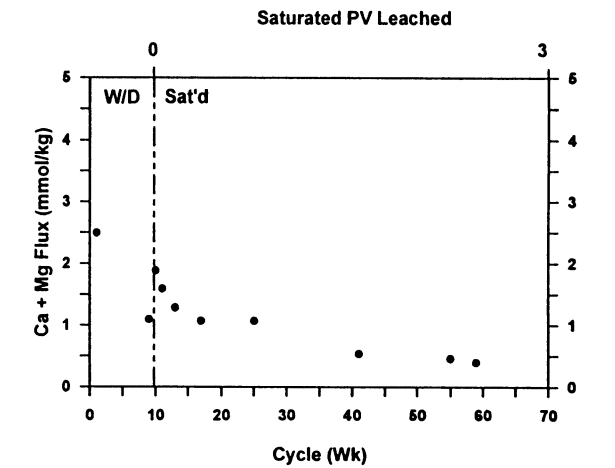

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FIGURE 3.5-63

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND SATURATED PORE VOLUMES LEACHED IN LEACHATE FROM THE BACKFILL CEMENTED COARSE TAILINGS (AL-17)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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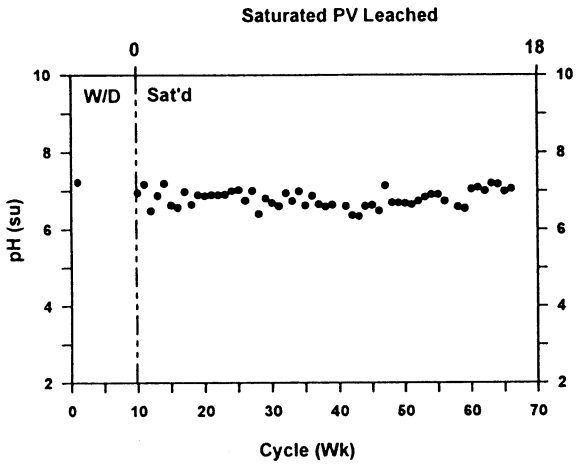

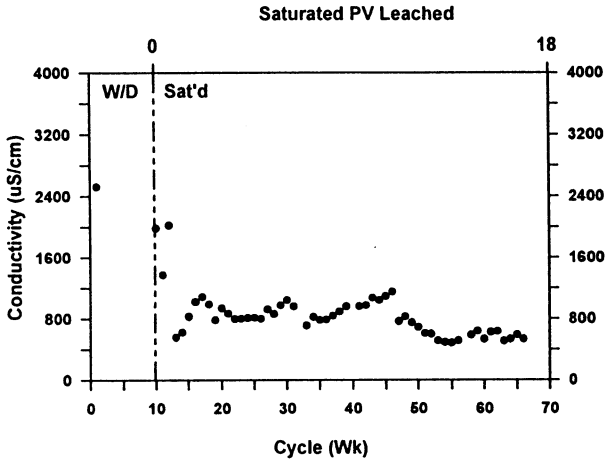

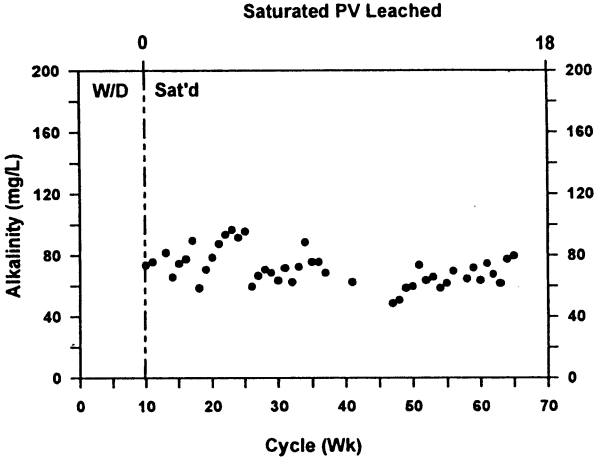

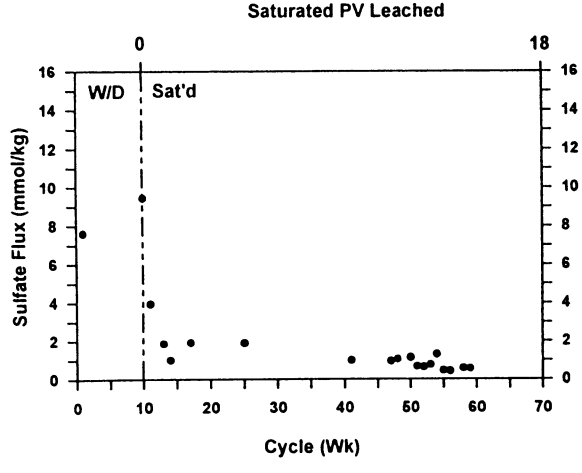

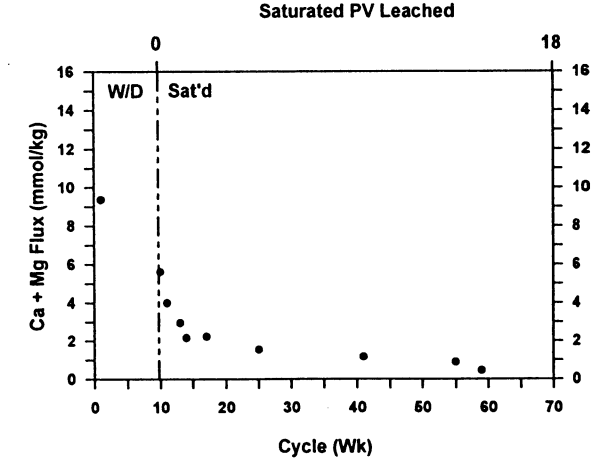

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FIGURE 3.5-64

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND SATURATED PORE VOLUMES LEACHED IN LEACHATE FROM THE BACKFILL WHOLE TAILINGS (AL-13)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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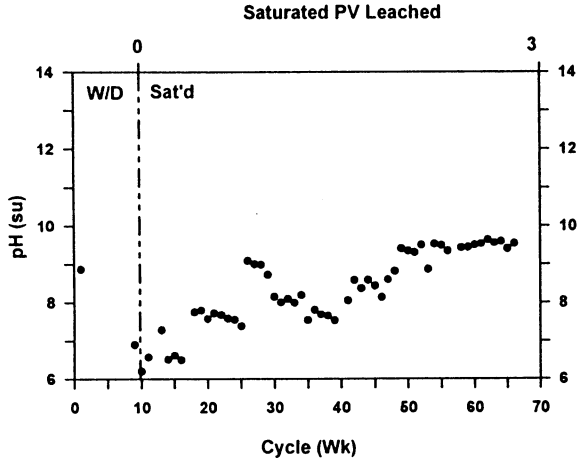

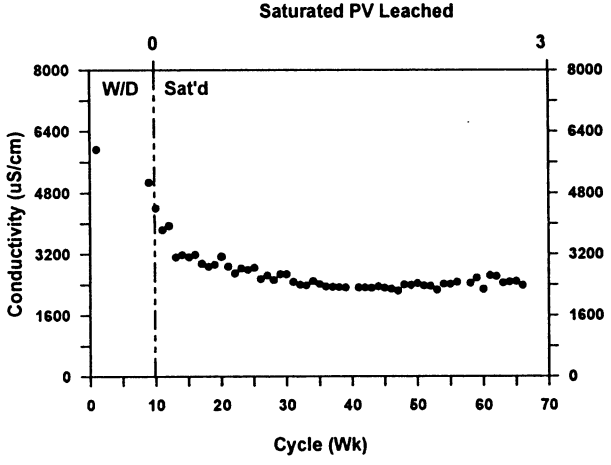

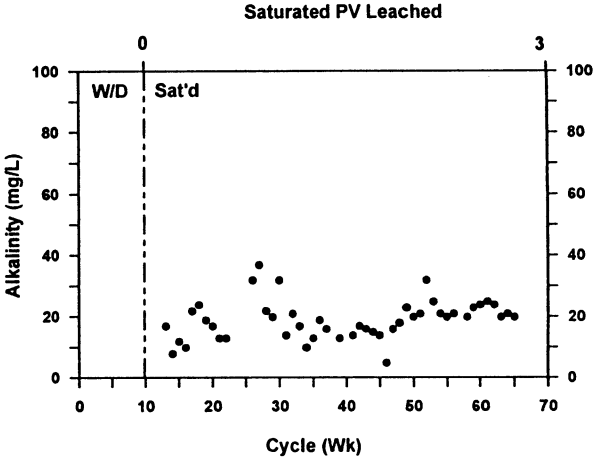

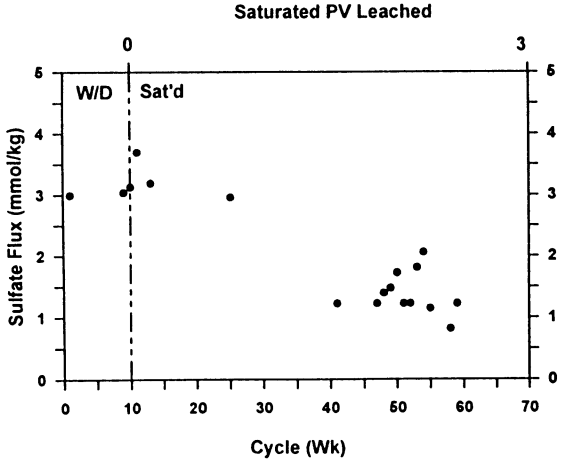

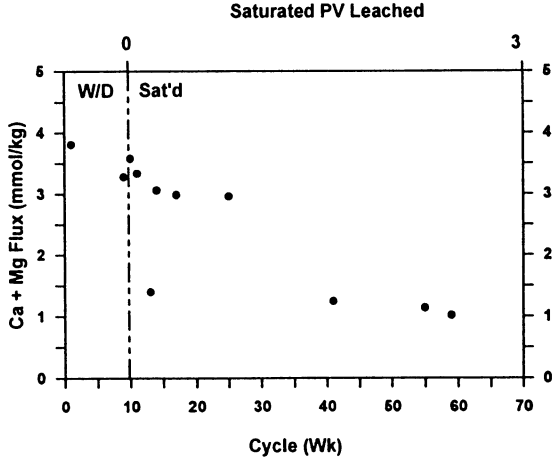

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FIGURE 3.5-65

VARIATIONS IN SELECTED PARAMETERS AND FLUXES WITH TIME AND SATURATED PORE VOLUMES LEACHED IN LEACHATE FROM THE BACKFILL CEMENTED WHOLE TAILINGS (AL-16)

Scale:	AS SHOWN	Date:	JULY, 1997
Prepared By:	Foth & Van Dyke	By:	JET

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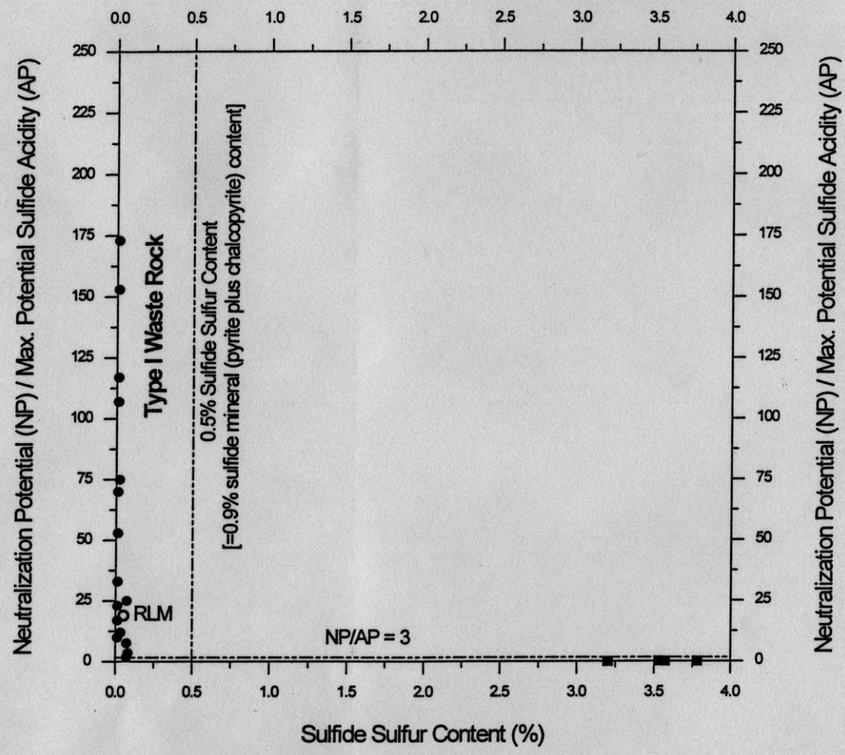

Figure 3.5-66a. Neutralization Potential / Max. Potential Sulfide Acidity (NP/AP) as a Function of Sulfide Sulfur Content (%) for the Rice Lake Master Composite (RLM, open circle), the Randomly Selected Core Intervals Used to Evaluate ABA Variability within the Master Composite (closed circles), and the High Sulfur Composites (squares).

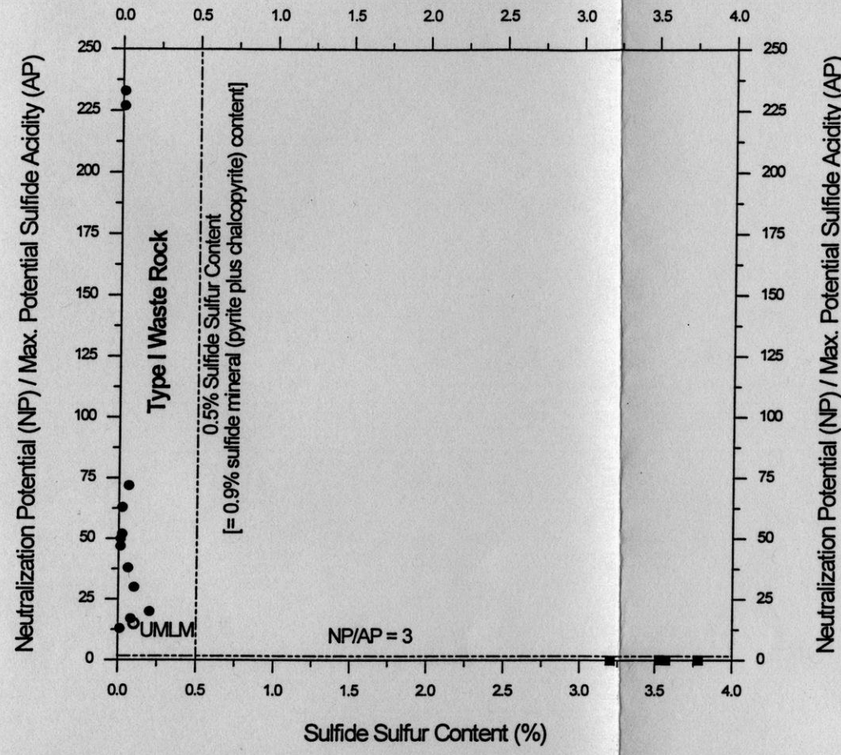

Figure 3.5-66b. Neutralization Potential / Max. Potential Sulfide Acidity (NP/AP) as a Function of Sulfide Sulfur Content (%) for the Upper Mole Lake Master Composite (UMLM, open circle), the Randomly Selected Core Intervals Used to Evaluate ABA Variability within the Master Composite (closed circles), and the High Sulfur Composites (squares).

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	MLD2	DATE: JULY '97
APPROVED BY:	GWS	DATE: JULY '97
APPROVED BY:		DATE:

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FIGURE 3.5-66
RESULTS OF ABA TESTS IN TERMS OF CALCULATED NP/AP VALUES AND SULFIDE SULFUR CONTENT FOR RICE LAKE AND UPPER MOLE LAKE RANDOM CORES

Scale:	AS SHOWN	Date:	JULY '97
Prepared By:	Foth & Van Dyke	By:	JOW

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Environmental Impact Report

Section 3.6

Groundwater

Crandon Mining Company
Environmental Impact Report

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3.6 Groundwater

The purpose of project groundwater and hydrogeologic investigations was to assess existing hydrogeologic conditions with respect to groundwater occurrence, hydrogeologic properties, groundwater flow; to assess groundwater interaction with surface water bodies such as lakes, streams and wetlands; and to establish data regarding background groundwater quality.

Since the late 1970s, numerous investigations have been conducted to characterize the groundwater regime within the project study area. These investigations were conducted in three main phases in the late 1970s and early 1980s by Dames & Moore (1982), Golder Associates (1981b, 1982), and STS Consultants, Ltd (1984a and b). Work included extensive drilling and the installation of groundwater monitoring wells and piezometers to characterize the groundwater regime within the primary hydrostratigraphic units within the study area. The study area is defined as the area bounded by Lake Metonga to the north; St. John's and Rolling Stone Lakes to the south; Pickerel Creek and Mole Lake to the west; and Ground Hemlock, Walsh, Clark and St. John's Lakes to the east. Figure 3.5-1 shows the approximate geographic boundaries of the groundwater study area.

In addition to the regional studies, focused investigations were conducted in the 1980s and 1994 by STS Consultants, Ltd.(1982, 1984c, 1986), Dames and Moore (1985), Foth & Van Dyke (1994a CMC, 1994), and Subsurface Detections Investigations, Inc. (SDII, 1994) that assessed hydrogeologic characteristics that control the interaction between lakes and wetlands located in the immediate project vicinity with the regional groundwater system. Additional studies were conducted in the 1980s and 1994 by Camp, Dresser & McKee (CDM, 1982), Golder Associates (1982), Dames & Moore (1978), Exxon (Landers, 1981), STS Consultants, Ltd. (1984a and b), and Foth & Van Dyke (1995a and b) that assessed major hydraulic characteristics of the glacial overburden and bedrock. Numerous wells and piezometers have been installed in the project study area to characterize groundwater flow, and quality and to evaluate hydraulic parameters. The logs for these borings, soil testing results and some well construction and development data, are contained in appendices previously referenced in Section 3.5 of this report. Additional well construction and development data and in situ hydraulic conductivity testing data is provided in appendices relating to this section of the EIR.

Groundwater quality testing was performed as part of specific studies in the late 1970s and early 1980s. Groundwater quality validation sampling was conducted in 1994 by Foth & Van Dyke. A discussion of the field and laboratory methods employed in the work and results and interpretations follows.

3.6.1 Field and Laboratory Methods

Project groundwater and hydrogeologic studies have been designed to document and describe the hydrogeologic conditions within the study area. Initially, groundwater resources and hydrogeologic conditions were reviewed based on information available from the U.S. Geological Survey (USGS), topographic maps, and information available from the 1976 exploratory drilling program. Based on this initial review, subsequent detailed field investigations were designed for characterization of the regional hydrogeologic conditions and the location and design of the TMA. The remainder of this section contains a description of each investigation and the methods employed.

3.6.1.1 Historical Drilling & Monitoring Well Installation Programs

Well installations have been conducted in various stages that date back to 1977. The following is a description of the major historical well installation programs and the methods employed.

3.6.1.1.1 1977-1979 Dames & Moore Investigations

From 1977 to 1979, 78 monitoring wells were installed in three different phases for hydrogeologic characterization (Dames & Moore 1982). For the first phase, locations were selected for the installation of monitoring wells (DMA series wells) based on the review of available literature on groundwater resources in the vicinity of the project study area. This phase was designed to provide a basic understanding of the hydrogeologic system and groundwater resources within the project study area. Information obtained from this phase was then used to select locations for the next phase of well installations (DMB series wells). The third phase of well installations (DMC series wells) were conducted to obtain information on the hydrogeologic conditions and groundwater resources along the eastern edge of the study area. Additional borings and wells (DMI, DMP, DMS, DW, TW, and WW series) were completed to evaluate the feasibility of various design alternatives. The location of the wells are shown on Figures 3.6-1 and 3.6-2.

Wells constructed of two inch schedule 40 PVC casing fitted with a three to 15 foot section of slotted tubing with 0.01 inch slots were installed in the following manner. Once the borehole drilling was completed, one to two feet of sand and/or pea gravel was poured into the hole. The slotted section of the well was wrapped with a geofabric to discourage fouling of the slots with silts or sands. The screen was then lowered into position so that it rested on the sand and/or pea gravel. Once in position, sand and/or pea gravel was added to the annulus until the material was approximately two feet above the screened interval of the monitoring well. A layer of fine sand was then added to prevent the bentonite-cement slurry from migrating downward and possibly plugging the screen. A bentonite-cement slurry was added to fill the annulus to the ground surface. This material was used to prevent the downward migration of water from water-bearing strata located above the screened interval. Before the bentonite-cement slurry solidified, a protector pipe with a locking protective cap was installed over the top of the well. As each well was installed, construction data were recorded on preprepared forms. A summary of the construction details for each of the wells is contained in Table 3.6-1. Well construction information is provided on boring logs in Appendix 3.5-1.

Wells were not disturbed for a minimum of 24 hours after construction to allow the bentonite-cement slurry time to harden. The wells were then developed using a pitcher pump, bailer, or air lift to surge the water back and forth through the screened interval. This was done to remove the fine material resulting from boring and well installations, and was continued until a relatively clear water sample was obtained.

Table 3.6-1
Summary of Well Completion Data

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Well ID	Date(s) Installed	State Plane Coordinates (ft)		Elevation (msl)		Condition	Construction Details													
		North	East	Ground	PVC		Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
BE-211-1	3/3/81	116533.635	2276308.686	1647.53	1649.61	TA	200.50	158.00	1489.53	197.00	1450.53	143.00	1504.53	200.00	1447.53	2	Grout	1	SS/MS/EWT	P	4
BE-211-2L	2/19/81	116451.725	2276560.523	1660.92	1662.64	TA	188.50	180.00	1480.92	187.00	1473.92	173.00	1487.92	188.00	1472.92	3/4	Grout	2	SS/MS	P	
BE-211-2U	2/19/81	116451.725	2276560.523	1660.92	1662.72	TA	188.50	130.00	1530.92	150.00	1510.92	118.00	1542.92	160.00	1500.92	3/4	Grout	2	EWT	P	4
BE-211-3L	3/19/81	116476.081	2276300.595	1647.89	1650.70	TA	220.50	208.00	1439.89	218.00	1429.89	198.00	1449.89	221.00	1426.89	3/4	Grout	2	SS/MS	P	5
BE-211-3U	3/19/81	116476.081	2276300.595	1647.89	1650.70	TA	220.50	183.00	1464.89	193.00	1454.89	169.00	1478.89	193.00	1454.89	3/4	Grout	2	MS/EWT	P	
BE-213-1	2/13/81	116025.402	2278436.725	1618.92	1621.66	Ab	92.50	65.00	1553.92	90.00	1528.92	53.00	1565.92	93.00	1525.92	2	Grout	1	SS/MS/EWT/CO	P	3
BE-213-2	2/17/81	116063.997	2278664.481	1616.09	1619.35	Ab	95.00	65.00	1551.09	90.00	1526.09	54.00	1562.09	95.00	1521.09	2	Grout	1	SS/MS/EWT/CO	P	4
BE-213-3L	3/24/81	116112.337	2278467.363	1623.74	1625.60	Ab	115.00	103.00	1520.74	113.00	1510.74	97.00	1526.74	115.00	1508.74	3/4	Grout	2	SS	P	
BE-213-3U	3/24/81	116112.337	2278467.363	1623.74	1625.70	Ab	115.00	77.00	1546.74	87.00	1536.74	67.00	1556.74	89.00	1534.74	3/4	Grout	2	MS/EWT/CO	P	4
BE-216-1	3/10/81	116252.761	2277530.922	1657.45	1659.20	TA	151.50	129.00	1528.45	149.00	1508.45	119.00	1538.45	152.00	1505.45	2	Grout	1	MS/EWT/SS	P	4
BE-216-2	3/18/81	116327.310	2277744.023	1655.18	1657.11	TA	140.50	118.00	1537.18	138.00	1517.18	113.00	1542.18	141.00	1514.18	3/4	Grout	1	MS/EWT/SS	P	
BE-216-3L	4/14/81	116338.082	2277555.071	1661.98	1664.08	TA	178.50	160.00	1501.98	170.00	1491.98	156.00	1505.98	178.50	1483.48	3/4	Grout	2	SS	P	5
BE-216-3U	4/14/81	116338.082	2277555.071	1661.98	1664.08	TA	178.50	123.00	1538.98	149.00	1512.98	111.00	1550.98	150.00	1511.98	3/4	Grout	2	MS/EWT	P	4
CDM-4 ~	12/81	116533.290	2275382.320	1641.39	1644.04	TA	195.00	60.00	1581.39	90.00	1551.39	60.00	1581.39	90.00	1551.39	2	NR	1	CO	WT	
CDM-15	12/81	119587.670	2276543.210	1645.76	1646.44	TA	180.00	60.00	1585.76	90.00	1555.76	60.00	1585.76	90.00	1555.76	2	NR	1	CO	WT	
CDM-16	12/81	114360.100	2277074.010	1595.56	1597.01	A	180.00	50.00	1545.56	80.00	1515.56	NR	NR	NR	NR	2	NR	1	FO	P	
CDM-17	12/81	114387.870	2277034.440	1596.71	1598.37	TA	9.70	7.70	1589.01	9.70	1587.01	None	None	None	None	2 - SWP	None	1	FO	WT	
CDM-18	12/81	114345.430	2277078.070	1595.15	1596.81	A	29.10	27.10	1568.05	29.10	1566.05	None	None	None	None	2 - SWP	None	1	CO	P	
CDM-19	12/81	114345.430	2277078.070	1595.15	1596.67	A	8.00	6.00	1589.15	8.00	1587.15	None	None	None	None	2 - SWP	None	1	FO	WT	
CDM-20	12/81	114320.070	2277138.120	1594.50	1597.07	TA	8.00	6.00	1588.50	8.00	1586.50	None	None	None	None	2 - SWP	None	1	FO	WT	
DMA-1	3/14/77	113660.000	2272030.000	1637.96	1639.60	TA	55.00	51.00	1586.96	55.00	1582.96	45.00	1592.96	55.00	1582.96	2	Grout	1	CO	DRY	
DMA-10	3/15/77	110510.000	2275400.000	1593.58	1595.07	Ab	46.00	42.00	1551.58	46.00	1547.58	33.00	1560.58	46.00	1547.58	2	Grout	1	CO	WT	2
DMA-12	3/24/77	117887.267	2279966.309	1621.18	1622.92	A	45.00	41.00	1580.18	45.00	1576.18	35.00	1586.18	45.00	1576.18	2	Grout	1	CO	WT	2
DMA-13	5/14/77	110450.000	2265800.000	1554.66	1556.04	Ab	40.50	35.00	1519.66	39.00	1515.66	32.50	1522.16	39.00	1515.66	2	Bent/Grout	1	FO/LA	P	2
DMA-16	3/17/77	123792.874	2271254.081	1589.93	1591.28	Ab	60.30	56.00	1533.93	60.00	1529.93	52.00	1537.93	60.00	1529.93	2	Bent/Grout	1	CO/LWT	WT	2
DMA-17	4/6/77	106565.370	2275547.040	1563.95	1565.48	Ab	36.00	27.50	1536.45	31.50	1532.45	20.00	1543.95	34.00	1529.95	2	Bent/Grout	1	CO	P	
DMA-18	4/6/77	111757.520	2269883.645	1619.36	1621.09	A	70.50	66.00	1553.36	70.00	1549.36	55.00	1564.36	70.50	1548.86	2	Grout	1	CO	WT	2
DMA-19	3/21/77	115003.778	2279719.951	1597.24	1598.45	A	30.00	22.00	1575.24	26.00	1571.24	15.00	1582.24	26.00	1571.24	2	Grout	1	CO/LWT	WT	2
DMA-1N	5/77	113664.490	2272028.860	1637.96	1638.86	Ab	55.00	14.00	1623.96	18.00	1619.96	10.00	1627.96	18.00	1619.96	2	Grout	1	LWT	PERCHED	
DMA-1S	5/77	113661.403	2272029.866	1637.96	1638.88	Ab	55.00	51.00	1586.96	55.00	1582.96	45.50	1592.46	55.00	1582.96	2	Grout	1	LWT/CO	DRY	
DMA-20	3/28/77	119200.231	2272622.047	1591.97	1593.18	A	54.00	50.00	1541.97	54.00	1537.97	36.00	1555.97	54.00	1537.97	2	Grout	1	CO/LWT	WT	2
DMA-22B	11/8/79	113800.000	2297350.000	1629.19	1630.74	Ab	100.40	90.00	1539.19	100.00	1529.19	78.80	1550.39	100.40	1528.79	2	Bent/Grout	1	CO	P	2
DMA-29	3/26/77	101230.000	2251380.000	1537.11	1538.60	Ab	40.00	17.00	1520.11	21.00	1516.11	9.00	1528.11	40.00	1497.11	2	Grout	1	LA	WT	
DMA-29AL	5/12/77	101250.000	2251380.000	1536.69	1538.45	Ab	53.00	50.00	1486.69	53.00	1483.69	48.00	1488.69	53.00	1483.69	3/4	Bent	2	CO	P	
DMA-29AU	5/12/77	101250.000	2251380.000	1539.69	1538.46	Ab	53.00	42.00	1497.69	46.00	1493.69	38.50	1501.19	46.00	1493.69	2	Grout	2	LA	P	
DMA-3	3/11/77	115494.403	2273938.327	1647.51	1648.95	Ab	45.00	39.00	1608.51	43.00	1604.51	32.00	1615.51	45.00	1602.51	2	Grout	1	LWT	DRY	
DMA-31	4/18/77	120160.000	2281570.000	1592.09	1593.53	A	25.00	21.00	1571.09	24.00	1568.09	15.00	1577.09	24.00	1568.09	2	Bent/Grout	1	LWT	WT	1
DMA-32A	4/28/77	112050.000	2290580.000	1592.14	1593.55	Ab	175.00	33.00	1559.14	37.00	1555.14	30.00	1562.14	42.00	1550.14	2	Bent/Grout	1	CO	WT	2
DMA-34	4/15/77	114000.000	2248050.000	1535.92	1537.03	Ab	30.50	18.00	1517.92	22.00	1513.92	15.00	1520.92	22.00	1513.92	2	Bent/Grout	1	LWT/LA	WT	
DMA-35	5/14/77	111180.000	2245820.000	1570.39	1571.79	Ab	29.50	25.00	1545.39	29.00	1541.39	20.00	1550.39	29.50	1540.89	2	Grout	1	CO	WT	
DMA-38	5/3/77	141150.000	2249880.000	1772.00	1773.49	Ab	30.00	24.50	1747.50	28.50	1743.50	19.50	1752.50	30.00	1742.00	2	Grout	1	LWT/CO	DRY	
DMA-4	3/23/77	111424.715	2280846.947	1612.03	1613.55	TA	30.00	26.00	1586.03	30.00	1582.03	14.00	1598.03	30.00	1582.03	2	Grout	1	LWT	WT	1
DMA-43	3/25/77	137000.000	2272720.000	1624.70	1626.58	Ab	40.00	36.00	1588.70	40.00	1584.70	25.00	1599.70	40.00	1584.70	2	Grout	1	LWT	P	1
DMA-45	5/1/77	100630.000	2310200.000	1640.61	1641.98	Ab	49.20	44.00	1596.61	48.00	1592.61	33.00	1607.61	48.00	1592.61	2	Grout	1	CO	WT	
DMA-46	5/02/77	117420.000	2319400.000	1714.52	1715.75	Ab	72.50	68.50	1646.02	72.50	1642.02	45.00	1669.52	72.50	1642.02	2	Grout	1	CO	DR	
DMA-47	3/30/77	121392.614	2276057.949	1573.62	1574.71	Ab	31.00	23.00	1550.62	27.00	1546.62	17.50	1556.12	31.00	1542.62	2	Grout	1	LWT	WT	1
DMA-48	3/26/77	118981.495	2268708.522	1547.42	1548.71	A	29.50	24.00	1523.42	28.00	1519.42	20.00	1527.42	28.00	1519.42	2	Grout/Bent	1	CO	WT	2
DMB-1	5/11/78	114405.000	2282890.000	1627.30	N/A	TA	59.30	5.00	1622.30	15.00	1612.30	5.00	1622.30	15.00	1612.30	2	Grout	1	LWT	DRY	
DMB-10	6/23/78	117720.000	2271170.000	1619.11	1620.67	A	99.50	89.50	1529.61	99.50	1519.61	62.00	1557.11	99.50	1519.61	2	Bent/Grout	1	FO/LWT	P	2
DMB-11	6/27/78	109960.000	2273820.000	1656.85	1658.95	A	100.00	89.50	1567.35	99.50	1557.35	86.00	1570.85	99.50	1557.35	2	Bent/Grout	1	CO	WT	2
DMB-12	6/27/78	107390.000	2275205.000	1586.05	1587.59	Ab	81.90	70.00	1516.05	80.00	1506.05	70.00	1516.05	80.00	1506.05	2	Bent/Grout	1	LWT	P	2
DMB-13	6/29/78	107110.000	2269980.000	1609.39	1611.03	Ab	60.00	50.00	1559.39	60.00	1549.39	48.00	1561.39	60.00	1549.39	2	Bent/Grout	1	LWT	WT	2
DMB-14	6/29/78	110075.000	2270985.000	1638.69	N/A	Ab	100.90	90.00	1548.69	100.00	1538.69	87.00	1551.69	100.00	1538.69	2	Bent/Grout	1	CO	P	

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Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft)		Elevation (msl)		Condition	Construction Details												# of Wells per Boring	Formation Monitored	Well Type	Model Layer
		North	East	Ground	PVC		Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal					
DMB-15	6/7/78	113660.000	2272025.000	1637.52	1639.50	TA	79.50	69.50	1568.02	79.50	1558.02	60.00	1577.52	79.50	1558.02	2	Bent/Grout	1	CO	WT	
DMB-16	6/9/78	111880.000	2273475.000	1674.63	1675.44	TA	99.20	88.50	1586.13	98.50	1576.13	63.00	1611.63	98.50	1576.13	2	Grout	1	CO	DRY	
DMB-17	6/9/78	108960.000	2268755.000	1648.95	1650.43	Ab	80.50	70.00	1578.95	80.00	1568.95	70.00	1578.95	80.00	1568.95	2	Bent/Grout	1	CO	DRY	
DMB-18	6/10/78	110560.000	2268060.000	1601.40	1602.50	Ab	80.90	70.00	1531.40	80.00	1521.40	65.00	1536.40	80.00	1521.40	2	Bent/Grout	1	CO	WT	2
DMB-19	6/21/78	110450.000	2265815.000	1554.64	1554.29	Ab	160.70	76.50	1478.14	86.50	1468.14	65.00	1489.64	86.50	1468.14	2	Grout	1	CO	P	
DMB-1A	5/16/78	114405.000	2282900.000	1627.94	1629.60	A	79.40	69.00	1558.94	79.00	1548.94	30.00	1597.94	79.00	1548.94	2	Grout	1	CO/LWT	WT	1
DMB-2	5/17/78	114995.000	2285800.000	1706.28	1707.99	TA	100.30	90.20	1616.08	100.20	1606.08	68.20	1638.08	100.20	1606.08	2	Bent/Grout	1	CO/LWT	DRY	
DMB-20	6/10/78	115725.000	2270530.000	1605.80	1607.61	TA	40.00	29.20	1576.60	39.20	1566.60	25.50	1580.30	39.20	1566.60	2	Bent/Grout	1	CO/LA	PERCHED	
DMB-20A	11/27-28/78	115720.000	2270545.000	1606.20	1607.77	TA	84.80	79.50	1526.70	84.50	1521.70	75.00	1531.20	84.50	1521.70	2	Bent/Grout	1	CO	P	2
DMB-21	6/12/78	112820.000	2265775.000	1559.32	1561.25	Ab	49.50	38.90	1520.42	48.90	1510.42	30.00	1529.32	48.90	1510.42	2	Bent/Grout	1	CO	P	2
DMB-22	6/13/78	113240.000	2269090.000	1616.48	1618.13	Ab	79.00	68.60	1547.88	78.60	1537.88	70.00	1546.48	78.60	1537.88	2	Bent/Grout	1	CO	WT	2
DMB-23	6/21/78	115900.000	2268205.000	1563.30	1564.96	A	99.20	89.00	1474.30	99.00	1464.30	88.00	1475.30	99.20	1464.10	2	Bent/Grout	1	FO	P	3
DMB-24	12/18/78	102060.000	2271375.000	1565.43	1566.84	Ab	49.00	43.20	1522.23	48.20	1517.23	42.00	1523.43	48.20	1517.23	2	Bent/Grout	1	CO	P	2
DMB-25	12/15-18/78	105725.000	2268525.000	1644.66	1646.01	Ab	129.50	124.50	1520.16	129.50	1515.16	118.00	1526.66	129.50	1515.16	2	Bent/Grout	1	CO	WT	3
DMB-26	12/12-13/78	105520.000	2282250.000	1712.98	1714.29	Ab	134.10	124.00	1588.98	134.00	1578.98	120.00	1592.98	134.00	1578.98	2	Bent/Grout	1	CO	WT	2
DMB-27	12/6/78	108675.000	2283695.000	1649.04	1650.57	Ab	83.90	73.80	1575.24	83.80	1565.24	72.00	1577.04	83.80	1565.24	2	Bent/Grout	1	CO	WT	2
DMB-28	12/5/78	106840.000	2285425.000	1642.13	1643.70	Ab	70.00	64.50	1577.63	69.50	1572.63	63.00	1579.13	69.50	1572.63	2	Bent/Grout	1	CO	WT	2
DMB-29	11/29/78	104385.000	2288110.000	1629.98	1631.53	Ab	69.30	64.30	1565.68	69.30	1560.68	62.00	1567.98	69.30	1560.68	2	Bent/Grout	1	CO/LWT	WT	2
DMB-3	5/18/78	116895.000	2287465.000	1587.93	1590.31	Ab	61.50	55.00	1532.93	60.00	1527.93	50.00	1537.93	60.00	1527.93	2	Grout	1	CO	P	2
DMB-4	5/22-23/78	118405.000	2283785.000	1644.49	1645.93	A	80.30	69.50	1574.99	79.50	1564.99	69.50	1574.99	79.50	1564.99	2	Bent/Grout	1	LWT/CO	WT	1
DMB-5	5/24/78	112135.000	2285540.000	1688.77	1690.43	TA	98.50	88.40	1600.37	98.40	1590.37	68.00	1620.77	98.40	1590.37	2	Grout	1	CO/LWT	WT	1
DMB-5A	12/4/78	112130.000	2285545.000	1689.33	1690.68	TA	120.20	110.00	1579.33	120.00	1569.33	96.00	1593.33	120.00	1569.33	2	Bent/Grout	1	LWT/CO	P	1
DMB-6	5/26/78	112385.000	2283015.000	1666.47	1668.12	A	86.00	75.50	1590.97	85.50	1580.97	61.60	1604.87	85.50	1580.97	2	Bent/Grout	1	LWT	WT	1
DMB-7	6/6/78	106150.000	2287845.000	1653.67	1654.97	Ab	79.20	69.00	1584.67	79.00	1574.67	59.00	1594.67	79.00	1574.67	2	Bent/Grout	1	CO	WT	2
DMB-8	6/7/78	114595.000	2287840.000	1622.74	1624.58	Ab	50.70	45.00	1577.74	50.00	1572.74	40.00	1582.74	50.00	1572.74	2	Bent/Grout	1	LWT	WT	1
DMB-9A	6/24-26/78	110555.000	2287235.000	1661.61	1663.11	Ab	260.50	217.00	1444.61	227.00	1434.61	218.00	1443.61	243.00	1418.61	1	Bent	3	EWT/FO	P	3
DMB-9B	6/24-26/78	110555.000	2287325.000	1661.61	1663.11	Ab	260.50	190.00	1471.61	200.00	1461.61	183.00	1478.61	210.00	1451.61	1	Bent	3	FO	P	3
DMB-9C	6/24-26/78	110555.000	2287235.000	1661.61	1663.11	Ab	260.50	152.00	1509.61	162.00	1499.61	136.00	1525.61	168.00	1493.61	1	Grout	3	FO/CO	P	3
DMC-1	11/13/79	115120.000	2292330.000	1614.34	1615.99	Ab	47.50	37.00	1577.34	47.00	1567.34	34.00	1580.34	47.50	1566.84	2	Bent/Grout	1	CO/FO	WT	2
DMC-2	11/12/79	126510.000	2288740.000	1588.60	1590.02	Ab	51.50	39.00	1549.60	49.00	1539.60	36.00	1552.60	51.50	1537.10	2	Bent/Grout	1	CO	P	3
DMC-3	11/19/79	106940.000	2291715.000	1610.02	1611.94	Ab	46.50	35.00	1575.02	45.00	1565.02	29.00	1581.02	46.50	1563.52	2	Bent/Grout	1	FO	WT	2
DMI-1	6/14/77	116746.693	2278815.316	1636.74	1638.24	TA	109.00	106.00	1530.74	108.50	1528.24	52.00	1584.74	109.00	1527.74	1	Grout	1	UDB/SS/MS/EWT	P	4
DMI-2L	6/21/77	116608.916	2278750.054	1629.43	1630.61	TA	139.00	134.00	1495.43	139.00	1490.43	88.00	1541.43	139.00	1490.43	3/4	Grout	2	UDB	P	6
DMI-2U	6/21/77	116608.916	2278750.054	1629.43	1630.60	TA	139.00	50.00	1579.43	53.00	1576.43	40.00	1589.43	53.00	1576.43	1	Grout	2	EWT	WT	4
DMP-1	10/30/79	116675.000	2278480.000	1647.62	1649.33	TA	70.70	63.70	1583.92	70.70	1576.92	60.00	1587.62	70.70	1576.92	2	Grout	1	EWT/CO	WT	3
DMP-2	10/31/79	115135.000	2278685.000	1595.58	1596.88	TA	36.50	30.60	1564.98	35.60	1559.98	28.50	1567.08	36.50	1559.08	2	Grout	1	LWT	P	1
DMP-3	11/2/79	113665.000	2275625.000	1623.55	1625.19	TA	65.60	57.50	1566.05	65.50	1558.05	53.20	1570.35	65.60	1557.95	2	Bent/Grout	1	CO	P	2
DMS-1	9/16/77	117104.143	2278219.913	1661.65	1663.77	A	128.00	95.00	1566.65	105.00	1556.65	50.00	1611.65	105.00	1556.65	2	Grout	1	EWT	WT	
DMS-2	9/27/77	117926.677	2277889.698	1641.19	1643.33	TA	184.00	80.00	1561.19	90.00	1551.19	50.00	1591.19	90.00	1551.19	2	Grout	1	CO	WT	4
DW-1A	3/77	116334.871	2276266.441	1648.49	1649.43	A	71.00	58.00	1590.49	70.00	1578.49	53.00	1595.49	71.00	1577.49	1-1/4	Cement Grout	1	EWT	WT	4
DW-1L	3/77	116320.893	2276261.008	1648.32	1649.63	A	215.00	137.00	1511.32	147.00	1501.32	130.00	1518.32	147.00	1501.32	1	Cement Grout	2	EWT	P	4
DW-1U	3/77	116320.893	2276261.008	1648.42	1649.63	A	215.00	92.00	1556.42	97.00	1551.42	85.00	1563.42	105.00	1543.42	1	Cement Grout	2	EWT	P	4
DW-2L	3/77	116776.783	2279794.404	1600.74	1601.70	TA	95.00	85.00	1515.74	90.00	1510.74	77.00	1523.74	95.00	1505.74	3/4	Cement Grout	2	EWT	P	
DW-2U	3/77	116776.783	2279794.404	1600.74	1601.69	TA	95.00	55.00	1545.74	70.00	1530.74	47.00	1553.74	71.00	1529.74	1	Cement Grout	2	CO	P	4
DW-3L	3/77	116254.648	2274840.101	1657.07	1658.61	A	169.00	128.00	1529.07	133.00	1524.07	121.00	1536.07	136.00	1521.07	3/4	Cement Grout	2	EWT	P	4
DW-3U	3/77	116254.648	2274840.101	1657.07	1658.58	TA	169.00	88.00	1569.07	98.00	1559.07	63.00	1594.07	102.00	1555.07	1-1/4	Cement Grout	2	EWT	WT	3
EX-10AL	3/16/84	115111.000	2284239.000	1674.93	1678.17	A	256.00	245.00	1429.93	248.00	1426.93	243.00	1431.93	250.00	1424.93	2	Cem/Bent/Grout	2	LA	P	4
EX-10AU	3/16/84	115111.000	2284239.000	1674.93	1678.22	A	256.00	194.00	1480.93	197.00	1477.93	192.00	1482.93	201.00	1473.93	2	Cem/Bent/Grout	2	FO	P	3
EX-10BL	3/16/84	115109.000	2284216.000	1673.62	1677.18	TA	147.00	142.00	1531.62	145.00	1528.62	140.00	1533.62	147.00	1526.62	2	Cem/Bent/Grout	2	LWT	P	1
EX-10BU	3/16/84	115109.000	2284216.000	1673.62	1677.17	TA	147.00	80.00	1593.62	95.00	1578.62	65.00	1608.62	97.00	1576.62	2	Cem/Bent/Grout	2	LWT	WT	1
EX-11AL	3/24/84	113254.000	2283698.000	1682.05	1685.31	TA	285.00	267.00	1415.05	270.00	1412.05	261.00	1421.05	272.00	1410.05	2	Cem/Bent/Grout	2	LA/CO	P	3
EX-11AU	3/24/84	113254.000	2283698.000	1682.05	1685.34	TA	285.00	222.00	1460.05	225.00	1457.05	220.00	1462.05	227.00	1455.05	2	Cem/Bent/Grout	2	FO	P	3
EX-11BL	3/25/84	113260.000	2283714.000	1681.75	1684.54	TA	174.00	169.00	1512.75	172.00	1509.75	167.00	1514.75	174.00	1507.75	2	Cem/Bent/Grout	2	CO	P	2
EX-11BU	3/25/84	113260.000	2283714.000	1681.75	1684.54	TA	174.00	137.00	1544.75	140.00	1541.75	135.00	1546.75	142.00	1539.75	2	Cem/Bent/Grout	2	LWT	P	1
EX-11CL	3/27/84	113259.000	2283684.000	1681.98	1685.29	TA	102.00	85.00	1596.98	100.00	1581.98	75.00	1606.98	102.00	1579.98	2	Cem/Bent/Grout	1	LWT	WT	1
EX-12AL	3/2-7/84	113156.000	2284707.000	1687.76	1691.10	A	305.00	291.00	1396.76	294.00	1393.76	289.00	1398.76	296.00	1391.76	2	Cem/Bent/Grout	2	LA	P	4

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Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
EX-12AU	3/2-7/84	113156.000	2284707.000	1687.76	1691.08	A	305.00	232.00	1455.76	235.00	1452.76	227.00	1460.76	237.00	1450.76	2	Cem/Bent/Grout	2	EWT	P	4
EX-12BL	3/7/84	113163.000	2284692.000	1688.02	1691.24	A	186.07	181.00	1507.02	184.00	1504.02	179.00	1509.02	186.00	1502.02	2	Cem/Bent/Grout	2	CO	P	2
EX-12BU	3/7/84	113163.000	2284692.000	1688.02	1691.25	A	186.07	107.00	1581.02	122.00	1566.02	87.00	1601.02	124.00	1564.02	2	Cem/Bent/Grout	2	LWT	WT	1
EX-13AL	2/20/84	111555.000	2283499.000	1657.32	1659.70	TA	235.00	228.00	1429.32	231.00	1426.32	226.00	1431.32	235.00	1422.32	2	Cem/Bent/Grout	1	EWT	P	4
EX-13BL	2/21-22/84	111541.000	2283510.000	1657.71	1660.21	A	193.01	188.00	1469.71	191.00	1466.71	186.00	1471.71	193.00	1464.71	2	Cem/Bent/Grout	2	EWT/FO	P	3
EX-13BU	2/21-22/84	111541.000	2283510.000	1657.71	1660.24	A	193.01	141.00	1516.71	144.00	1513.71	135.00	1522.71	151.00	1506.71	2	Cem/Bent/Grout	2	CO	P	2
EX-13CL	2/27/84	111538.000	2283501.000	1657.56	1660.68	TA	108.00	104.00	1553.56	107.00	1550.56	101.00	1556.56	108.00	1549.56	2	Cem/Bent/Grout	1	LWT	P	1
EX-13DL	2/29/84	111534.000	2283508.000	1657.88	1661.13	TA	75.00	58.00	1599.88	73.00	1584.88	46.00	1611.88	75.00	1582.88	2	Cem/Bent/Grout	1	LWT/CO	WT	1
EX-14AL	2/23/84	110251.000	2286304.000	1682.67	1685.32	A	283.00	265.00	1417.67	268.00	1414.67	263.00	1419.67	270.00	1412.67	2	Cem/Bent/Grout	2	LA	P	4
EX-14AU	2/23/84	110251.000	2286304.000	1682.67	1685.32	A	283.00	200.00	1482.67	203.00	1479.67	198.00	1484.67	205.00	1477.67	2	Cem/Bent/Grout	2	FO	P	3
EX-14BL	2/25/84	110257.000	2286282.000	1682.78	1685.01	A	167.00	162.00	1520.78	165.00	1517.78	160.00	1522.78	167.00	1515.78	2	Cem/Bent/Grout	2	LWT	P	3
EX-14BU	2/25/84	110257.000	2286282.000	1682.78	1685.01	A	167.00	100.00	1582.78	115.00	1567.78	67.00	1615.78	117.00	1565.78	2	Cem/Bent/Grout	2	CO	WT	2
EX-15AL	2/10-12/84	112443.000	2280005.000	1626.64	1629.24	TA	235.00	219.50	1407.14	222.50	1404.14	217.00	1409.64	226.00	1400.64	2	Cem/Bent/Grout	2	EWT	P	4
EX-15AU	2/10-12/84	112443.000	2280005.000	1626.64	1629.24	TA	235.00	117.00	1509.64	120.00	1506.64	115.00	1511.64	122.50	1504.14	2	Cem/Bent/Grout	2	CO	P	2
EX-15BL	2/11/84	112447.000	2280010.000	1626.10	1629.30	A	52.00	35.00	1591.10	50.00	1576.10	10.00	1616.10	52.00	1574.10	2	Cem/Bent/Grout	1	FO	WT	1
EX-16AL	2/13-14/84	113316.000	2282043.000	1614.70	1617.39	A	145.00	139.00	1475.70	142.00	1472.70	137.00	1477.70	145.00	1469.70	2	Cem/Bent/Grout	2	FO	P	3
EX-16AU	2/13-14/84	113316.000	2282043.000	1614.70	1617.43	A	145.00	104.00	1510.70	107.00	1507.70	102.00	1512.70	109.00	1505.70	2	Cem/Bent/Grout	2	CO	P	2
EX-16BL	3/1/84	113322.000	2282041.000	1614.62	1616.84	A	70.57	55.00	1559.62	70.00	1544.62	42.00	1572.62	70.00	1544.62	2	Cem/Bent/Grout	1	LWT/FO	WT	1
EX-1AL	2/29-3/1/84	104151.000	2273714.000	1555.48	1558.00	Ab	132.80	126.00	1429.48	129.00	1426.48	124.00	1431.48	132.50	1422.98	2	Cem/Bent/Grout	2	EWT	P	4
EX-1AU	2/29-3/1/84	104151.000	2273714.000	1555.48	1558.00	Ab	132.80	103.00	1452.48	106.00	1449.48	101.00	1454.48	108.00	1447.48	2	Cem/Bent/Grout	2	CO/EWT	P	3
EX-1BL	3/1/84	104144.000	2273710.000	1555.16	1557.56	Ab	47.00	42.00	1513.16	45.00	1510.16	40.00	1515.16	47.00	1508.16	2	Cem/Bent/Grout	2	CO	P	2
EX-1BU	3/1/84	104144.000	2273710.000	1555.16	1557.53	Ab	47.00	5.00	1550.16	20.00	1535.16	2.50	1552.66	22.00	1533.16	2	Cem/Bent/Grout	2	CO	WT	2
EX-2AL	3/27/84	110340.000	2262240.000	1592.11	1594.91	Ab	192.00	152.00	1440.11	155.00	1437.11	150.00	1442.11	157.00	1435.11	2	Cem/Bent/Grout	2	FO	P	
EX-2AU	3/27/84	110340.000	2262240.000	1592.11	1594.91	Ab	192.00	70.00	1522.11	73.00	1519.11	68.00	1524.11	75.00	1517.11	2	Cem/Bent/Grout	2	CO	P	
EX-2BL	3/27/84	110340.000	2262240.000	1591.99	1694.62	Ab	37.00	15.00	1576.99	35.00	1556.99	10.00	N/A	37.00	N/A	2	Bent. Seal	1	LWT	DRY	
EX-2CL	5/17/84	110340.000	2262240.000	1592.11	1594.60	Ab	47.00	30.00	1562.11	45.00	1547.11	27.00	1565.11	47.00	1545.11	2	Cem/Bent/Grout	1	LWT	WT	
EX-3AL	3/30/84	110285.000	2263941.000	1559.09	1562.05	Ab	162.00	144.00	1415.09	147.00	1412.09	142.00	1417.09	149.00	1410.09	2	Cem/Bent/Grout	2	EWT	P	
EX-3AU	3/30/84	110285.000	2263941.000	1559.09	1562.02	Ab	162.00	110.00	1449.09	113.00	1446.09	108.00	1451.09	115.00	1444.09	2	Cem/Bent/Grout	2	FO	P	
EX-3BL	3/30/84	110287.000	2263932.000	1559.38	1562.36	Ab	75.00	70.00	1489.38	73.00	1486.38	68.00	1491.38	75.00	1484.38	2	Cem/Bent/Grout	2	CO	P	
EX-3BU	3/30/84	110287.000	2263932.000	1559.38	1562.38	Ab	75.00	40.00	1519.38	43.00	1516.38	38.00	1521.38	45.00	1514.38	2	Cem/Bent/Grout	2	FO	P	
EX-3CL	3/31/84	110280.000	2263921.000	1560.09	1562.62	Ab	12.00	3.00	1557.09	11.00	1549.09	2.50	1557.59	12.00	1548.09	2	Bent. Powder	1	FO	WT	
EX-4AL	2/6-8/84	119912.000	2274288.000	1573.87	1577.06	TA	119.00	114.50	1459.37	117.50	1456.37	112.50	1461.37	119.00	1454.87	2	Cem/Bent/Grout	2	EWT	P	4
EX-4AU	2/6-8/84	119912.000	2274288.000	1573.87	1577.02	TA	119.00	91.50	1482.37	94.50	1479.37	89.00	1484.87	97.00	1476.87	2	Cem/Bent/Grout	2	FO	P	3
EX-4BL	2/6-8/84	119917.000	2274278.000	1573.68	1577.15	A	67.95	62.50	1511.18	65.50	1508.18	60.50	1513.18	66.50	1507.18	2	Cem/Bent/Grout	2	CO	P	3
EX-4BU	2/6/84	119917.000	2274278.000	1573.68	1577.08	A	67.95	37.00	1536.68	40.00	1533.68	35.00	1538.68	42.00	1531.68	2	Cem/Bent/Grout	2	LWT	P	2
EX-4CL	2/7/84	119929.000	2274283.000	1573.58	1577.03	TA	29.00	11.00	1562.58	26.00	1547.58	4.00	1569.58	29.00	1544.58	2	Concrete	1	CO	WT	2
EX-5AL	2/7-8/84	119857.000	2276790.000	1632.50	1635.39	TA	189.00	183.00	1449.50	186.00	1446.50	181.00	1451.50	189.00	1443.50	2	Cem/Bent/Grout	2	UDB	P	7
EX-5AU	2/7-8/84	119857.000	2276790.000	1632.50	1635.39	TA	189.00	160.00	1472.50	163.00	1469.50	158.00	1474.50	165.00	1467.50	2	Cem/Bent/Grout	2	UDB	P	5
EX-5BL	2/15-16/84	119858.000	2276781.000	1632.54	1635.83	TA	112.00	107.00	1525.54	110.00	1522.54	105.00	1527.54	112.00	1520.54	2	Cem/Bent/Grout	2	CO	P	2
EX-5BU	2/15-16/84	119858.000	2276781.000	1632.54	1635.83	TA	112.00	43.00	1589.54	58.00	1574.54	20.00	1612.54	60.00	1572.54	2	Cem/Bent/Grout	2	LWT	DRY	
EX-5CL	4/3/84	119851.000	2276781.000	1632.78	1635.75	A	75.88	58.00	1574.78	73.00	1559.78	48.00	1584.78	75.00	1557.78	2	Cement Grout	1	LWT	WT	1
EX-6AL	3/6-7/84	120340.000	2289928.000	1606.94	1609.63	Ab	196.00	175.00	1431.94	178.00	1428.94	173.00	1433.94	180.00	1426.94	2	Cement Grout	2	EWT	P	4
EX-6AU	3/6-7/84	120340.000	2289928.000	1606.94	1609.61	Ab	196.00	119.00	1487.94	122.00	1484.94	117.00	1489.94	124.00	1482.94	2	Cem/Bent/Grout	2	CO	P	3
EX-6BL	3/7/84	120341.000	2289919.000	1606.80	1609.78	Ab	87.00	82.00	1524.80	85.00	1521.80	80.00	1526.80	87.00	1519.80	2	Cem/Bent/Grout	2	FO	P	2
EX-6BU	3/7/84	120341.000	2289919.000	1606.80	1609.78	Ab	87.00	15.00	1591.80	30.00	1576.80	10.00	1596.80	32.00	1574.80	2	Cem/Bent/Grout	2	CO	WT	2
EX-7AL	3/8/84	117862.000	2286791.000	1580.35	1583.42	Ab	169.00	156.50	1423.85	159.50	1420.85	154.00	1426.35	161.00	1419.35	2	Bent. Slurry	1	EWT	P	4
EX-7BL	3/9/84	117856.000	2286783.000	1580.67	1583.91	Ab	112.00	107.00	1473.67	110.00	1470.67	105.00	1475.67	112.00	1468.67	2	Cem/Bent/Grout	2	EWT	P	4
EX-7BU	3/9/84	117856.000	2286783.000	1580.67	1583.92	Ab	112.00	67.00	1513.67	70.00	1510.67	66.50	1514.17	73.50	1507.17	2	Cem/Bent/Grout	2	CO	P	3
EX-7CL	3/8/84	117853.000	2286779.000	1581.15	1583.06	Ab	11.50	3.50	1577.65	9.50	1571.65	3.50	1577.65	11.50	1569.65	2	Bent/Grout	1	FO	WT	2
EX-8AL	3/14/84	116362.000	2287655.000	1586.46	1589.26	A	175.00	161.00	1425.46	164.00	1422.46	159.00	1427.46	166.00	1420.46	2	Cem/Bent/Grout	2	EWT	P	4
EX-8AU	3/14/84	116362.000	2287655.000	1586.46	1589.26	A	175.00	102.00	1484.46	105.00	1481.46	100.00	1486.46	107.00	1479.46	2	Cem/Bent/Grout	2	EWT	P	4
EX-8BL	3/12/84	116371.000	2287651.000	1586.62	1589.40	A	77.74	72.00	1514.62	75.00	1511.62	70.00	1516.62	77.00	1509.62	2	Cem/Bent/Grout	2	FO	P	3
EX-8BU	3/12/84	116371.000	2287651.000	1586.62	1589.40	A	77.74	5.00	1581.62	13.00	1573.62	4.00	1582.62	14.00	1572.62	2	Cem/Bent/Grout	2	CO	WT	2
EX-9AL	3/21/84	116461.000	2284725.000	1708.86	1712.34	A	280.00	275.00	1433.86	278.00	1430.86	273.00	1435.86	280.00	1428.86	2	Cem/Bent/Grout	2	UDB	P	5
EX-9AU	3/21/84	116461.000	2284725.000	1708.86	1712.33	A	280.00	243.00	1465.86	246.00	1462.86	241.00	1467.86	248.00	1460.86	2	Cem/Bent/Grout	2	FO	P	3
EX-9BL	3/30/84	116472.000	2284729.000	1708.64	1711.68	A	193.50	187.00	1521.64	190.00	1518.64	185.00	1523.64	192.00	1516.64	2	Cem/Bent/Grout	2	CO	P	2

Table 3.6-1 (Continued)

revision #1 8/01/95

Well ID	Date(s) Installed	State Plane Coordinates (ft)		Elevation (msl)		Condition	Construction Details														
		North	East	Ground	PVC		Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
EX-9BU	3/30/84	116472.000	2284729.000	1708.64	1711.71	A	193.50	115.00	1593.64	135.00	1573.64	105.00	1603.64	137.00	1571.64	2	Cem/Bent/Grout	2	CO/LWT	WT	1
G40-D24	12/20/79	108060.000	2266940.000	1629.93	1632.17	Ab	188.50	174.00	1455.93	184.00	1445.93	167.00	1462.93	188.50	1441.43	2	Bent/Grout	1	EWT	P	4
G40-H16	3/28/79	113260.000	2269110.000	1617.10	1619.33	Ab	268.00	145.00	1472.10	155.00	1462.10	110.00	1507.10	158.00	1459.10	2	Bent/Grout	1	EWT/FO	P	3
G40-H27	12/20/79	105930.000	2269650.000	1602.12	1603.78	Ab	250.00	171.00	1431.12	181.00	1421.12	157.00	1445.12	250.00	1352.12	2	Bent/Grout	1	EWT/UDB	P	
G40-J15	3/02/79	113810.000	2270150.000	1603.60	1605.52	TA	51.50	37.00	1566.60	47.00	1556.60	32.00	1571.60	51.50	1552.10	2	Bent/Grout	1	LWT	WT	2
G40-K13	3/01/79	115130.000	2270885.000	1600.90	1603.34	TA	50.25	34.00	1566.90	44.00	1556.90	25.00	1575.90	44.00	1556.90	2	Bent/Grout	1	CO/FO	WT	2
G40-L23	1/15/80	108920.000	2271065.000	1639.30	1641.06	Ab	90.90	77.00	1562.30	87.00	1552.30	74.00	1565.30	90.90	1548.40	2	Bent/Grout	1	LWT/CO	WT	2
G40-M15	4/11/79	113660.000	2271735.000	1637.60	1639.15	Ab	310.00	264.00	1373.60	274.00	1363.60	264.00	1373.60	310.00	1327.60	2	Bent/Grout	1	EWT	P	
G40-P10A	1/15/82	116745.000	2272895.000	1651.35	1655.05	Ab	160.00	86.00	1565.35	96.00	1555.35	80.00	1571.35	160.00	1491.35	2	Bent/Grout	1	CO/EWT/UDB	WT	3
G40-P20	1/3/80	111070.000	2273515.000	1641.09	1643.13	Ab	81.00	66.00	1575.09	76.00	1565.09	60.00	1581.09	81.00	1560.09	2	Bent/Grout	1	CO	WT	2
G40-Q7	1/17/80	119050.000	2274350.000	1608.07	1609.68	Ab	70.50	57.00	1551.07	67.00	1541.07	50.00	1558.07	70.50	1537.57	2	Bent/Grout	1	LWT	WT	2
G40-R23	1/8/80	108770.000	2274805.000	1620.30	1622.09	Ab	81.00	66.00	1554.30	76.00	1544.30	60.00	1560.30	81.00	1539.30	2	Bent/Grout	1	FO/LWT	WT	2
G40-S17	12/17/81	112295.000	2275770.000	1595.65	1598.14	A	150.76	116.00	1479.65	126.00	1469.65	111.00	1484.65	150.70	1444.95	2	Bent/Grout	1	EWT/FO	P	4
G40-S17A	12/18/81	112335.000	2275790.000	1595.90	1598.12	TA	30.00	21.00	1574.90	26.00	1569.90	16.00	1579.90	30.00	1565.90	2	Bent/Grout	1	LWT	WT	1
G40-T30	2/11/82	105765.000	2278410.000	1590.40	1592.66	Ab	162.00	105.00	1485.40	115.00	1475.40	100.00	1490.40	162.00	1428.40	2	Bent/Grout	1	CO/EWT	P	4
G40-X1	1/15/82	121515.000	2277990.000	1616.55	1618.85	TA	143.00	75.00	1541.55	85.00	1531.55	69.00	1547.55	143.00	1473.55	2	Bent/Grout	1	LWT/EWT/CO	P	3
G40-X1A	1/14/82	121930.000	2277830.000	1578.90	1581.22	Ab	75.00	50.00	1528.90	60.00	1518.90	41.00	1537.90	75.00	1503.90	2	Bent/Grout	1	EWT/CO/LWT	P	2
G40-Y15	12/17/81	113655.000	2279180.000	1593.40	1595.85	A	175.00	84.00	1509.40	94.00	1499.40	79.00	1514.40	175.00	1418.40	2	Bent/Grout	1	CO	P	3
G40-Y15A	12/17/81	113665.000	2279170.000	1593.70	1595.90	A	20.00	5.00	1588.70	10.00	1583.70	5.00	1588.70	20.00	1573.70	2	Bent/Grout	1	LA	WT	1
G40-Y21	12/28/81	110730.000	2278040.000	1592.80	1595.46	TA	20.00	12.00	1580.80	17.00	1575.80	11.00	1581.80	20.00	1572.80	2	Bent/Grout	1	CO	WT	2
G40-Y22	1/22/82	108880.000	2278310.000	1609.10	1611.42	Ab	196.00	162.00	1447.10	172.00	1437.10	154.00	1455.10	196.00	1413.10	2	Bent/Grout	1	CO/FO	P	3
G40-Y26	1/20/82	106680.000	2278800.000	1590.70	1592.77	Ab	128.00	93.00	1497.70	103.00	1487.70	88.00	1502.70	128.00	1462.70	2	Bent/Grout	1	CO/FO/EWT	P	3
G41-A23	1/18/82	108070.000	2280288.000	1608.00	1610.26	A	48.00	37.50	1570.50	43.00	1565.00	32.00	1576.00	48.00	1560.00	2	Bent/Grout	1	LWT	P	1
G41-A24	6/9/81	107060.000	2280500.000	1614.08	1616.64	Ab	180.00	100.00	1514.08	110.00	1504.08	85.00	1529.08	180.00	1434.08	2	Bent/Grout	1	CO/FO/EWT/UDB	P	3
G41-B12	12/31/81	116120.000	2280610.000	1610.65	1613.25	TA	126.00	75.00	1535.65	85.00	1525.65	68.00	1542.65	126.00	1484.65	2	Bent/Grout	1	CO/LWT/EWT/UDB	P	4
G41-C15	3/7/79	113350.000	2282075.000	1615.60	1617.12	TA	217.30	195.00	1420.60	205.00	1410.60	190.00	1425.60	217.30	1398.30	2	Bent/Grout	1	EWT/LA	P	4
G41-C15A	3/9/79	113365.000	2282080.000	1615.60	NR	Ab	145.00	130.80	1484.80	133.00	1482.60	None	None	None	None	2	None	1	FO	P	
G41-C15B	3/30-31/79	113265.000	2281850.000	1611.60	1613.81	A	26.50	21.50	1590.10	26.50	1585.10	19.00	1592.60	26.50	1585.10	2	Bent/Grout	1	FO	P	
G41-C15C	1/18/82	113160.000	2281790.000	1611.35	1613.88	TA	22.00	13.00	1598.35	18.00	1593.35	10.50	1600.85	22.00	1589.35	2	Bent/Grout	1	IM	PERCHED	
G41-C32	2/9/82	102500.000	2282115.000	1739.80	1742.89	Ab	262.00	213.00	1526.80	223.00	1516.80	200.00	1539.80	262.00	1477.80	2	Bent/Grout	1	FO/EWT/UDB	P	3
G41-E13	3/6/79	114395.000	2282889.000	1627.30	1629.34	A	250.50	227.00	1400.30	237.00	1390.30	225.00	1402.30	250.50	1376.80	2	Bent/Grout	1	UDB/FO	P	3
G41-E13A	3/27/79	114395.000	2282890.000	1626.70	1629.50	TA	191.00	188.83	1437.87	191.00	1435.70	None	None	None	None	2	None	1	FO	P	
G41-E17	4/2/79	112385.000	2283005.000	1666.40	1668.37	A	260.00	235.00	1431.40	245.00	1421.40	228.00	1438.40	260.00	1406.40	2	Bent/Grout	1	EWT/UDB	P	4
G41-E19A	5/15/81	110260.000	2283290.000	1645.59	1648.97	A	276.00	115.00	1530.59	125.00	1520.59	108.00	1537.59	126.00	1519.59	2	Bent/Grout	1	CO/FO	P	3
G41-E22	1/04/82	109970.000	2282570.000	1609.75	1611.93	A	224.00	115.00	1494.75	125.00	1484.75	110.00	1499.75	224.00	1385.75	2	Bent/Grout	1	FO	P	3
G41-E22A	1/06/82	109955.000	2282590.000	1609.50	1611.71	TA	42.10	33.00	1576.50	38.00	1571.50	28.00	1581.50	42.10	1567.40	2	Bent/Grout	1	LWT	WT	1
G41-F24	1/8/80	107255.000	2283465.000	1653.50	1656.18	Ab	243.00	83.00	1570.50	93.00	1560.50	75.00	1578.50	243.00	1410.50	2	Bent/Grout	1	CO/EWT/FO	WT	3
G41-G12	3/31/79	115825.000	2284430.000	1675.70	1678.57	TA	21.00	14.50	1661.20	19.50	1656.20	13.00	1662.70	21.00	1654.70	2	Bent/Grout	1	LWT	PERCHED	
G41-G13	6/4/81	115260.000	2284725.000	1709.58	1712.19	TA	319.00	247.00	1462.58	255.00	1454.58	225.00	1484.58	319.00	1390.58	2	Bent/Grout	1	CO/LWT	P	4
G41-G14A	11/16/79	114080.000	2284315.000	1706.91	1708.43	TA	241.00	221.00	1485.91	241.00	1465.91	190.00	1516.91	241.00	1465.91	2	Bent/Grout	1	LWT	P	3
G41-G14B	11/30/79	114055.000	2284315.000	1706.80	1708.71	TA	360.10	272.00	1434.80	292.00	1414.80	263.00	1443.80	360.10	1346.70	2	Bent/Grout	1	EWT	P	4
G41-G14C	12/4/79	114030.000	2284315.000	1706.33	1708.51	TA	160.00	131.00	1575.33	151.00	1555.33	124.00	1582.33	150.00	1556.33	2	Bent/Grout	1	LWT	WT	1
G41-G14D	12/11/79	113855.000	2284315.000	1705.56	1707.42	TA	257.00	222.00	1483.56	242.00	1463.56	215.00	1490.56	245.00	1460.56	2	Bent/Grout	1	FO/CO	P	3
G41-G14E	12/07/79	113830.000	2284315.000	1705.61	1707.81	TA	165.00	134.00	1571.61	154.00	1551.61	129.00	1576.61	154.00	1551.61	2	Bent/Grout	1	CO	P	1
G41-G14F	11/6/79	113805.000	2284315.000	1703.50	1706.73	TA	332.00	290.00	1413.50	310.00	1393.50	281.00	1422.50	310.00	1393.50	2	Bent/Grout	1	EWT	P	4
G41-G15	4/9/79	113415.000	2284420.000	1691.50	1694.19	TA	338.00	240.00	1451.50	250.00	1441.50	234.00	1457.50	338.00	1353.50	2	Bent/Grout	1	EWT/UDB/LA	P	4
G41-G15A	3/9/79	113480.000	2284390.000	1692.75	1695.61	TA	113.00	101.50	1591.25	111.50	1581.25	92.00	1600.75	113.00	1579.75	2	Bent/Grout	1	CO	WT	1
G41-G15B	3/13/79	113440.000	2284385.000	1692.10	NR	TA	170.00	158.00	1534.10	168.00	1524.10	146.00	1546.10	170.00	1522.10	2	Bent/Grout	1	LWT	P	1
G41-G21	12/5/79	109495.000	2284265.000	1664.83	1665.95	Ab	100.50	90.00	1574.83	99.00	1565.83	67.00	1597.83	100.50	1564.33	2	Bent/Grout	1	LWT	WT	2
G41-H17	2/28/79	112145.000	2284960.000	1684.50	1686.89	TA	74.30	22.50	1662.00	32.50	1652.00	20.00	1664.50	33.00	1651.50	2	Bent/Grout	1	CO/LWT	DRY	
G41-H18	3/9/79	111430.000	2285125.000	1684.30	1686.30	TA	75.30	17.00	1667.30	27.00	1657.30	12.00	1672.30	30.00	1654.30	2	Bent/Grout	1	LWT	DRY	
G41-H18A	3/30/79	111590.000	2285065.000	1680.40	1684.38	TA	21.50	17.00	1663.40	20.00	1660.40	16.00	1664.40	20.00	1660.40	2	Bent/Grout	1	LWT	PERCHED	
G41-H18B	6/3/81	110995.000	2285335.000	1683.80	1686.99	A	288.00	147.00	1536.80	157.00	1526.80	140.00	1543.80	288.00	1395.80	2	Bent/Grout	1	CO/LWT/EWT/FO/LA	P	4
G41-H9	5/26/81	117330.000	2285000.000	1702.04	1704.69	A	315.00	230.00	1472.04	240.00	1462.04	210.00	1492.04	315.00	1387.04	2	Bent/Grout	1	CO/LWT/FO/LA/EWT	P	3
G41-J18	3/13/79	111215.000	2285495.000	1679.70	1682.98	TA	70.50	23.00	1656.70	33.00	1646.70	18.00	1661.70	36.00	1643.70	2	Bent/Grout	1	CO/LWT	DRY	
G41-K13	4/9/79	114755.000	2285965.000	1699.70	1702.79	A	285.00	260.00	1439.70	270.00	1429.70	240.00	1459.70	285.00	1414.70	2	Bent/Grout	1	EWT/UDB	P	4

Table 3.6-1 (Continued)

revision #1 8/01/95

Well ID	Date(s) Installed	State Plane Coordinates (ft)		Elevation (msl)		Condition	Construction Details											# of Wells per Boring	Formation Monitored	Well Type	Model Layer
		North	East	Ground	PVC		Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal				
G41-K13A	3/31/79	114770.000	2285955.000	1699.90	1702.88	TA	122.20	109.30	1590.60	119.30	1580.60	105.50	1594.40	122.20	1577.70	2	Bent/Grout	1	LWT	WT	2
G41-K13B	3/28/79	114850.000	2286070.000	1696.80	1698.70	TA	20.00	15.00	1681.80	20.00	1676.80	10.00	1686.80	20.00	1676.80	2	Bent/Grout	1	LWT	DRY	
G41-K26	5/11/81	106260.000	2286445.000	1686.10	1688.14	Ab	330.00	157.00	1529.10	167.00	1519.10	137.00	1549.10	168.00	1518.10	2	Bent/Grout	1	FO/LA/CO/EWT/UDB	P	3
G41-M11	4/28/81	116270.000	2287725.000	1582.79	1585.61	Ab	160.50	50.00	1532.79	60.00	1522.79	42.00	1540.79	160.50	1422.29	2	Bent/Grout	1	FO	P	4
G41-M24	12/5/79	107900.000	2287176.000	1653.11	1655.30	Ab	30.80	21.50	1631.61	30.80	1622.31	8.00	1645.11	30.80	1622.31	2	Bent/Grout	1	CO/LWT	PERCHED	
G41-N21	12/1/79	109170.000	2288410.000	1727.36	1729.40	Ab	150.50	138.50	1588.86	148.40	1578.96	76.00	1651.36	150.50	1576.86	2	Bent. Grout	1	CO	WT	2
G41-P16	4/27/81	113755.000	2288760.000	1588.72	1592.33	Ab	181.00	44.00	1544.72	54.00	1534.72	39.00	1549.72	181.00	1407.72	2	Bent. Grout	1	LWT/CO/EWT	WT	3
G41-P18	3/27/79	111645.000	2288825.000	1588.90	1591.41	Ab	130.00	100.00	1488.90	110.00	1478.90	95.00	1493.90	125.00	1463.90	2	Bent. Grout	1	CO/LWT	P	3
G41-P18B	3/29/79	111390.000	2288820.000	1589.10	1591.24	Ab	44.50	35.00	1554.10	40.00	1549.10	33.00	1556.10	40.00	1549.10	2	Bent. Grout	1	LWT	WT	2
G41-P24	12/20/79	107550.000	2288660.000	1681.95	1684.21	Ab	345.00	103.00	1578.95	113.00	1568.95	95.00	1586.95	345.00	1336.95	2	Bent. Grout	1	CO/FO/LWT/EWT	WT	3
G41-Q22	5/8/81	108460.000	2289190.000	1612.30	1615.46	Ab	316.50	177.00	1435.30	187.00	1425.30	170.00	1442.30	316.50	1295.80	2	Bent. Grout	1	FO/LA/CO/EWT/UDB	P	3
STS-B1	1/25/80	116792.120	2278140.830	1655.70	1657.72	TA	110.30	NR	NR	84.70	1571.00	NR	NR	NR	NR	2	Bent. Grout	1	NR	NR	
STS-DHL-1	2/13/84	108983.000	2281442.000	1605.40	1606.50	Ab	43.00	38.80	1566.60	41.80	1563.60	38.00	1567.40	41.80	1563.60	1-1/2	Grout	1	LWT	P	
STS-DL-1	2/8/84	112581.000	2281760.000	1611.80	1613.70	Ab	60.00	56.70	1555.10	59.70	1552.10	55.70	1556.10	59.70	1552.10	1-1/2	Bent. Pellets	1	FO	P	
STS-DL-2 ~	10/25/85	113175.000	2281778.000	1611.70	1614.20	A	34.50	31.50	1580.20	34.50	1577.20	None	None	None	None	2 - Galv	Bent. Pellets	1	LWT/FO	P	
STS-DL-3 ~	10/25/85	113882.000	2281574.000	1612.50	1616.00	TA	19.50	17.00	1595.50	19.00	1593.50	None	None	None	None	2 - Galv	Bent. Pellets	1	FO	WT	
STS-DL-4 ~	10/25/85	113114.000	2281514.000	1612.60	1615.60	A	20.00	17.50	1595.10	19.50	1593.10	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA/FO	P	
STS-DL-5 ~	10/25/85	112448.000	2280776.000	1612.60	1615.70	A	20.00	17.50	1595.10	19.50	1593.10	None	None	None	None	2 - Galv	Bent. Pellets	1	FO	WT	
STS-DL-6 ~	10/25/85	111630.000	2280917.000	1615.20	1615.20	A	20.00	17.50	1597.70	19.50	1595.70	None	None	None	None	2 - Galv	Bent. Pellets	1	LWT	WT	
STS-EVS	3/21/78	116340.800	2278955.800	1614.40	1616.50	TA	83.80	55.50	1558.90	65.50	1548.90	24.50	1589.90	74.20	1540.20	2	Cem Ben Grout	1	NR	P	
STS-OL-1	2/9-10/84	114464.000	2273195.000	1633.47	1635.20	Ab	53.00	47.00	1586.47	50.00	1583.47	46.30	1587.17	50.00	1583.47	1-1/2	Grout	1	CO/LA	DRY	
STS-SL-1	2/9/84	117588.000	2280516.700	1598.00	1599.70	Ab	17.40	14.40	1583.60	17.40	1580.60	12.30	1585.70	17.40	1580.60	1-1/2	Grout	1	CO	P	
STS-SL-3 ~	10/25/85	117765.800	2281033.500	1598.40	1600.30	A	6.00	4.00	1594.40	5.80	1592.60	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA	WT	
STS-SL-4 ~	10/25/85	118074.100	2281309.100	1600.30	1602.70	TA	7.50	5.00	1595.30	7.00	1593.30	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA	WT	
STS-SL-5 ~	10/25/85	117778.900	2281095.900	1598.70	1601.20	A	26.00	23.50	1575.20	25.50	1573.20	None	None	None	None	2 - Galv	Bent. Pellets	1	CO	P	
STS-LSL-1	3/18/82	114280.000	2278245.000	1591.90	NR	Ab	52.00	52.00	1539.90	54.00	1537.90	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-2	3/22/82	113575.000	2277080.000	1591.90	NR	Ab	40.50	40.50	1551.40	42.50	1549.40	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-4	3/20-21/82	112345.000	2276430.000	1591.90	NR	Ab	47.50	47.10	1544.80	49.10	1542.80	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-6	3/20/82	110950.000	2276590.000	1591.90	NR	Ab	36.00	34.00	1557.90	36.00	1555.90	None	None	None	None	NR	NR	1	CO	P	
STS-WVS	3/22/78	116744.500	2274385.900	1683.40	1685.20	TA	189.50	135.00	1548.40	145.00	1538.40	28.00	1655.40	189.50	1493.90	2	Cem Ben Grout	1	NR	P	
TW-1	N/A	116883.850	2279723.300	1601.19	1602.57	A	55.00	40.00	1561.19	55.00	1546.19	30.00	1571.19	55.00	1546.19	8 - Steel	Bent. Slurry	1	EWT	PW	3
TW-2	N/A	116282.490	2274923.310	1654.40	1655.80	TA	96.00	86.00	1568.40	96.00	1558.40	70.00	1584.40	96.00	1558.40	8 - Steel	Bent. Slurry	1	EWT	PW	
TW-41	1/29/81	114130.000	2284315.000	1707.19	1708.68	TA	340.00	150.80	1556.39	316.00	1391.19	113.00	1594.19	340.00	1367.19	12 - Steel	Cement	1	MS/EWT/FO/CO	PW	
WP-1L	3/15/84	110547.000	2265406.000	1553.85	1556.04	Ab	33.00	30.00	1523.85	33.00	1520.85	None	None	None	None	2 - Galv.	Cement	1	FO	P	2
WP-1U	3/15/84	110540.000	2265404.000	1553.85	1556.09	Ab	6.00	2.00	1551.85	6.00	1547.85	None	None	None	None	2 - Galv.	Cement	1	FO	WT	2
WP-2L	3/30/84	119694.000	2267150.000	1536.12	1537.67	Ab	32.60	29.60	1506.52	32.60	1503.52	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-2U	3/30/84	119698.000	2267150.000	1536.03	1538.48	Ab	6.00	2.00	1534.03	6.00	1530.03	None	None	None	None	2 - Galv.	Bent. Powder	1	PT/CO	WT	1
WP-3L	3/29/84	119269.000	2268045.000	1537.73	1539.67	Ab	33.00	30.00	1507.73	33.00	1504.73	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-3U	3/29/84	119246.000	2268023.000	1540.89	1543.27	Ab	11.00	3.00	1537.89	11.00	1529.89	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	WT	2
WP-4L	3/29/84	121799.000	2274240.000	1541.18	1543.30	A	32.00	29.00	1512.18	32.00	1509.18	None	None	None	None	-" Galv.	Cem Ben Slurry	1	CO	P	2
WP-4U	3/29/84	121825.000	2274236.000	1545.29	1547.35	A	10.20	2.20	1543.09	10.20	1535.09	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	WT	2
WP-5L	4/2/84	120871.000	2274355.000	1548.02	1550.25	A	33.00	30.00	1518.02	33.00	1515.02	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	LWT/CO	P/ART	
WP-5U	4/2/84	120865.000	2274352.000	1547.98	1550.12	A	5.00	2.00	1545.98	5.00	1542.98	None	None	None	None	2 - Galv.	Bent. Powder	1	CO	WT	2
WP-6L	3/30/84	118254.000	2287403.000	1579.60	1581.61	Ab	33.00	30.00	1549.60	33.00	1546.60	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-6U	3/30/84	118247.000	2287407.000	1579.51	1581.66	Ab	6.50	2.50	1577.01	6.50	1573.01	None	None	None	None	2 - Galv.	Bent. Powder	1	PT/FO	WT	2
WP-7L	3/14/84	116486.000	2287958.000	1580.08	1583.94	Ab	33.00	30.00	1550.08	33.00	1547.08	None	None	None	None	2 - Galv.	Bent Cem Gt	1	LWT/CO	P	2
WP-7U	3/14/84	116494.000	2287958.000	1580.26	1582.53	Ab	6.00	2.00	1578.26	6.00	1574.26	None	None	None	None	2 - Galv.	Bent Cem Gt	1	LWT/CO	WT	1
WW-1	7/26-8/2/76	116903.198	2277828.575	1671.20	1671.50	TA	124.50	119.00	1552.20	124.00	1547.20	NR	NR	NR	NR	6 - Steel	NR	1	NR	PW	
WW-2	9/20-22/76	116442.007	2276157.379	1645.39	1645.89	TA	155.00	140.00	1505.39	155.00	1490.39	140.00	1505.39	155.00	1490.39	8 - Steel	NR	1	NR	PW	4
WW-3	3/28-30/76	NS	NS			TA	60.00	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	PW	
WW-4	4/4-5/81	116170.970	2278391.910	1623.67	1625.30	TA	98.00	87.60	1536.07	97.80	1525.87	NR	NR	NR	NR	8 - Steel	NR	1	NR	PW	
CMC-03R	4/4/94	113563.600	2286751.700	1705.20	N/A	Ab	98.00	81.00	1624.20	96.00	1609.20	78.70	1626.50	98.00	1607.20	2	Chipped Bent.	1	LWT/CO	DRY	
CMC-01	3/31/94	116166.600	2282677.100	1650.20	1653.15	A	92.50	77.00	1573.20	92.00	1558.20	75.00	1575.20	92.50	1557.70	2	Chipped Bent.	1	CO/LWT	P	
CMC-01R	5/3/94	116156.500	2282675.100	1650.15	1653.07	A	68.00	48.00	1602.15	63.00	1587.15	46.00	1604.15	68.00	1582.15	2	Chipped Bent.	1	LWT	WT	
CMC-01P	3/25/94	116168.300	2282682.700	1650.15	1653.67	A	202.00	141.00	1509.15	146.00	1504.15	138.80	1511.35	149.80	1500.35	2	Chipped Bent.	1	CO	P	
CMC-02	3/28/94	115308.700	2286070.100	1697.90	NS	Ab	95.00	78.00	1619.90	93.00	1604.90	73.50	1624.40	95.00	1602.90	2	Chipped Bent.	1	CO	DRY	

SVD1\MLD2\93C049\welllist.wb2

Table 3.6-1 (Continued)

revision #1 8/01/95

Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
CMC-02P	3/22/94	115306.800	2286077.300	1697.90	1700.96	A	191.10	185.00	1512.90	190.00	1507.90	183.00	1514.90	191.10	1506.80	2	Chipped Bent.	1	CO	P	
CMC-02R	9/8/94	115299.210	2286062.480	1697.66	1700.15	A	120.00	100.00	1597.66	115.00	1582.66	95.00	1602.66	117.00	1580.66	2	Chipped Bent./Grout	1	CO/LWT	WT	
CMC-03	3/24/94	113563.600	2286751.700	1705.20	NS	Ab	86.00	68.00	1637.20	83.00	1622.20	66.00	1639.20	86.00	1619.20	2	Chipped Bent.	1	LWT	DRY	
CMC-03RR	4/27/94	113563.600	2286751.700	1705.20	1707.90	A	128.00	108.00	1597.20	123.00	1582.20	106.00	1599.20	128.00	1577.20	2	Chipped Bent.	1	LWT/CO	WT	
CMC-03P	3/22/94	113560.100	2286745.300	1705.20	1708.61	A	201.00	190.00	1515.20	195.00	1510.20	188.00	1517.20	201.00	1504.20	2	Chipped Bent./Grout	1	CO	P	
CMC-04	3/10/94	111448.500	2285112.200	1683.90	1687.10	A	113.00	95.00	1588.90	110.00	1573.90	93.00	1590.90	113.00	1570.90	2	Chipped Bent.	1	CO	WT	
CMC-05	3/10/94	111541.200	2283490.000	1656.90	1660.17	A	79.00	63.00	1593.90	78.00	1578.90	61.00	1595.90	79.00	1577.90	2	Chipped Bent.	1	LWT	WT	
CMC-06P	3/10/94	112380.300	2283011.500	1666.50	1669.64	A	152.00	143.00	1523.50	148.00	1518.50	137.50	1529.00	152.00	1514.50	2	Chipped Bent.	1	CO	P	
CMC-07	3/28/94	114389.200	2282896.000	1626.90	1630.41	A	51.00	32.00	1594.90	47.00	1579.90	29.90	1597.00	51.00	1575.90	2	Chipped Bent.	1	CO	WT	
CMC-08	3/1/94	117115.900	2278213.600	1662.50	1665.76	A	75.00	59.00	1603.50	74.00	1588.50	57.00	1605.50	75.00	1587.50	2	Chipped Bent.	1	CO/EWT	WT	
CMC-08P	4/18/94	117107.100	2278200.200	1662.50	1665.60	A	113.50	90.00	1572.50	95.00	1567.50	88.00	1574.50	101.00	1561.50	2	Chipped Bent.	1	EWT	P	
CMC-09	3/30/94	116258.800	2274907.300	1653.50	1656.96	A	90.00	71.00	1582.50	86.00	1567.50	68.50	1585.00	90.00	1563.50	2	Chipped Bent.	1	CO	WT	
CMC-09P	4/15/94	116258.800	2274914.700	1653.30	1656.11	A	168.50	137.00	1516.30	142.00	1511.30	135.00	1518.30	148.50	1504.80	2	Chipped Bent.	1	EWT	P	
CMC-10	3/30/94	116056.600	2278575.400	1621.10	1624.34	A	50.00	33.00	1588.10	48.00	1573.10	31.00	1590.10	50.00	1571.10	2	Chipped Bent.	1	CO	WT	
CMC-10P	3/3/94	116046.900	2278514.200	1620.80	1624.02	A	101.50	80.00	1540.80	85.00	1535.80	78.00	1542.80	89.00	1531.80	2	Chipped Bent.	1	EWT	P	
CMC-B0-101A	2/7/94	117361.700	2283366.800	1637.30	1640.73	A	16.20	10.70	1626.60	15.70	1621.60	9.70	1627.60	15.90	1621.40	2	Chipped Bent.	1	LA	PERCHED	
CMC-BO-101B	2/1/94	117357.700	2283369.500	1637.30	1640.69	A	41.50	34.10	1603.20	39.10	1598.20	32.10	1605.20	41.10	1596.20	2	Chipped Bent.	1	CO	DRY	
CMC-SL-103A	2/7-8/94	117856.600	2281146.900	1599.20	1602.41	A	30.00	23.30	1575.90	28.30	1570.90	21.30	1577.90	29.30	1569.90	2	Chipped Bent.	1	IM	P	
CMC-SL-103B	2/8/94	117848.700	2281133.900	1599.20	1602.28	A	50.00	42.50	1556.70	47.50	1551.70	37.70	1561.50	48.50	1550.70	2	Chipped Bent.	1	CO	P	
CMC-DL-103A	2/11/94	113334.650	2281957.000	1613.60	1616.41	A	9.00	2.70	1610.90	7.70	1605.90	2.20	1611.40	7.80	1605.80	2	Chipped Bent.	1	LWT	PERCHED	
CMC-DL-103B	2/11/94	113333.300	2281954.300	1613.60	1616.49	A	36.50	16.70	1596.90	21.70	1591.90	14.70	1598.90	23.70	1589.90	2	Chipped Bent.	1	LWT/FO	WT	
CMC-LSL-102B	2/14/94	114284.900	2279010.600	1592.10	1595.00	Ab	34.00	31.30	1560.80	32.30	1559.80	30.80	1561.30	32.30	1559.80	2	Chipped Bent.	1	CO	P	
CMC-LSL-102A	2/15/94	114399.100	2278953.700	1592.10	1595.19	Ab	18.50	16.20	1575.90	18.20	1573.90	15.60	1576.50	18.20	1573.90	2	Chipped Bent.	1	LA	P	
CMC-LSL-104A	2/13/94	112076.200	2275945.000	1592.10	1594.72	Ab	18.00	14.70	1577.40	16.70	1575.40	13.20	1578.90	16.70	1575.40	2	Chipped Bent.	1	LA	P	
CMC-LSL-104B	2/13/94	112072.700	2275937.400	1592.10	1594.69	Ab	28.00	22.10	1570.00	25.10	1567.00	21.60	1570.50	25.10	1567.00	2	Chipped Bent.	1	CO	P	
CMC-SCC-102A	2/07/94	120038.800	2280679.900	1583.70	1587.41	A	11.00	4.70	1579.00	9.70	1574.00	4.20	1579.50	11.00	1572.70	2	Chipped Bent.	1	LWT	WT	
CMC-SCC-102B	2/7/94	120042.700	2280678.300	1583.70	1587.17	A	22.50	16.80	1566.90	21.80	1561.90	14.80	1568.90	22.50	1561.20	2	Chipped Bent.	1	CO	P	
CMC-OWA-5	10/15/94	115990.280	2277837.120	1648.60	1651.29	A	132.00	125.00	1523.60	130.00	1518.60	123.00	1525.60	132.00	1516.60	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-4	10/11/94	116367.710	2277607.170	1661.20	1663.85	A	126.00	120.00	1541.20	125.00	1536.20	118.00	1543.20	126.00	1535.20	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-3	10/18/94	116218.570	2277666.070	1657.80	1660.05	A	131.00	125.00	1532.80	130.00	1527.80	123.00	1534.80	131.00	1526.80	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-2	10/20/94	116283.020	2277645.760	1658.70	1661.07	A	191.00	185.00	1473.70	190.00	1468.70	183.00	1475.70	190.50	1468.20	2	Bent/Bent. Slurry	1	SS	P	
CMC-OWA-1	10/17/94	116229.250	227761.240	1657.60	1660.10	A	205.00	181.00	1476.60	186.00	1471.60	179.00	1478.60	190.00	1467.60	2	Bent/Bent. Slurry	1	SS	P	
CMC-14P	10/7/94	115996.510	2278987.850	1608.90	1611.31	A	110.00	93.00	1515.90	94.00	1514.90	91.00	1517.90	95.00	1513.90	2	Bent/Bent. Slurry	1	MS	P	
CMC-13P	10/3/94	116352.220	2276978.090	1684.40	1686.77	A	236.00	211.00	1473.40	212.00	1472.40	209.60	1474.80	213.00	1471.40	2	Bent/Bent. Slurry	1	MS	P	
CMC-12P	10/13/94	116478.660	2276322.760	1648.00	1650.44	A	205.00	194.00	1454.00	195.00	1453.00	192.00	1456.00	196.00	1452.00	2	Bent/Bent. Slurry	1	MS	P	
CMC-11P	10/15/94	116228.680	2275939.770	1643.50	1645.89	A	215.00	202.00	1441.50	203.00	1440.50	198.70	1444.80	205.00	1438.50	2	Bent/Bent. Slurry	1	MS	P	
CMC-10PP	10/18/94	116050.240	2278600.210	1619.70	1621.67	A	110.00	101.00	1518.70	102.00	1517.70	100.00	1519.70	103.00	1516.70	2	Bent/Bent. Slurry	1	MS	P	
CMC-PWA	9/25/94	116169.000	2277699.690	NS	NS	A	230.00	180.00	NR	230.00	NR	None	None	None	None	6 - Steel	Neat Cement	1	SS	PW	
CMC-PWB ~	10/9/94	116040.800	2278646.220	1616.50	NS	A	400.00	180.00	1436.50	400.00	1216.50	None	None	None	None	6 - Steel	Neat Cement	1	SS/UDB	PW	
CMC-PWAR ~	10/4/94	116183.060	2277679.090	1656.80	NS	A	270.00	219.00	1437.80	250.00	1406.80	None	None	None	None	6 - Steel	Neat Cement	1	SS	PW	
CMC-SP-01	12/2/94	114244.4	2279412.2	1595.15	1597.3	A	1589.5	2.65	1592.5	5.65	1589.5	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-02	12/1/94	114181.3	2279306.4	1594.75	1596.95	A	1589.2	2.55	1592.2	5.55	1589.2	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-03A	12/1/94	114628.8	2278974.6	1594.45	1597.2	A	1589.41	2.04	1592.41	5.04	1589.41	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-03B	12/2/94	114627.6	2278975.8	1594.39	1596.04	A	1573.07	18.32	1576.07	21.32	1573.07	None	None	None	None	1.25 SWP	None	1	LA	P	
CMC-SP-04	12/1/94	114726.9	2279029.4	1593.49	1596.19	A	1588.46	2.03	1591.46	5.03	1588.46	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-05A	12/1/94	114907.4	2278578.4	1592.63	1597.28	A	1589.51	0.12	1592.51	3.12	1589.51	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-05B	12/1/94	114908.8	2278580.5	1593.79	1594.84	A	1572.35	18.44	1575.35	21.44	1572.35	None	None	None	None	1.25 SWP	None	1	LA	P	
CMC-SP-06	12/1/94	114977.8	2278619.2	1594.55	1597.55	A	1589.76	1.79	1592.76	6.79	1587.76	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-07	12/1/94	115104.1	2278023.5	1594.52	1597.64	A	1584.89	1.63	1592.89	4.63	1589.89	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-08	12/1/94	115222.1	2278024.2	1595.82	1596.92	A	1589.15	3.67	1592.15	6.67	1589.15	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-09	12/1/94	115000.5	2279219.9	1596.7	1597.2	A	1590.17	3.53	1593.17	6.53	1590.17	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-10	2/16/95	109595.2	2278780.3	1606.4	1608.46	A	1583.13	20.27	1586.13	23.27	1583.13	None	None	None	None	1.25 SWP	None	1	LWT	DRY	
CMC-SP-11A	2/27/95	113325.8	2278711.5	1593.16	1597.01	A	1589.26	0.9	1592.26	3.9	1589.26	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-11B	2/27/95	113325.5	2278712.5	1593.28	1595.18	A	1572.13	18.15	1575.13	21.15	1572.13	None	None	None	None	1.25 SWP	None	1	LA	P	
SG-WP-1	1984	110564.3	2265584.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	FO	SG	2
SG-WP-3	1984	119324.1	2267815.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	1

Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	East	Elevation (msl) Ground	PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
SG-WP-4	1984	121833.9	2274311.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	2
SG-WP-6	1984	117798.5	2286975.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	FO	SG	2
SG-WP-7	1984	116437.0	2287828.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	1

NS - Not Surveyed
NR - Not Reported or Recorded
BGS - Depth Below Ground Surface
msl - Mean Sea Level
TA - Temporarily Abandoned
A - Active
Ab - Abandoned
~ - Approximate Depth From Logs

LEGEND
SWP - Steel Well Point
Bent/Grout - Bentonite Seal With Grout Annular Space Seal
Note-Wells drilled through ice have the ice level for the ground elevation
Cem. Bent. Gt - Cement Bentonite Grout
SG-WP-1, -3, -4, -6, & -7 : Staff Gages in Creek

P=Piezometer
WT=Well used as water table well
PW=Pump Well
ART= Flowing Artesian Well
Perched=Well Monitoring Perched Zone
DRY= Dry Well

FORMATION MONITORED
LWT - Late Wisconsinan Till
EWT - Pre-Early Wisconsinan Till
CO - Coarse Outwash
FO - Fine Outwash
LA - Lacustrine
IM - Ice Marginal
MS - Massive Saprolite
SS - Structured Saprolite
UDB - Undifferentiated Bedrock
UKN - Unknown

Prepared by: MLB (TLM)
Checked by: EAS (JJA)
Revised by: SVD1
Checked By: TH

Layer Number corresponds to groundwater model layer: Layer 1=Late Wisconsinan Till, Layers 2 and 3 = Outwash layers, Layer 4= Pre- to Early Wisconsinan Till.
Shaded cells = revised number.

3.6.1.1.2 1979-1982 Golder Investigations

From 1979 to 1982, 110 borings were drilled and 64 monitoring wells were installed as part of the hydrogeologic and geotechnical investigations for the siting and design of the TMA (Golder 1981b). The investigations were completed in several phases and consisted of concurrent detailed characterization studies in two areas. The first site (Area 40, G40 series borings and wells) encompassed an area between Little Sand lake on the east, Mole Lake to the west, Rolling Stone Lake to the south and Swamp Creek to the north. The second site (Area 41, G41 series borings and wells) encompassed area between Ground Hemlock Lake on the east, Little Sand Lake to the west, Swamp Creek to the north and Walsh Lake to the south. The location of the wells are shown on Figure 3.6-1 and 3.6-2.

Drilling and soil sampling methods for these wells were described in Section 3.5.1.2.3. Wells for the observation of groundwater levels were placed at various depths over the prospective sites. The installation depths were varied to provide water quality samples from different levels and to observe the relationship between the hydrostatic head at these depths.

The observation wells consisted of five to 20 feet of machine slotted O.D. PVC pipe set at the desired depth with a gravel backfill. Solid two inch O.D. PVC pipe was then continued to the surface. Water was flushed through the assembly until the drilling mud and filter cake was washed from the hole. Gravel was then placed around the slotted and solid PVC pipe to the desired depth. A bentonite clay seal, a minimum of three feet thick, was placed over the gravel. The annulus around the solid pipe was then backfilled with cement grout to the surface. The PVC pipe was cut off two to three feet above the ground surface and capped with a steel protection pipe with hinged top and lock. Specific well installation details are presented with their respective boring logs in Appendix 3.5-2. Well construction is summarized in Table 3.6-1.

3.6.1.1.3 1981 Ore Body Pump Test Piezometer Installation Program

In 1981 a series of monitoring wells were installed in the vicinity of the ore body as part of an ore body pump test program (Section 3.6.1.6.3) to identify the hydraulic characteristics at the contact between the ore body and glacial overburden. The wells were installed under the direction of Camp, Dresser & McKee (CDM series monitoring wells) and Braun Engineering (BE series monitoring wells). The location of these monitoring wells are shown on Figure 3.6-1 and 3.6-2.

The drilling methods for installation of the CDM and BE series wells were described in Section 3.5.1.2.4. CDM wells CDM-15 and CDM-16, were constructed of two inch diameter PVC with 30 foot slotted screens. No information is available with regard to gravel pack dimensions or material used to seal the annular space. Given past well construction practices, it is assumed that the annular space above the screen of these two wells was sealed with a bentonite or cement grout. Boring logs are provided in Appendix 3.5-4. In addition to the two CDM wells, Camp Dresser & McKee also installed several shallow sand points on the northwest side of Little Sand Lake, referred to as monitoring points CDM-17, 18, 19 and 20. These sand points consist of galvanized pipe with two foot long screens. The construction information for the CDM wells and sand points is presented in Table 3.6-1.

The BE series wells were installed in the vicinity of the ore body. These wells were constructed with two inch or 3/4 inch diameter PVC equipped with screen lengths ranging from seven feet to 40 feet in length. The monitoring wells were screened in the bedrock, the glacial overburden, or

across the glacial overburden bedrock contact. The gravel packs of the BE series wells typically extended from zero to ten feet below the screen bottom and extended from four to 15 feet above the top of the screen. The remainder of the annular space was sealed with grout. Table 3.6-1 summarizes construction details for these wells. Boring logs and well completion forms are contained in Appendices 3.5-3 and 3.6-1 respectively.

3.6.1.1.4 1984 Investigation

In 1984, STS Consultants, Ltd. (1984a and b) completed 16 borings that were converted to nested wells and installed seven nested well points along creeks, such as Hemlock, Swamp, and Pickerel, that act as groundwater discharge points. This investigation was designed to provide increased resolution of the hydrostratigraphic units and groundwater flow regime within the study area through the placement of nested wells and the completion of extensive grain size analyses.

The drilling program included sixteen soil borings and multiple well installations at the EX locations (EX-1 through EX-16). Details on drilling methods are described in Section 3.5.1.2.5.

Shallow well points were installed at seven locations (WP-1 through WP-7) by STS adjacent to groundwater discharge areas using either power augers or the wash boring technique. Two well points at different elevations were installed at each location. No drilling muds were used for the well point installations. The locations for the well points and EX borings are presented on Figures 3.6-1 and 3.6-2.

Three to five piezometers were installed at each EX location. Where possible, two piezometers were installed in a single borehole. The deepest borehole at each location was designated A, and the progressively shallower boreholes were designated B, C, and D. Within a single borehole, the lowest piezometer was designated "L", and the uppermost piezometer in the borehole was designated "U".

The specific construction details for each piezometer installation are shown on Field Well Installation Diagrams in Appendix 3.6-1. Each piezometer consisted of a two inch diameter, Schedule 40 PVC riser pipe with solvent-welded belled couplings. Prior to placing the well screen in the borehole, approximately two feet of pea gravel was placed. A three foot long well screen with No. 20 slot was then inserted in the borehole. Typically, Barafos was pumped into the well screen area to help disperse the bentonite wall cake. Pea gravel was then placed around the well screen to approximately two feet above the well screen.

In the first few piezometer installations (EX-4,5,15 and 16), bentonite pellets were placed above the pea gravel to seal the piezometer tip into a particular soil stratum. Grout was then placed to fill the annulus to the next piezometer or the ground surface. The grout consisted of a mixture of seven gallons of water for each 94 pound bag of Type I Portland Cement with two pounds of bentonite powder. Two pounds of calcium chloride were also added to the grout to accelerate hardening. The grout was placed by using a tremie pipe. However, during initial installations problems developed with the grout displacing the bentonite pellet seal and entering the well screen. On the remaining installations, the cement grout and bentonite pellets were replaced with Benseal, a granulated bentonite. The Benseal was mixed with EZ Mud, a polymer, to retard swelling long enough to allow the driller to pump the mixture through a tremie pipe to the desired depth of the borehole. Benseal worked satisfactorily and reduced the waiting time between piezometer installations in a single borehole.

The shallowest piezometer at each multiple installation was designed as a water table observation well. It typically consisted of a two inch diameter PVC pipe with a 15 to 20 foot long well screen with No. 20 slot backfilled with pea gravel.

All the piezometers were developed after installation using compressed air for approximately 30 minutes. In addition, prior to conducting permeability tests, a plunger was used in each of the piezometers to surge the well screen at the request of the WDNR. After review of the field permeability test results, 17 piezometers were selected for further development. Most of these were located within fine sand layers. It appeared that the surging caused fine sand to enter the well screen and fill a portion of the riser pipe. These partially plugged wells were successfully redeveloped by using both water and compressed air to remove the fine sand.

STS installed 14 well points at seven locations (WP-1 through WP-7). Each location consisted of one shallow water table well and one deep piezometer. Well Installation Diagrams for these well points are presented in Appendix 3.6-1. The shallow well points typically ranged in depth from five to ten feet, and consisted of a four to eight foot length of PVC well screen with No. 10 slot. The shallow well points were installed within an auger hole and pea gravel was placed adjacent to the well screen. The PVC well screen was attached to a galvanized riser pipe and the annulus was sealed with a bentonite slurry. The lower well points were approximately 33 feet deep, and consisted to two inch diameter galvanized pipe with three foot long stainless steel well point with No. 10 slot. In general, the borehole was advanced to 30 feet, and then the well point was driven the final three feet. The borehole annulus was then sealed with grout. The well points were not developed.

3.6.1.2 Lake Bed and Wetland Drilling Studies

An extensive number of investigations have been completed to identify the hydrogeologic characteristics of lake beds and wetlands within the immediate study area. These investigations were conducted in the early and mid 1980s. Subsequent investigations were conducted in 1994. Section 3.5.1.3 summarized the drilling programs that were completed to characterize the soil properties that comprise the lake bottoms. In addition to the borings described in Section 3.5.1.3, monitoring wells were completed within and below the lake bottoms to assess the hydraulic relationship between lakes and the regional groundwater system. Following is a summary of the wells installed for each investigation. Figure 3.6-3 shows the location of lake and wetland borings and piezometers. Table 3.6-1 summarizes piezometer construction information.

3.6.1.2.1 1982 Little Sand Lake Piezometer Installation Program

In 1982, STS Consultants, Inc. (1982) conducted a drilling program (STS-LSL series borings) on Little Sand Lake to characterize lake bed sediments with regard to thickness, physical characteristics and permeability. A total of six borings were completed on Little Sand Lake, of which four were used as piezometers to measure hydraulic head beneath the lake bed. The location of the borings and piezometers are presented in Figure 3.6-3, and consist of the STS-LSL series.

At four of the boring locations the boreholes were bailed, and water level observations were made in the casing over a period of five days until the water level in the casing had stabilized. Since the casing was advanced into the outwash deposits, the water level in the casing reflected

the hydraulic head in the outwash deposits that form part of the regional aquifer. Boring logs for the STS-LSL wells are contained in Appendix 3.5-7.

3.6.1.2.2 1984 Deep Hole, Duck, Skunk, and Oak Lake Drilling Program

In 1984, a second lake bed piezometer installation program was completed by STS Consultants, Ltd. (1984c) to characterize thickness, physical characteristics, and hydraulic conductivity of additional lakes within the project study area. The lakes that were investigated were Oak, Deep Hole, Duck and Skunk Lakes (STS-OL, STS-DHL, STS-DL and STS-SL series borings and wells). The borings were completed via conventional rotary wash methods with casing advanced through the lake bed down to the top of the underlying outwash/till deposits. Undisturbed soil samples were obtained of the lake bed for grain size analysis and permeability testing. After completion of the borings, wells were installed in the borings. After stabilized water level measurements were obtained from the wells, they were abandoned with a cement-bentonite grout. The boring and well locations are shown in Figure 3.6-3. Boring logs were provided in Appendix 3.5-8. Well construction forms are provided in Appendix 3.6-1.

3.6.1.2.3 1985 Duck and Skunk Lake Wetland Drilling Program

In 1985, a third investigation was conducted related to the lakes in the vicinity of the project site by STS Consultants, Ltd. (1986). The focus of this investigation was the wetlands in the vicinity of Duck and Skunk Lakes. This investigation consisted of four well installations in the Skunk Lake wetland and five well installations in the Duck Lake wetland. Figure 3.6-3 shows the location of the well installations (STS-DL-2, 3, 4, 5 and 6, and STS-SL-3, 4, 5 and 6) that were completed. The wells were installed manually with a hand auger, and thus no undisturbed soil samples were obtained for permeability testing. Boring logs with referenced well completion information is contained in Appendix 3.5-9.

3.6.1.2.4 1994 Little Sand Lake and Wetland Drilling Program

In 1994, Foth & Van Dyke (1994a; CMC 1994) completed a fourth lake bed and wetland piezometer installation program. The objectives of this program were to:

- further define the hydraulic relationships between lake/wetlands, and the regional groundwater system; and,
- to further define the hydraulic properties of lake beds and wetland soils through in situ hydraulic conductivity tests on piezometers and lab permeability tests performed on undisturbed soil samples.

The areas that were investigated as part of this program were:

- the littoral zone of Little Sand Lake (CMC-LSL series borings and wells);
- the Skunk and Duck Lake wetlands (CMC-DL, and CMC-SL series borings and wells); and,

- Burr Oak Swamp, the Swamp Creek Cedars Wetland and the Swamp Creek Wetland (CMC-BO, CMC-SCC, and CMC-SC series borings and wells, respectively).

Figure 3.6-3 shows the location of piezometer nests that were completed in 1994. Drilling procedures were described in Section 3.5.1.3.4. One piezometer nest was completed in each of the Swamp Creek Cedars, Burr Oak Swamp and Skunk Lake wetlands. One piezometer was installed immediately adjacent to the Duck Lake wetland since the wetland could not be accessed by any drilling equipment. Previous studies on Little Sand Lake focused on lacustrine clay thickness and hydraulic characteristics in the center of the lake. For the current study, in addition to the four borings described in Section 3.5.1.3.4, two piezometer nests were installed around the perimeter (littoral zone) of Little Sand Lake to assess the hydraulic characteristics of lacustrine clay in shoreline areas and the hydraulic relationship between the lake and underlying outwash.

All borings not used for piezometer installations were abandoned in accordance with NR 141 of the Wis. Adm. Code. Wells installed in Little Sand Lake were left in place for approximately three weeks. After water levels stabilized (approximately two weeks) slug tests were performed to assess the in situ hydraulic conductivity of the lacustrine clay lake bed. Slug tests were performed by instantaneously increasing the water level in the well by quickly inserting a solid PVC pipe and measuring the rate at which the water level returned to equilibrium. This data was analyzed according the method described by Bouwer and Rice (1976) and Bouwer (1989). Several days after completion of the slug tests, the wells in Little Sand Lake were abandoned in accordance with NR 141 of the Wis. Adm. Code. All abandonment forms are provided in Appendix 3.5-10.

Lake bed and wetland piezometers were constructed in accordance with NR 141 of the Wis. Adm. Code and comments from the WDNR. Piezometers were constructed of two inch diameter Schedule 40 PVC or black pipe with a one to five foot long 10 slot PVC screen. The riser extended to three feet above the lake or wetland surface. All wells were developed in accordance with NR 141 of the Wis. Adm. Code. Well construction and development documentation is provided in Appendix 3.6-1.

3.6.1.3 1994 Groundwater Verification Monitoring Well Installation Program

Groundwater was sampled in 1994 and 1995 to validate the characterization of the groundwater quality work performed by Dames & Moore from 1978 to 1981. Described in this section is the rationale for selecting the monitoring well locations for this program and the well construction procedure used.

3.6.1.3.1 Selection of Well Locations for Monitoring

Forty-four wells were previously monitored by Dames & Moore (1982). Of these wells ten were sampled once, fourteen were sampled three to five times and 20 were sampled more than six times each. Additionally of these 44 wells, 24 had been abandoned in the mid-1980s, 13 were temporarily abandoned. Six were open and were being monitored quarterly for groundwater levels between the mid-1980s and 1994. Of the 20 wells that had been sampled more than six times, 12 have been abandoned, two wells have been temporarily abandoned, and five wells are active.

The purpose of the 1994 groundwater quality validation program was based on the following assumptions:

- The data collected by Dames & Moore was representative of the regional groundwater quality.

- Additional groundwater quality monitoring should concentrate on the locations identified as the areas of direct project impact (plant site and TMA) so that the data collected in 1994 could serve as baseline data for continued monitoring during the project after permits were obtained.

Planning for the groundwater quality validation program included reviewing the cumulative hydrogeological data collected by the various consultants in the 1970s and 1980s. Based on this review, a definitive groundwater quality validation program was developed. The first step in this program was to select the zones for monitoring. Like the 1970/1980 program, the 1994/1995 program focused on the overburden aquifer. The specific zones identified and the reasons for choosing them are:

- For the TMA, at the water table interface since this is the first contact that water recharging the aquifer has with groundwater, and within the outwash sand and gravel since this is the zone with the highest horizontal permeability.

- For the plant site, at the water table interface since the aquifer is thinner and the water table occurs in the outwash, and within the till immediately above the bedrock. These two zones would provide groundwater quality data for the groundwater that will flow into the mine.

Once the planned zones for monitoring were chosen, existing plant site and TMA area wells were evaluated to determine their applicability to the program. As part of this assessment, wells which were temporarily abandoned were opened so that a field evaluation could be conducted for well continuity. The evaluation also included wells which were being actively monitored for groundwater levels. Each well was assessed by visual inspection, measurement of the water level, measurement of total depth, and recording of the well size, condition and total depth. In addition, one or two photographs of each well were taken for documentation of existing conditions.

Based on the above the baseline groundwater validation program for the TMA was established to include two existing water table monitoring wells, four existing piezometers, the addition of six new water table wells and the addition of four new piezometers. Validation of groundwater quality at the plant site was established to include three new water table wells and three new piezometers. Table 3.6-2 lists the new and existing wells selected for the 1994 program. The location of the wells is shown on Figure 3.6-2a.

The original plan presented in the NOI/SOS (Foth & Van Dyke, 1994c) was to use an existing well (DMS-1) as a piezometer at the plant site. After well installation work began in the spring of 1994, it became apparent that DMS-1, which has a very long filter pack, would not serve well as a piezometer for the planned program. Therefore, CMC-08P was installed in its place. Also the plan presented in the NOI/SOS had referred to the use of existing well EX-9AL. The correct reference is to well EX-9BL. Well EX-9BL was the well used in the validation program.

Table 3.6-2

Groundwater Quality Validation Wells

Well	Formation to be Monitored	Existing (E) or New (N)
TMA		
CMC-01R	water table	N
CMC-01P	outwash	N
EX-9BU	water table	E
EX-9BL	outwash	E
CMC-02R	water table	N
CMC-02P	outwash	N
CMC-03RR	water table	N
CMC-03P	outwash	N
CMC-04	water table	N
G41-H18B	outwash/Late Wisconsinan Till	E
CMC-05	water table	N
EX-13BU	outwash	E
DMB-6	water table	E
CMC-06P	outwash	N
CMC-07	water table	N
DMB-1A	outwash/Late Wisconsinan Till	E
Plant Site		
CMC-08	outwash	N
CMC-08P	till above bedrock	N
CMC-09	outwash	N
CMC-09P	till above bedrock	N
CMC-10	outwash	N
CMC-10P	till above bedrock	N

Prepared by: LLA
Checked by:SVD1

3.6.1.3.2 Well Construction

To supplement historical groundwater quality data obtained in the study area, a series of new groundwater monitoring wells were installed in 1994. These wells are referred to as CMC-01R, -01P, -02R, -02P, -03RR, -03P, -04, -05, -06P, -07, -08, -08P, -09, -09P, -10 and -10P. The drilling methods for the installation of these wells was described previously in Section 3.5.1.4 of this report. The wells were constructed in accordance with NR 141 of the Wis. Adm. Code. All wells were constructed of two-inch diameter Schedule 40 or Schedule 80 PVC. The annular space of the well was sealed with bentonite chips or slurry. Water table wells were constructed with 15-foot long slotted PVC screens. The filter pack was constructed of Red Flint Filter Sand. Approximately two feet of fine sand was placed between the gravel pack and the bottom of the annular space seal. After the well was set, a four-inch diameter locking steel casing was placed over the well. All wells were developed in accordance with NR 141. Well completion and development forms are provided in Appendix 3.6-1. Table 3.6-1 summarizes the construction information for these wells.

The existing wells used in the validation program were installed prior to the promulgation of NR 141. A comparison of the completion information for these wells to NR 141 requirements is shown on Table 3.6-3. As shown in the table the existing wells were installed with screens, filter packs and impermeable annular space seals and therefore, were deemed suitable for groundwater sampling as part of the 1994 program. Prior to using the existing wells for groundwater sampling, each well was redeveloped by surging and purging with a pump until the water was clear and readings for pH, temperature, and conductivity had stabilized.

3.6.1.4 1994 Saprolite Investigation Monitoring Well Installation Program

A component of the 1994 saprolite investigation was the installation of monitoring wells within the structured saprolite, bedrock, and overlying massive saprolite and glacial till. These wells were used for slug tests and observation points in a large scale pump test to characterize the hydraulic characteristics of a massive saprolite layer that resides over the ore body. The monitoring wells that were installed as part of this program include CMC-10PP, 11PP, 12P, 13P and 14P; and CMC-OWA1, 2, 3, 4 and 5. Table 3.6-1 summarizes the construction information for these wells. Figure 3.6-2 shows their geographic location.

The monitoring wells and pump test observation wells constructed as part of the saprolite investigation program were installed either in the Pre-to Early Wisconsinan till, the massive saprolite, or structured saprolite. Five monitoring wells were installed and sealed within the massive saprolite (CMC-10PP, CMC-11P, CMC-12P, CMC-13P, CMC-14P). Two pump test observation wells were installed and sealed within structured saprolite (CMC-OWA1, CMC-OWA2). Three pump test observation wells were installed and sealed within the lower portion of the Pre-to Early Wisconsinan till (CMC-OWA3, CMC-OWA4, CMC-OWA5).

The borings for the massive saprolite wells were cored a minimum of ten feet into structured saprolite for observation of the full thickness of the massive saprolite present at each location. The lower portion of the borehole was backfilled with Holeplug™ up into the lower one to two feet of the massive saprolite. One to two feet of filter pack sand were then placed above the

Table 3.6-3

Comparison of Existing Wells to NR 141

NR 141	EX-9BU	EX-9BL	G41-H18B	EX-13BU	DMB-6	DMB-1A
Total Depth-Borehole (Ft)	193.5	193.5	288	193	86	79.4
Total Depth-Well (Ft)[D]	138	193	160	147	87	81
Borehole Diameter (In)	6.25	6.25	[B]	6.25	6	6
Well Casing (In)	2	2	2	2	2	2
Well Casting Material	Sch 40 PVC	Sch 40 PVC	PVC[A]	Sch 40 PVC	PVC[A]	PVC[A]
Well Screen Length (Ft)	20	3	10	3	10	10
Well Screen Material	PVC	PVC	PVC	PVC	PVC	PVC - 2 in
Screen Size	#20 Slot	#20 Slot	[C]	#20 Slot	[C]	[C]
Filter Pack	Pea Gravel 2 Ft Below Screen 10 ft above Screen	Pea Gravel 2 Ft Below Screen 2 Ft above Screen	Pea Gravel 131 Ft Below Screen 7 Ft above Screen	Pea Gravel 7 Ft Below Screen 6 Ft above Screen	Gravel Pack 23.9 Ft	Gravel Pack 49 Ft
Filter Pack Seal	17 Ft Bentonite Slurry	28 Ft Bentonite Slurry	3 Ft Bentonite Slurry	7 Ft Bentonite Slurry	7.8 Ft Sand 3.8 Ft Bentonite	6 Ft Sand
Annular Space Seal	88 Ft Cement Bentonite Grout	32 Ft Pea Gravel 17 Ft Bentonite Slurry 88 Ft Cement/Bentonite Grout	140 Ft Grout	128 Ft Cement/Bentonite Grout	50 Ft Grout	24 Ft Grout
Ground Surface Seal	Cement/Bentonite Grout	Cement/Bentonite Grout	Grout	Cement/Bentonite Grout	Grout	Grout
Note	EX-9BU and EX-9BL are in common borehole	EX-9AU and EX-9AL are in common borehole.		EX-13BU and EX-13BL are in a common borehole.		

A Schedule of PVC not noted on borelog by installer.
B Borehole diameter not noted on drill log.
C Screen slot size not noted on drill log.
D Reported to nearest foot, reloaded from top of casing.

Prepared by: LLA
Checked by: SVD1

Holeplug™ below the bottom of the well screen. Schedule 80 PVC flush threaded well screen and casing were used for wells greater than 100 feet in depth. Schedule 40 PCV flush threaded well screen and casing were used for wells less than 100 feet in depth. A one-foot long well screen with a factory cut 0.006-inch slot was installed in each massive saprolite well.

The filter pack, filter pack seal and bentonite seal lengths were field fit in accordance to the plan presented in the *Work Plan for Investigation and Identification of Saprolite Properties* (Foth & Van Dyke, 1994b). The thinner massive saprolite zones had filter packs which extended one-foot above the top of the screen and filter pack seals nine-inches thick so that the wells were sealed within the massive saprolite. Thicker massive saprolite zones had filter packs which extended two feet above the well screen and filter pack seals which extended two feet above the filter packs in conformance with Wisconsin Administrative Code NR 141. These wells were also sealed within the massive saprolite. Bentonite seals in the massive saprolite wells ranged in thickness from three to 17 feet thick. Thicker bentonite seals were the result of the driller placing more Holeplug™ before filling the remaining annular space with bentonite slurry. The remaining annular space was sealed with bentonite slurry ranging in weight from 10.5 to 12.2 pounds per gallon. The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

Observation wells installed in the structured saprolite were constructed with schedule 80 PVC flush threaded well screen and casing. The well screens were five feet long and were factory cut 0.006-inch slots. The filter packs extended two feet above the well screens and the filter pack seals extended two feet above the filter packs. Bentonite seals in the structured saprolite wells ranged in thickness from four to six feet. The remaining annular space was sealed with bentonite slurry which weighed approximately 12 pounds per gallon. The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

Observation wells installed in the Pre- to Early Wisconsinan till were constructed with schedule 80 PVC flush threaded well screen and casing. The well screens were five feet long and were factory cut 0.006-inch slots. The filter packs extended two feet above the wells screen and the filter pack seals extended approximately two feet above the filter packs. Bentonite seals on the Pre- to Early Wisconsinan till wells ranged in thickness from 11 to 22 feet. The remaining annular space was sealed with a high solids grout (per NR 141). The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

All wells were developed prior to pump or slug testing. Well development consisted of bailing only for wells which could be purged dry and surging and bailing for wells which could not be purged dry. In all cases, because well recovery rates were slow, the development effort was performed on two consecutive days for each well. Well construction and development details are provided in Appendix 3.6-1. Boring logs are provided in Appendix 3.5-13.

Three pump test production wells were drilled. Because of caving conditions in the open production interval of CMC-PWA it was unusable. Well CMC-PWB did not produce enough water for a pump test. The third well, CMC-PWAR, was used in the pump test. Conditions encountered during drilling resulted in the modification of each well installation. The saprolite work plan proposed wells that were drilled 20 feet into the structured saprolite and were steel cased and grouted. The production portion of the well was planned to be a 50-foot interval drilled below the bottom of the casing, with additional 50-foot drilled zones added if necessary to produce the required quantity of water. A high capacity well permit was granted by the WDNR on September 2, 1994.

Drilling of CMC-PWA was initiated on September 22, 1994. A ten-inch diameter borehole was drilled a depth of 180 feet by mud rotary drilling using Quick-Gel™, a Department-approved drilling mud with an additive. A 19.18 pound per foot new black steel Sawhill T&C A-53B casing was placed in the borehole and was held slightly off the bottom. The annular space was pressure grouted with neat cement grout. The grout was placed in the bottom of the casing and forced under the casing and up through the annular space. Grouting continued until fresh grout flowed out of the borehole between the casing and the borehole. The grout had a nominal mud weight of 16.6 pounds per gallon. After the grout was placed, but prior to setting, the casing was driven 27 inches into the bedrock with a casing driver that had been welded onto the lower end of the casing. The neat cement was allowed to cure for 72-hours prior to completion of the open portion of the well.

On September 27, 1994, the drilling of the open portion of the well was initiated. The drilling method for the lower portion of the well was completed by air rotary methods using a nominal six-inch down-hole hammer bit. High pressure air was used to lift cuttings and groundwater out of the borehole. Estimates of the amount of groundwater being produced can be made by this drilling method. The first twenty feet of drilling encountered soft friable structured saprolite. This material continued to cave into the hole even as the hole was advanced for an open interval of 50 feet to a total depth of 230 feet. The drill rods were removed and the well was allowed to equilibrate overnight. The next day the hole was found to have a total depth of 180 feet, which was the depth to the bottom of the casing, indicating that the hole had caved. Because of the variable nature of the ore body, a decision was made to install a replacement production well with a longer cased interval beyond this friable zone.

The second well, CMC-PWAR was located approximately 20 feet to the west of CMC-PWA. Drilling of CMC-PWAR was initiated on September 29, 1994 and was completed in a manner similar to CMC-PWA. The upper portion of the well was drilled by mud rotary methods to a total depth of 220 feet. The well was grouted as described above. The open portion of the well was started and completed on October 4, 1994 to total depth of 270 feet. Well construction reports, WDNR Form 3300-77A, for CMC-PWA and CMC-PWAR are included in Appendix 3.6-1. Boring logs are provided in Appendix 3.5-13.

Specific capacity testing of CMC-PWAR produced many fine-grained materials which increased in frequency as the well was pumped. A decision was made to place a four-inch Johnson channel pack screen in the well so that the production zone would stay open during the pump test. The well screen was a 30-foot long four-inch pipe size (5.25-inch O.D. by 4.0-inch I.D.), 8-slot screen

with a 40 by 60 filter pack which was factory installed between two screens. The screen was lowered into the well on a ten-foot length of blank casing and sealed in the bottom of the well by a K-packer. The lower 20 feet of CMC-PWAR had caved so the total depth of the well was only 250 feet at the time of installation of the well screen.

The drilling of CMC-PWB was initiated on October 5, 1994 and was completed in a manner similar to CMC-PWA. The upper portion of the well was drilled by mud rotary methods to a total depth of 220 feet. The casing was not grouted. Instead the casing was driven into the rock to refusal and the annular space remained filled with bentonite drilling mud. This procedure was implemented in case a sloughing zone was encountered and the casing needed to be driven deeper. Drilling of the open portion of the well was started on October 6, 1994 and completed on October 9, 1994. The first 50-feet of open zone drilled produced an estimated five gallons per minute of groundwater. An additional 130 feet of open hole was drilled in an attempt to intercept a water-bearing fracture zone. After this additional drilling CMC-PWB still would produce only an estimated five gallons per minute of groundwater. The well construction report, WDNR Form 3300-77A, for CMC-PWB is included in Appendix 3.6-1. The boring log for CMC-PWB is provided in Appendix 3.5-13.

Past drilling records in the area of CMC-PWB were again reviewed. The rock materials encountered in the drilling of CMC-PWB were consistent with rock cores obtained during exploratory drilling programs. Limited groundwater was encountered in the southern extent of the ore body and footwall during the previous drilling efforts. Therefore, it was concluded that additional drilling attempts along the southern extent of the ore body would not be expected to produce the quantity of water desired for an ore body-footwall pump test. If the production well moved northward, the well would produce water from the ore body-hanging wall contact instead of from the ore body-footwall contact. As a result, the CMC-PWB pump test was deleted from the saprolite investigation program.

3.6.1.5 1994 Little Sand Lake Sand Point Installation Program & Miscellaneous Well Installations

In December 1994 and February 1995 CMC installed 14 sand points in the vicinity of Little Sand Lake to further define the relationship between lake stage and shallow groundwater around Little Sand Lake and between Little Sand and Deep Hole Lakes. The sand points that were installed include the CMC-SP series wells shown on Figure 3.6-2. The sand points were constructed of 1¼ inch galvanized pipe with a three foot steel screen attached to the end of the pipe. The sand points were installed by manually driving the point into the soils with a weight. Table 3.6-1 summarizes the completion information for these sand points. Sand point installation information is provided in Appendix 3.6-1.

During the late 1970s several wells were installed in the vicinity of the plant site to evaluate various facility design alternatives. These wells include the DW Series, production wells TW-1 and TW-2 and the WW Series wells. Wells STS-EVS and STS-WVS, were installed as part of the evaluation and design of the east and west vent shafts. Well TW-41 was installed in the vicinity of the TMA and used for the 24-day pump test discussed in Section 3.6.1.6.3 below. Available well construction reports are provided in Appendix 3.6-1. Note that well construction reports are not available for the WW Series wells.

3.6.1.6 Hydraulic Conductivity Testing

A number of programs have been conducted since the late 1970s to evaluate the hydraulic conductivity of major hydrogeologic units that control regional groundwater flow and the interaction of groundwater between the ore body/bedrock and the glacial overburden. These testing programs consisted of lab permeability tests, slug tests on monitoring wells, ore body pump tests in 1981 and 1994, packer tests in open bedrock exploration holes and a pump test in the glacial drift. A brief description of each testing program is presented below.

3.6.1.6.1 Soil Permeability Tests 1977-1979

Soil Permeability tests in the study area were completed as part of the regional hydrogeologic investigation during the installation of DMA, DMB, and DMC series borings and monitoring wells. Information on in situ permeability was collected by conducting falling and rising head slug tests on selected DM series wells.

Rising head and falling head tests were conducted on 36 monitoring wells (Dames & Moore 1982). These tests were conducted by changing the static water level in the well by adding or removing water. The subsequent return of the water level to the static condition is then recorded over time. Field data collected during the falling and rising head tests were analyzed using Hvorslev's relationship (1951), which is an exponential curve function that relates the change in head in a piezometer verses time to arrive at an estimate of in situ soil permeability. Figures 3.6-4 and 3.6-5 show the location of DM series wells that slugs were performed on. Slug test data is provided in Appendix 3.6-2.

3.6.1.6.2 Bedrock Packer and Slug Tests

In 1978, 1981, 1983 and 1984 a number of single well packer tests and slug tests were conducted on wells and exploration holes screened and sealed within the Precambrian bedrock. The purpose of these tests was to assess the water-producing ability and hydraulic conductivity of the ore body, host rock and regional bedrock.

In 1978, Dames & Moore (1978) conducted a series of packer tests in deep exploration holes 165, 155, 70, 66, 91 and 77. Within any given exploration hole, multiple zones were tested. The tests were performed with multiple packers used to isolate selected zones between the packers or with a single packer used to isolate a zone between the packer and the bottom of the hole. Recovery data was analyzed according to the methodology of Ferris, et. al. (1962).

In 1981, Exxon (Landers, 1981) conducted a series of packer tests in exploration hole 213 to evaluate the change in hydraulic conductivity within a weathered zone along the contact between the hanging wall and ore body. Like the Dames & Moore tests, multiple zones were tested.

In 1983, Exxon (Rowe, 1984) conducted a number of single well slug tests of the upper regions of the ore body. The tests were conducted by instantaneously stressing the aquifer, through injection or removal of water, such that the resulting water level was above or below the pre-stressed potentiometric level and then measuring the rate of recovery of the water level in the well. The holes tested (253, 254, 255, 256 and 257) were cased through the glacial overburden and into the top of the bedrock. The test section of the wells were left as open holes with no screen or casing. The recovery data were analyzed according to the Jacob's straight line approximation method (Fetter, 1980).

In 1984, STS Consultants (1984a and b), as part of the regional hydrogeologic investigations, installed a number of wells in the regional bedrock that were used to conduct falling head permeability tests. The static water level in these wells was instantaneously increased by inserting a 15 foot long, one inch diameter PVC slug. The recovery of the water level in the well was then recorded over time. Recovery data was analyzed according to methodology developed by the Department of Navy (1971), which is equivalent to the Hvorslev method (1951) with the exception that the recovery data is not normalized. The location of the exploration holes and monitoring wells that were tested are shown on Figure 3.6-6. Bedrock permeability test data is provided in Appendix 3.6-3.

In 1995 Hydro-Geo Consultants, Inc. (Hydro-Geo, 1995) performed a series of additional packer permeability tests in open boreholes adjacent to the proposed mine. In addition, this new data and previously collected data were analyzed by Hydro-Geo Consultants, Inc. to characterize bedrock permeability at the project site. The results of this work are presented in *Hydrologic Investigation and Packer Permeability Testing of Bedrock at the Crandon Mine* which can be found in Appendix F of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3.

3.6.1.6.3 1981 Bedrock Pump Test

In 1981, two pump tests were conducted by Camp Dresser & McKee (1982) in the Crandon Formation to evaluate the hydraulic connection between the ore body and the overlying glacial overburden.

The pumping wells used in the pump test were open exploration holes drilled through the overburden and the bedrock north (hanging wall) of the ore body. The tests were labeled according to the hole number that was pumped. The open holes were cased into bedrock and thus only pumped water from within the ore body and bedrock. The pump test in hole 211 was conducted for a total of 170 hours at a discharge rate of 225 gallons per minute (gpm). The pump test on well 213 was conducted for 170 hours at a pumping rate of 560 gpm.

During the pump test groundwater levels were measured in wells and exploration holes completed in both the overburden and the ore body (angled core holes or vertical wells placed in the top of the bedrock). Drawdown and recovery data from the pump tests were analyzed utilizing standard type curve methods described in Lohman (1972) and Reed (1980) to arrive at values for bedrock transmissivity, storage coefficient and boundary correlation. The ore body pump tests are described in detail in the Camp Dresser & McKee (1982) pump test report. The Camp Dresser & McKee pump test is discussed extensively in the Saprolite Report (FVD, 1995a) submitted to the WDNR in February, 1995. Wells that were installed for this program include the CDM and BE Series wells. No construction records are available for the CDM wells. BE Series well construction records are provided in Appendix 3.6-1.

3.6.1.6.4 1981 Glacial Overburden Pump Test

In 1981, Golder Associates performed a pump test in the vicinity of the TMA to assess major hydraulic parameters of the glacial till and outwash deposits. The pump test was comprised of a test well, 13 primary observation wells, and 17 secondary observation wells.

The test well was screened over the full depth of the saturated glacial deposits. Observation wells were completed at various distances from the test well and at various depths. The drawdown phase of the pump test lasted 24 days, from June 27 to July 21, 1981, and was conducted at an average pumping rate of 1,420 gpm. Pump test drawdown and recovery data

was analyzed according to standard type curve analysis. Figure 3.6-7 shows the location of the test well and observation wells used in the pump test. The Golder Associates Pump Test Report is provided in Appendix 3.6-4.

3.6.1.6.5 1984 Slug Tests on Glacial Deposits

Field permeability or hydraulic conductivity tests were conducted by STS in 51 EX monitoring wells, seven well WP series points, and 27 older wells. Where possible, both rising and falling head tests were conducted in each well. Falling head tests were only conducted in wells sealed into very low permeability formations, such as bedrock. In the small diameter older BE series wells, rising head tests were conducted by using compressed air to remove the water column with the rate of water level recovery manually recorded. Except for the old small diameter wells, the field permeability tests were conducted using a pressure transducer and data logger.

The general procedures involved placing the 25 psi transducer approximately 20 feet below the static water level. The model PT-105V pressure transducer was connected to an Enviro Labs model DL120 data logger which has a microprocessor capable of being programmed to take and store transducer readings at any intervals from 10 seconds to 24 hours. Once the data logger was programmed to begin logging, a solid one inch diameter PVC slug approximately 15 feet long was dropped into the borehole to displace the column of water. Once the falling head test was completed, the slug was removed and a rising head test was conducted. After the test was completed, the data were printed out. Recovery data, which is provided in Appendix 3.6-5, was analyzed according to methodology developed by the Department of Navy (1971), known as the DM-7 Method. The DM-7 formula does not take into consideration changes in screen length or drainage from unsaturated gravel packs so field permeability tests were not conducted in the shallow water table piezometers or upper well points. The DM-7 formula is as follows:

$$K=\frac{r^2}{2L}\left(ln\frac{L}{R}\right)\left(\frac{lnH1/H2}{t2-t1}\right)$$

K = permeability
r = standpipe radius
L = gravel pack length
R = gravel pack radius
H = head level
t = time

This formula is equivalent to formula developed by Hvorslev (1951), with the exception that recovery data is not normalized. This formula is applicable when the radius of the intake point of the monitoring well differs from the radius of the standpipe. For the EX monitoring wells, the radius of the intake point is the radius of the borehole or gravel pack which is 3.125 inches. The radius of the standpipe is only one inch. Also, in all the EX wells, the gravel pack length exceeds the screen length. Therefore, the gravel pack length was used in the formula since water entering the entire gravel pack is immediately reflected in head level changes in the standpipe.

Field permeability test data is provided in Appendix 3.6-5. The first sheet provides a summary of the well construction details and permeability results. The second sheet is the graphical plot of the head ratio versus time. The third sheet is a summary of the field data (transducer readings). Figures 3.6-4 and 3.6-5 show the location of the EX and WP series wells and DM series wells that slug tests were performed on.

3.6.1.6.6 1994 Lake Bed and Wetland Slug Tests

Slug tests were performed on selected wells that were installed as part of the 1994 lake bed and wetland investigations. The wells that were tested include CMC-LSL-102 A/B, CMC-LSL-104 A/B, CMC-SL-102 A/B, CMC-DL-102B and CMC-BO-101A.

Slug tests were performed by instantaneously increasing the water level in the well by quickly inserting a solid PVC pipe and measuring the rate at which the water level returns to equilibrium. In the case of water table wells, a bailer was used to quickly remove a volume of water after which the water level rise in the well was recorded. This data was analyzed according to the method described by Bouwer and Rice (1976) and Bouwer (1989). Slug test data is provided in Appendix 3.6-6.

3.6.1.6.7 1994 Saprolite Investigation & Ore Body Pump Tests

In 1994, Foth & Van Dyke (1995a) conducted a detailed investigation of the hydraulic connection between the ore body and the glacial overburden. The focus of this investigation was to evaluate the hydraulic characteristics of a highly weathered bedrock layer or massive saprolite layer. The investigation consisted of the installation of monitoring wells placed along the strike of the ore body which were screened within the massive saprolite. Additional wells were placed above and below the massive saprolite in the vicinity of a high capacity well installed into the weathered bedrock (structured saprolite) above the ore body. A pump test was conducted in which the monitoring wells were used to measure drawdown below, within and above the massive saprolite. Slug tests were conducted on all observation wells. Pump test data was analyzed via numerical methods. The details of this investigation are discussed in the Saprolite Report (Foth & Van Dyke, 1995a) submitted to WDNR in February 1995. Slug test data is provided in Appendix 3.6-7.

3.6.1.7 Groundwater Level Measurements

Water levels from the monitoring wells installed during the above referenced investigations have been monitored with different frequencies dating back to the late 1970s. Water levels measured for each well are summarized in a database and on hydrographs contained in Appendix 3.6-8.

Prior to 1994 the depth to groundwater was recorded with an electronic water level indicator which measured groundwater to the nearest 0.05 ft, and estimated to the nearest 0.01 ft. This work was completed under the direction of CMC predecessor companies. From March 1994 through January 1995, groundwater elevations were measured monthly. The depth to groundwater was measured with a Well Wizard Model 6000 or Solinst Model 101 electronic water level indicator which measures to the nearest 0.01 ft.

All groundwater elevations were determined by subtracting the depth to water from the elevation of the measuring point (top of PVC casing). Each well was surveyed to establish vertical (ground surface and top of casing) and horizontal (coordinates) control. Vertical control was established to 0.01 feet. Horizontal control was established to 0.1 feet. The survey work was completed by Imman-Foltz and Associates, Inc. of Minocqua, Wisconsin and Foth & Van Dyke of Green Bay, Wisconsin. Survey work was completed under the direction of Wisconsin registered land surveyors.

3.6.1.8 Sample Collection, Analytical Procedures and Quality Control

Monthly sampling of 17 of the groundwater validation monitoring wells began in May of 1994. Monthly sampling of four additional wells began in June of 1994, while monthly sampling of CMC-02R began in October 1994. The June start-up related to the need to complete boring and well construction work. The October start related to the need to replace CMC-02 with CMC-02R, since the CMC-02 well screen as installed was not at the water table. In addition monitoring wells CMC-08, 08P, 09, 09P, 10 and 10P were not sampled in November of 1994 since they were included in water level monitoring programs for the saprolite pump test.

Collected samples were shipped under chain-of-custody procedures to the laboratory for analysis. Table 3.6-4 contains the list of parameters for the groundwater validation program. Analytical methods, target practical quantification limits, precision targets, etc. are outlined in the Project's Quality Assurance Plan (Foth & Van Dyke, 1995c) and in the updates to that plan contained in Appendix 3-1.

Sampling procedures were consistent with those outlined in Appendix E, Project Quality Assurance Plan of the project's NOI/SOS (Foth & Van Dyke, 1994c). A brief outline of the sampling procedures used follows.

Prior to purging, the depth to water was first determined by an electronic water level indicator. The well was then purged by removing four times the volume of water in the well or until the well was dewatered, whichever came first. Subsequent to purging, samples were be removed with either the dedicated PVC bailer or the Grundfos® submersible pump. Water samples were poured from the bailer, or from the pump tubing, into containers specifically prepared for the given parameter(s). Metal sample aliquots for dissolved metals analyses were filtered in the field prior to acidification. Documentation of purging and sampling activities was recorded on Groundwater Monitoring Field Forms. Upon collection, the temperature, specific conductivity and pH of each sample were measured.

Table 3.6-4

Groundwater Quality Validation Parameter List

Field Measured Parameters	Laboratory Analyzed Parameters	
Specific Conductance	Total Alkalinity	Antimony
pH	Total Hardness	Aluminum
Temperature	COD	Arsenic
	Fluoride	Barium
	Kjeldahl (N)	Cadmium
	Nitrite & Nitrate	Calcium
	Chloride	Chromium
	Sulfate	Cobalt
	Cyanide (total)	Copper
	Total Dissolved Solids	Iron
		Lead
		Magnesium
		Manganese
		Mercury
		Molybdenum
		Nickel
		Selenium
		Silver
		Zinc

Prepared by: LLA
Checked by: JWS

WDNR personnel were notified of the dates for each round of sampling so that they could, if they chose, observe procedures and/or split samples. WDNR personnel were present during the June through November 1994 sampling events.

3.6.2 Water Well Information

The following subsections discuss domestic water well inventory work completed in the area of the project and CMC plans for future water well installation relating to the project.

3.6.2.1 Domestic Water Well Inventory

CMC conducted an inventory of domestic water wells in the vicinity of the proposed mine in the summer of 1994. This inventory built upon two previous inventories of domestic water wells in the project vicinity. Dames and Moore conducted the first inventory in 1982 (Dames and Moore, 1982) and Northern Lake Services, Inc. (NLS) conducted a second inventory in 1984 (Northern Lake Service, 1984).

For the 1982 inventory, Dames & Moore developed a system of numbering plats. Each well that was identified was assigned a number corresponding to the number of the plat on which the well was located. The water well inventory resulted in the identification of 42 wells within the inventory area. The information on these wells was obtained from well logs or from personal communication with well owners.

In 1984 NLS conducted an inventory of a 36 square-mile area surrounding the proposed plant site. The numbering system of the Dames & Moore inventory was adopted and the region was divided into four zones. Zone I corresponded to that area which was estimated to experience greater than one meter (3.3 feet) of drawdown from mine dewatering, based on modeling done at the time. Zone I is the shaded region in Figure 3.6-8. Zones II, III, and IV represented three outer boundary zones. Within Zone I, scattered wells were assigned numbers 1-99, and wells clustered around Little Sand Lake were assigned numbers between 101-199. NLS supplemented the data collected by Dames & Moore with questionnaires to well owners. Owners that did not respond to the questionnaire were contacted by phone or in person. An effort was made to make on-site observations of all shallow-driven wells. Well driller reports provided by the Wisconsin Geologic and Natural History Survey (WGNHS) provided most of the information on drilled wells. Rigorous information collection was conducted only for Zone I. Of 54 estimated wells in Zone I, information was collected on 52 wells. In the entire 36-square mile inventory area, there were estimated to be 318 wells, and information was obtained on 211 of these wells.

3.6.2.1.1 1994 Inventory

The domestic water well inventory conducted in the summer of 1994 retained the numbering system of previous inventories. The inventory also focused on Zone I (Figure 3.6-8) since preliminary results from the regional groundwater model have indicated that the extent of drawdown from mine dewatering will be no greater than that predicted in the 1980's and likely will be less. Previously known wells were identified using the numbers they were assigned in the 1984 NLS inventory. Data from the NLS inventory was updated with a new survey of current landowners and with a new review of WGNHS files to identify new Well Construction Reports submitted since the last collection. Scattered new wells in Zone I were numbered following the 01-99 convention. New wells immediately surrounding Little Sand Lake were numbered using the 101-199 convention.

The inventory area included sections of both Forest County and Langlade County. The current Forest County Atlas and Plat Book and the current Langlade County Atlas and Plat Book were initially consulted to determine current land ownership. To further update the land ownership data from the plat books, the current Forest County treasury files and Langlade County treasury and real property lister files were consulted. From this information, the current property owners were identified in the inventory area. These property owners are listed in Table 3.6-5.

Since the 1984 inventory, many changes in land ownership had occurred. Approximately 40 percent of the property in the inventory area is currently owned by CMC. This property includes about 75 percent of the Little Sand Lake area, and a section unit to the immediate east, immediate north, and immediate west of Little Sand Lake. Properties purchased by CMC were not included in the survey because CMC plans to abandon any wells on these plats should they be affected by the groundwater drawdown.

A questionnaire was prepared for mailing to all current landowners within the inventory area. Property owners were placed in one of three categories: existing property owners that participated in the 1984 survey (Original Owners), owners of property not previously surveyed in the area (New Owners), and new owners of property previously surveyed (Transferred Owners). A questionnaire was prepared for Original Owners, and a separate questionnaire was prepared for New Owners/Transferred Owners. A different cover letter was prepared for each of the three groups.

Original Owners were asked to describe any maintenance or changes to their well system since 1984. Maintenance changes referenced on the questionnaire included well replacement, relining the well, deepening the well, and pump replacement. New Owners and Transferred Owners were asked to provide general information about their well such as primary water use, method and date of well installation, pump type, well depth, well diameter, screen length, static water level, water level during pumping, and casing material. All owners were asked to give an opinion of the water quality of their wells in terms of taste, odor, and quantity.

On July 11, 1994, questionnaires and cover letters were mailed to area property owners. On August 1, 1994, all owners who failed to respond to the July 11 questionnaires were mailed a second questionnaire. An attempt was made to contact by telephone each landowner who did not respond to either questionnaire.

In addition to the questionnaires, a review of WGNHS files for Well Construction Reports on properties in the inventory area was requested. Only Well Construction Reports up to 1990 were available. More current reports were still being sorted by WGNHS at the time of request.

3.6.2.1.2 Summary of Inventory Results

Of the 73 non CMC property owners in the inventory area, responses were received from 52 owners. Questionnaires were returned by 45 owners, and seven owners were reached by telephone. The remaining 21 landowners could not be reached.

Among those landowners reached, 30 wells were identified in the inventory area. Additionally, three wells were identified from Well Construction Reports or from the 1984 NLS inventory on properties belonging to owners who could not be reached. These wells were assumed to still be in operation. Thus, a total of 33 domestic wells were listed in the inventory. Some of the

Table 3.6-5

Property Owners and Domestic Water Wells in Inventory Area

Property Owner	Well Number	Form of Contact	Comments
Becker, William J.	108	phone	private well on property
Betters, William	118	returned survey	private well on property
Bishop, Joseph	--	returned survey	survey response not clear but appears no well
Bradley, Alicia	--	reviewed property tax records	Property tax records indicated improvements but no sewer or well permits were on file, therefore, no well likely exists
Bradley, Scott	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Bradley, Wallace	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Buckley, Gerald	167	returned survey	private well on property
Campshure, James	--	returned survey	no well on property
Cheslock, Richard	--	returned survey	no well on property
Clark, Thomas	33	returned survey	private well on property
Connor, Richard M.	--	returned survey	no well on property
Consolidated Papers, Inc.	--	returned survey	no well on property
Cook, Ralph J.	--	returned survey	own well, but well appears to be outside Zone I
Dhuey, David J.	166	returned survey	private well on property
Dietzler, Ruth	115	returned survey	private well on property
Dilley, Lyon	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Dix, Beverly	114	returned survey	private well on property
Fishler, Grace	--	phone	well identified in 1984 NLS inventory but owner claims no well
Forest County	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Freye, William	--	returned survey	own well, but well appears to be outside Zone I
Fritsche, Franklin J.	107	returned survey	private well on property
George, Lloyd E.	--	returned survey	no well on property
Haferman, Ralph W.	106	returned survey	private well on property
Hess, John	--	returned survey	no well on property
Hockers, C.J.	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Hoffman, Cynthia	--	returned survey	well identified in 1984 NLS inventory but owner claims no well
Hoffman, David	--	returned survey	abandoned well on property
Hoffman, Jerome	--	returned survey	no well on property
Hoffman, Joan	--	returned survey	no well on property

Table 3.6-5 continued.

Property Owner	Well Number	Form of Contact	Comments
Hoffman, Raymond H.	90, 91	returned survey	two private wells on properties; second well identified in 1984 NLS inventory
Jameson, John G., Jr.	--	phone	no well on property
Jansen, Jeff	32	returned survey	private well on property
Johnson, Archie	--	returned survey	no well on property
Johnson, Gary	162	returned survey	private well on property
Kelchner, Robert M.	105, 105a	returned survey	two private wells on property; second well identified by Well Construction Report
Keppert, Gerald D.	--	returned survey	own well, but well appears to be outside Zone I
Kloehn, Gerald	168	returned survey	private well on property
Kriegel, Elmyra	89, 89a	returned survey	two private wells on property; second well identified in 1984 NLS inventory
Langlade County, C.F.L.	--	not reached	no Well Construction Report on file, review of quadrangle revealed little probability of well
Lijewski, Edward	144	returned survey	private well on property
Mantey, James P.	121	not reached	well identified in 1984 NLS inventory
Mihalko Land and Logging	--	phone	no well on property
Mihalko, Thomas	--	phone	no well on property
Menominee Indian Tribe of Wisconsin	68	drive-by survey	private well likely on property, well Construction Report on file
Northern Woodlands, Inc.	--	not reached	no Well Construction Report on file, review of quadrangle revealed little probability of well
Noteboom, Maureen B.	--	returned survey	no well on property
Pallen, Herman	116	returned survey	private well on survey
Parker, R. W.	143	reviewed property tax records	Well Construction Report on file, well permit issued in 1977
Phalen, Patrick, Jr.	57	returned survey	private well on property
Pieritz, Richard	102	returned survey	private well on property
Pryor, Harold	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Schallock, Jerry L.	145	returned survey	private well on property
Schmidt, John	87, 87a	returned survey	two private wells on property
Schrading, Mark	--	returned survey	no well on property
Schultz, Delores	--	returned survey	no well on property
Seawell, Elizabeth	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Sokaogon Chippewa Community	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Solper, Gerald K.	--	returned survey	own well, but well appears to be outside Zone I

Table 3.6-5 continued.

Property Owner	Well Number	Form of Contact	Comments
State of Wisconsin	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Streur, William	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Tambellini, Thomas	--	returned survey	no well on property
Terzinski, Kathy	--	phone	no well on properties within Inventory Area
Thornton, Thomas J.	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Tomahawk and Timber	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Torgerson, Bernie	--	returned survey	own well, but well appears to be outside Zone I
Verlotta, Joseph	--	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Walentowski, Clement	84, 92, 93, 119	returned survey	four private wells on properties; survey mentioned one well; others identified in 1984 NLS inventory
Walentowski, Harold	--	phone	well identified in 1984 NLS inventory but owner claims no well
Webb, Richard	--	reviewed property tax records	owned well 102 but sold section to Pieritz
Wisconsin DNR	--	phone	no well on property
Wisconsin Timber Association	--	returned survey	no well on property
Yeager, Florence Ann	120	returned survey	private well on property
Younk, G.	--	returned survey	no well on property

-- No well known to be located on property.

Prepared by: JJA1/SCL
Checked by: XXC/JWS

landowners own several pieces of property in the inventory area. Others own additional properties outside of the inventory area or own properties that extend off the inventory area. When these landowners answered the questionnaire, it was not always clear which specific property their well was located on or even if the well was located in the inventory area. Table 3.6-5 lists the response of each property owner to the survey, and any special notes or uncertainties related to their wells or property. Figure 3.6-8 shows well locations for the entire inventory area. Figure 3.6-9 shows well locations immediately surrounding Little Sand Lake. Information on those wells which have been identified is summarized in Table 3.6-6. Since the July of 1994 survey, CMC has acquired purchase options for a number of the properties containing wells listed in Table 3.6-6. These properties are associated with well numbers 102, 115, 116, 118, 120, 162, 167, and 168.

In 1996, work was completed to gather additional information on properties included in the 1994 domestic water well survey for which a questionnaire was not returned. In order to determine whether groundwater wells exist on these properties a review of Forest County property tax records was performed. The property tax records review indicated that, with two exceptions, the questionnaires which were not returned in 1994 corresponded to properties with no improvements. Therefore, it is unlikely that groundwater wells exist on these properties. Two properties (Alicia Bradley and R. W. Parker), which did not have returned questionnaires, did list improvements based on the property tax records. The property of Alicia Bradley had no sewer or well permits on file and, therefore, likely has no groundwater well on site. The property of R. W. Parker had a well permit issued in 1977. Data was previously obtained on the Parker well from the 1980s well surveys and is included in the survey data base.

Generally, the wells in this area are shallow. The average well depth is approximately 35 feet. The deepest is 96 feet. In most cases the static depth to water is less than 30 feet, but in one well the static depth to water was 72 feet. The oldest well was installed in approximately 1948, with the newest installed in 1993. Most are driven wells, although some are drilled wells. Most use shallow well type pumps and nearly all are used for private domestic purposes. They draw from aquifers in either the undifferentiated Late Wisconsinan Till or the underlying outwash deposits. Most well owners are of the opinion that the water provided by their well is of good quality and there are very few problems with taste, staining, odor, or insufficient flow. A few well owners reported that in their opinion their well had some degree of problem with iron.

3.6.2.2 New CMC Water Supplies

A new potable well will be constructed for the project approximately one-half mile south of the plant site, and approximately 1,200 feet northwest of Little Sand Lake. This well, as shown on Figure 3.6-8, will be located in a relatively undeveloped area in the SE¼ of the NE¼ of Section 36, T35N, R12E Nashville Township. It will be the sole supplier of potable water to the project's various facilities.

A second non-potable well will be installed to provide construction water for the TMA. The TMA well location is also shown on Figure 3.6-8. The well will be located approximately 300 feet north of the north-west corner of the TMA in the NW¼ of the SE¼ of Section 29, T35N, R13E of Lincoln Township. This well will be used for seasonal processing of site glacial material and for seasonal wash plant operations during the construction phases of the TMA, estimated to occur approximately every three years. Details regarding both wells can be found in the project's October 1995 *High Capacity Well Permit Application*.

3.6.3 Regional Hydrogeology/Groundwater Quality

The project area is located, as defined by Olcott (1968) in the Fox-Wolf River Hydrologic Basin. On a regional scale, the hydrogeologic conditions around the project area generally consist of saturated glacial till and outwash overlying Precambrian bedrock. According to NR 182.08(2)(c), the term regional is defined as "that area which may affect or be affected by a proposed site. In most cases this will be the proposed site and, the area within a radius of up to five miles from the site." Figure 3.6-10 illustrates the five mile radial area surrounding the project area. NR 182.08(2)(c)(4) states that the regional hydrogeology discussion should include discussions on depth to groundwater, groundwater flow characteristics, recharge and discharge areas, groundwater divides, aquifers and groundwater use. Each of these topics plus regional groundwater quality is discussed below.

3.6.3.1 Groundwater Aquifers

On a regional scale, groundwater in the vicinity of the project area occurs within two primary hydrostratigraphic units. These units consist of the Precambrian bedrock and the glacial overburden. The glacial overburden can be subdivided into glacial till and outwash. Regionally, the water table resides within the glacial deposits.

The bulk of the Precambrian bedrock, although locally fractured and showing secondary permeability features, typically yields only small amounts of water to wells. As such it does not fit any of the conventional definitions (Freeze and Cherry, 1979) of an aquifer. Figure 3.6-10a shows the location of known wells completed in the bedrock within a five mile radius of the site. Appendix 3.6-15 contains constructor's reports or construction information for these wells. A review of the data provided in the appendix shows that the majority of the wells completed in the bedrock produce 5 gpm or less of water.

Table 3.6-6

Description of Domestic Water Wells in Inventory Area

	Well Number	Location	Water Use	Year of Installation	Installation Method	Well Details			Depth to Water (ft)		Casing Material	Pump Type	Water Quality (Owner's Opinion)	Description of Well Repairs
						Depth (ft.)	Diam. (in.)	Screen (ft.)	Static	Pumping				
Jansen, Jeff	32	S4-T34N-R13E	Private	1993	Driven	12	1.75	3	--	--	Galv.	Hand Pump	Good taste, very clear	none
Clark, Thomas	33	S4-T34N-R13E	Private	1988	Driven	25	2	--	--	--	Galv.	Shallow Well	Excellent, almost no mineral taste, no odor, minimal staining	Pump replaced - 02/94
Phalen, Patrick	57	S35-T35N-R12E	Private	1991	Drilled	60	6	3	45	--	--	Submersible	Very clear	N/A
Menominee Indian Tribe of Wisconsin	68	S25-T35N-R12E	Private	1988	Drilled	83.5	6	3	72	75	Blk Steel	--	--	
Walentowski, Clement	84	S26-T35N-R12E	Private	--	Driven	26	1.25	--	14	--	Galv.	--	Good	
Schmidt, John	87	S26-T35N-R12E	Private	Unknown	Driven	28	1.25	--	--	--	Galv.	--	Taste OK, no odor, very little staining	New pump motor, point and pipe
Schmidt, John	87a	S25-T35N-R12E	Private	1993	Drilled	31	6	3	--	--	Steel	Submersible	Taste OK, no odor	
Kriegel, Elmyra	89	S26-T35N-R12E	Private	1960 (est)	Driven	20	1.25	3	20	--	Galv.	Shallow Well	Taste OK, no odor, hard	Well not in use
Kriegel, Elmyra	89a	S26-T35N-R12E	Private	--	Driven	20	1.25	3	--	--	Galv.	No Pump	Rusty, bacteriologically unsafe	Not in use
Hoffman, Raymond H.	90	S26-T35N-R12E	Private	1948 (est)	Driven	27	1.25	4	21	--	Galv.	Shallow Well	Good, slightly hard	Not repaired or re
Hoffman, Raymond H.	91	S26-T35N-R12E	Private	--	Driven	28	1.25	4	22	--	Galv.	Shallow Well	Excellent	Not repaired or re
Walentowski, Clement	92	S26-T35N-R12E	Private	--	Drilled	63	5	3	14	19	Blk Steel	Shallow Well	Good taste, no odor, some rust	
Walentowski, Clement	93	S26-T35N-R12E	Domestic Commercial	--	Driven	28	1.25	3	20	--	Galv.	Shallow Well	Iron taste and color	
Pieritz, Richard	102	S36-T35N-R12E	Private	1959	Drilled	58	4	3	25	45	Std. Steel	Deep Well Jet	Good, some iron	None
Kelchner, Robert M.	105	S36-T35N-R12E	Private	1977	Drilled	54	6	3	21	26	ASTMA 53	Submersible	Excellent	No repairs
Kelchner, Robert M.	105a	S36-T35N-R12E	Private	1962	Driven	22	2	2	--	--	Galv.	Shallow Well	Good, clear, soft	
Haferman, Ralph W.	106	S36-T35N-R12E	Private	1956	Driven	17	1.25	--	5	--	Galv.	Shallow Well	Okay	None
Fritsche, Franklin J.	107	S36-T35N-R12E	Private	1961	Driven	20	1.25	4	14	--	Galv.	Shallow Well	Excellent quantity - good taste, no odor	Pump replaced - 06/89 new point 06/90
Becker, William J.	108	S36-T35N-R12E	Private	1965	Driven	25	1.25	--	--	--	Galv.	--	Good, clear	

Table 3.6-6 continued.

	Well Number	Location	Water Use	Year of Installation	Installation Method	Well Details			Depth to Water (ft)		Casing Material	Pump Type	Water Quality (Owner's Opinion)	Description of Well Repairs
						Depth (ft.)	Diam. (in.)	Screen (ft.)	Static	Pumping				
Dix, Beverly	114	S35-T35N-R12E	--	--	Driven	18	--	--	--	--	--	--	Good tasting and very clear	New pump
Dietzler, Ruth	115[1]	S36-T35N-R12E	Private	1968	Driven	20-30	1.25	--	--	--	--	Shallow Well	Good taste, no odor, no iron staining	None
Pallen, Herman	116[1]	S36-T35N-R12E	Private	--	Driven	23	1.25	3	6	--	Galv.	--	Water is clear, tastes excellent, no iron	
Betters, William	118[1]	S36-T35N-R12E	Private	1978	Driven	23	1.25	--	6	--	Galv.	Shallow Well	Good, no odor	None
Walentowski, Clement	119	S36-T35N-R12E	Private	--	Drilled	20-30	3	--	11	--	--	Shallow Well	Not the best taste	
Yeager, Florence Ann	120[1]	S36-T35N-R12E	Private	--	Driven	30	1.25	3	25	--	Galv.	Shallow Well	Pure water - not hard, good taste	Pump Replaced
Mantey, James P.	121	S31-T35N-R13E	Private	1970	Driven	24	1.25	4	--	--	Galv.	Shallow Well	Good, clear	
Parker, R. W.	143	S31-T35N-R13E	Private	1977	Drilled	64	5	3	23	--	Galv.	Submersible	Good	
Lijewski, Edward	144	S31-T35N-R13E	Private	1975	Drilled	58	5	2	23	50	Blk steel	Submersible	Excellent, clear water	None
Shallock, Jerry L.	145	S31-T35N-R13E	Private	1974	Drilled	96	0.5	--	20	--	--	Submersible	Good taste, some iron	No Repairs
Johnson, Gary	162[1]	S6-T34N-R13E	Private	--	--	--	--	--	--	--	--	--	No problem.	No Repairs.
Dhuey, David J.	166	S6-T34N-R13E	Private	--	Driven	32	2	--	25	--	Galv.	Deep Well Jet	Good, no problems	No repairs.
Buckley, Gerald	167[1]	S6-T34N-R13E	Private	1980	Drilled	57	5	2	26	50	Blk Steel	Submersible	Very good taste, no odor, little staining, sufficient quantity	None
Kloehn, Gerald	168[1]	S36-T35N-R12E	Private	--	Drilled	37.5	4	--	23	--	N/A	No Pump	--	No Repairs

[1]CMC land purchase option obtained since the 1994 well inventory.

Prepared by: CH/MLD2
Checked by: JJA1/JWS

The glacial aquifer consists of saturated deposits of glacial till and glacial outwash. The glacial till typically has a low permeability and typically would not be used as an aquifer except where embedded lenses of sand and gravel exist. Based on the work of Simpkins, et. al. (1987), the outwash deposits are relatively prolific on a regional scale. These outwash deposits are typically sand and gravel, and therefore are permeable enough to yield significant amounts of water. As such the outwash deposits form the primary regional aquifer for domestic and municipal water supplies. Section 3.6.2 contains information on the domestic water supply wells located in the vicinity of the project area.

The depth to groundwater within the glacial deposits is quite variable. This is attributed to the considerable topographic relief in the vicinity of the project area. Near groundwater discharge areas such as streams, lakes and wetlands, the depth to groundwater is on the order of several feet. In groundwater recharge areas located at topographic highs, or in upland areas, the depth to groundwater can be more than 100 feet.

3.6.3.2 Regional Groundwater Flow System

Groundwater flow occurs primarily within the glacial till and outwash deposits with the majority of flow occurring within the more permeable outwash deposits. Flow within the outwash can typically be characterized as occurring under unconfined conditions. However, semi-confined conditions may occur locally within the outwash due to the presence of lacustrine clay lake beds overlying the outwash or in instances where the outwash deposits are overlain by less permeable glacial till.

On a regional scale, groundwater flows from areas of high hydraulic head to areas of low hydraulic head or from potentiometric highs to potentiometric lows. The potentiometric surface is defined as the as the height to which water will rise in a well tapping a confined aquifer and is the water table under unconfined conditions. Thus under unconfined conditions, areas of high hydraulic head correspond to topographic highs in the regional water table. Similarly, areas of low hydraulic head correspond to topographic lows in the regional water table. Under unconfined conditions the potentiometric surface and water table are essentially the same except in areas where strong vertical gradients exists, such as would occur near discharge points and some lakes.

High water table elevations occur within upland areas and around upland lakes and wetlands. Low water table elevations occur in low land areas associated with streams, wetlands or lakes. Groundwater is replenished in recharge areas defined as an area where the net vertical component of flow is downward. Recharge areas are typically associated with upland areas, upland lakes and high water table elevations. Groundwater discharge areas are defined as areas where the net vertical component of flow is upwards. Groundwater discharge areas are typically restricted to a narrow band around streams, wetlands and or lakes. Thus recharge to the glacial aquifer occurs over much of the regional study area.

In 1982 Golder Associates (1982) prepared a regional potentiometric surface map depicting the horizontal flow of groundwater within the glacial deposits. This potentiometric surface map, shown in Figure 3.6-11, was prepared from water levels taken in study area in February 1982, in addition to data on regional groundwater elevations available from the USGS. The map covers a large geographic area encompassing Lakes Metonga and Lucerne to the north; Roberts and Lost Lakes to the east; Pickerel, Crane, and Rolling Stone Lakes to the south; and Bishop Lake to the west.

The potentiometric surface map is roughly equivalent to the regional water table, depicting the change in the water table elevation and the horizontal hydraulic gradient on a regional scale. Areas where the potentiometric surface map would not be equivalent to the water table, would be in the vicinity of upland lakes, such as Little Sand Lake, that are hydraulically connected to the regional groundwater system. In these localized areas a mounded water table exists due to the occurrence of low permeability lacustrine clay and silt lake beds which create semi-confined conditions in the underlying glacial till and outwash. The large scale potentiometric surface map does not reflect these small localized mounded systems. Rather, in the vicinity of the upland lakes, the regional potentiometric surface map represents the potentiometric surface in the semi-confined underlying glacial till and outwash.

Figure 3.6-11 shows a well defined groundwater flow system constrained by a network of creeks and lakes. The near project area controlling surface water features, moving clockwise from the north, are Lake Metonga, Swamp Creek, Hemlock Creek, Ground Hemlock Lake, Crane Lake, Pickerel Lake, Rolling Stone Lake, Pickerel Creek, Mole Lake, Rice Lake and Gliske Creek. Groundwater flows from water table highs located in upland areas to discharge areas controlled by the above referenced surface water features.

The regional groundwater high of about 1,640 feet is located in the vicinity of Lake Lucerne. The groundwater divide for the hydrologic basin is located just to the north of Lake Metonga and to the east of Lake Lucerne (Olcott, 1968). South and east of this divide groundwater flows into Lake Metonga or Swamp Creek. South and west of Lake Metonga groundwater flows into Outlet Creek, Swamp Creek, Rice Lake or Gliske Creek. Outlet Creek, which drains Lake Metonga, is a tributary of Swamp Creek.

A second groundwater divide exists south of Swamp Creek in the vicinity of the proposed TMA. Flow north of this divide is to Swamp and Hemlock Creeks and Ground Hemlock Lake. South of this divide flow is southeasterly and southwesterly toward Crane, Pickerel, and Rolling Stone Lakes, and Pickerel Creek between Rolling Stone and Mole Lakes.

3.6.3.3 Regional Groundwater Quality

Information on the regional water quality was obtained from Olcott (1968). Within the glacial overburden, the groundwater typically has a dissolved solids content ranging from 200 to 300 mg/L. However the concentration of dissolved solids can be quite variable and locally can be as high as 400 mg/L. Water within the glacial till and outwash is of the calcium magnesium bicarbonate type. It is moderately hard with high iron concentrations, a common occurrence in much of the area.

3.6.4 Project Site Hydrogeology

As described in Sections 3.5.1 and 3.6.1, the hydrogeology of the study area has been thoroughly characterized through numerous investigations that included several hundred soil borings, the installation of several hundred monitoring wells, multiple pump tests, slug tests, packer tests, geophysical studies, and studies on groundwater/lake interactions. The result of these investigations is a thoroughly evaluated and well understood hydrogeologic system. The

following narrative which presents the results of the groundwater investigations draws on data obtained from the studies described in Sections 3.5.1 and 3.6.1. The results of these investigations form the basis for predictions of impacts on the groundwater system due to mine activities which will be discussed later in this report.

Section 3.6.4.1 provides a detailed description of the principal hydrostratigraphic units, the hydrogeologic characteristics of which are presented in Section 3.6.4.2. Section 3.6.4.3 describes the groundwater flow system within the study area and addresses the interaction of groundwater with lakes and wetlands.

3.6.4.1 Study Area Hydrostratigraphic Units

The principal hydrostratigraphic units correspond to the major geologic formations depicted on the cross sections shown of Figures 3.5-26 through 3.5-32 in Section 3.5. Ascending the stratigraphic column the major hydrostratigraphic units across the study area consist of the Precambrian bedrock, the Pre to Early Wisconsinan till, the coarse and fine grained outwash, and the Late Wisconsinan till. Hydrostratigraphic units of a more local nature include lacustrine silts/clays that form the lake beds for many of the lakes within the study area such as Little Sand, Oak, Deep Hole, Duck and Skunk Lakes. The localized lacustrine deposits are also associated within the more extensive till and outwash deposits described above. In the vicinity of the ore body the bedrock has been differentiated into unweathered bedrock, structured saprolite and massive saprolite.

The Precambrian bedrock in the study area is part of the southern extension of the Canadian Shield referred to as the Southern Province. Within the study area, the Precambrian bedrock is composed of metavolcanic bedrock formed from the deposition of volcanic material just at and below the ocean floor. The deposition of the volcanic material, some of which constitutes the massive sulfide zinc and copper ore body, was followed by a period of lithification and metamorphism which hardened and solidified both the host rock and ore body over time. The bedrock was later uplifted resulting in the near vertical orientation of the volcanic layers and ore body.

The metamorphic Precambrian bedrock that exists in the study area exhibits both primary and secondary permeability features and weathering, or tertiary, permeability features. Since the porosity of metamorphic rock is typically less that two percent and the voids that make up the porosity are minute and not interconnected, the primary permeability of the bedrock in the study area is less than 2.8E-6 ft/d (1E-9 cm/s), impermeable in the context of most groundwater studies (Freeze and Cherry, 1979). The ability of the Precambrian bedrock to transmit water is therefore governed by interconnected fractures that occur within the near surface regions of the bedrock. These fractures, or secondary permeability features act as the principal conduit for groundwater movement within the bedrock. The source of these secondary permeability features is attributed to changes in stress conditions (Freeze and Cherry, 1979) caused by events such as glaciation. Packer test studies on the bedrock, the results of which are described below, were performed to measure the permeability associated with these secondary permeability features. The secondary permeability features are the principal source of groundwater within the Precambrian bedrock.

Associated with the Precambrian bedrock surface is a structured and massive saprolite layer developed from intense weathering of the Precambrian bedrock. The massive saprolite is a clay to sandy clay, thoroughly decomposed bedrock material formed in place by chemical weathering of the metavolcanic bedrock. Since the primary and secondary permeability features of the original bedrock have been destroyed during the weathering process, the massive saprolite functions hydraulically like a conventional porous medium. Below the massive saprolite is the structured saprolite, rock which has been weathered to mostly clays and iron oxides, but still retains the rock structure. Since the original rock structure of the structured saprolite has not been completely altered by weathering processes, the structured saprolite retains primary, secondary and weathering, or tertiary, modified permeability features. Below the structured saprolite is progressively less weathered bedrock.

The massive saprolite and structured saprolite are comparatively thin hydrostratigraphic units. Given the fact that these layers reside on top of the bedrock in the vicinity of the ore body subcrop, they are an important localized feature that will control, along with the overlying glacial till, the inflow of groundwater from the glacial overburden to the mine. Thus, the massive and structured saprolite have been differentiated primarily in the vicinity of the ore body. On the scale of the study area, the massive saprolite and structured saprolite do exist in localized areas depending on rock type but have not been differentiated since groundwater flow on the scale of the study area will be governed by the more predominant and transmissive glacial deposits.

The Pre- to Early Wisconsinan till resides on top of the Precambrian bedrock. In the vicinity of the ore body, the Pre- to Early Wisconsinan till resides stratigraphically on top of the massive saprolite. Deposited more than 40,000 years $\pm$ 2,000 years before present (BP), the Pre- to Early Wisconsinan till is nearly continuous across the entire study area and is composed of dark brown, brown or yellowish red calcareous to non-calcareous till of the Marathon and Lincoln Formations. Ice advances from the northwest and north during Pre and Early Wisconsinan time deposited this material. The Pre- to Early Wisconsinan till formation contains a higher content of expandable clay minerals, less sand and a higher silt and clay content than the outwash deposits, and younger overlying Late Wisconsinan age tills of the Horicon and Copper Falls Formations (Simpkins, et. al. 1987). Although this unit is thick in some areas and nearly always saturated, the suitability of the Pre- to Early Wisconsinan till as an aquifer is marginal at best. Occasional thin sand lenses may provide sufficient water for domestic uses. Across the study area the only known area where parts of the Pre- to Early Wisconsinan till is unsaturated is over the middle of the ore body where the water table resides within the till.

The Pre- to Early Wisconsinan till is typically separated from the younger and overlying Late Wisconsinan age till formations by undifferentiated deposits of coarse and fine grained outwash sands and gravel. Deposited by glacial meltwater streams during advances and retreat of the glaciers during the Wisconsinan glaciation period, the outwash deposits are ubiquitous across the study area. The outwash deposits tend to thin to the north in the vicinity of Swamp Creek and constitute the predominant glacial material south of Little Sand Lake. Extensive in nature, the outwash deposits comprise the principal aquifer across the study area. Swamp, Hemlock, Outlet, and Pickerel Creek and Creek 12-9 commonly incise the outwash and act as the principal sinks for groundwater discharge. Far field lakes such as Rolling Stone, Crane, Pickerel, Ground Hemlock and Mole also incise the outwash deposits and act as additional sinks for the discharge of groundwater from the outwash. Near the Plant Site, smaller lakes such as Little Sand, Oak,

Duck and Skunk reside on top of the outwash, separated from the outwash by a layer of lacustrine silt and clay. Across much of the study area the water table resides within the outwash deposits.

The Late Wisconsinan till is the upper most hydrostratigraphic unit, residing at the surface across upland areas. Deposited between 19,000 and 11,000 years BP this till is composed of the Horicon Formation and Copper Falls Formation till deposited by the advance of the Green Bay and Langlade Lobes, respectively. The Late Wisconsin till typically has a higher sand content than the older Pre- to Early Wisconsinan till, is reddish brown to yellowish red and has non-expandable illite as its predominant clay mineral (Simpkins et.al., 1987). The late Wisconsinan till is less extensive in nature than the other glacial formations, residing primarily in upland areas around the TMA and Plant Site. In areas where the Late Wisconsinan till is absent the outwash resides at the surface. As such, much of the recharge to the groundwater occurs through the till in upland areas. Where the till is absent, recharge occurs through the outwash sands and gravels. In the vicinity of the TMA, the water table resides in the Late Wisconsinan till. Elsewhere in the study area this unit is frequently unsaturated and thus is a marginal aquifer.

Localized deposits of lacustrine silt and clay in upland areas form the last recognized hydrostratigraphic unit in the study area. The lacustrine deposits are typically associated with and derived from the Late Wisconsinan till. Since the Late Wisconsinan till contains illite as its principal clay mineral, the clay fraction of the lacustrine deposits is primarily illite, a non-expandable clay. Being local in nature, these deposits play a minor role in governing the overall regional flow of groundwater across the study area. However, locally they play a dominant role in controlling the hydrologic interaction between the groundwater system and lakes and wetlands.

3.6.4.2 Hydrogeologic Characteristics

The hydrogeologic characteristics of the Precambrian bedrock, structured saprolite, massive saprolite, glacial overburden and lake beds have been extensively characterized via pump tests, slug tests, permeability tests and packer tests. Sections 3.6.4.2.1 through 3.6.4.2.4 present the results of these studies.

3.6.4.2.1 Bedrock

The hydrogeologic characteristics of the bedrock in the vicinity of the ore body have been extensively reviewed in the report Bedrock Hydrogeology at the Crandon Site (Foth & Van Dyke 1995b) which is contained in its entirety in Appendix 3.5-15. This report was submitted to relevant regulatory agencies and others in February 1995 and is the topic of continuing discussions between the reviewers and CMC. A brief summary of this report is provided below followed by the principal conclusions regarding the transmissive properties of the bedrock and the conceptual model for groundwater inflow to the mine.

Given the low primary permeability of metavolcanic bedrock as described above, secondary and tertiary permeability features, such as fractures and weathered bedrock, will control the transmissive characteristics of the bedrock in the vicinity of the ore body. These secondary and tertiary hydrogeologic characteristics of the bedrock were evaluated based on exploration

delineation and drilling, fracture characterization studies, bedrock weathering studies, packer tests, down hole temperature logging, bedrock water chemistry data and vertical gradients between the bedrock and glacial overburden.

Data to support the characterization of the Crandon deposit and surrounding bedrock has included six separate bedrock drilling programs totalling approximately 320,000 feet (60 miles) in over 200 angle holes in the immediate vicinity of the ore body. Figure 3.6-12 presents a plan map showing the traces of the bedrock drill holes. The six drilling campaigns were conducted over a 20 year period. Early drilling programs provided factual data on both near surface and deep structure and stratigraphy, particularly the location, trend and continuity of the Crandon Formation hanging wall and footwall contacts, and contained ore zones. Later drilling programs intersected contacts and ore zones at their interpreted locations. This means that there has been no significant north-south fault offsets, to the interpreted east-west stratigraphic trends, that could provide a means for transmission of water into the mine from the regional bedrock.

Fracture studies described in the bedrock hydrogeology report in Appendix 3.5-15 show that interconnected fractures that could give rise to flow within the bedrock, and ultimately from the bedrock to the mine, are limited to the near surface bedrock in the hanging wall and footwall rocks surrounding the Crandon Formation. Within the Crandon Formation, interconnected fractures exist to a depth of about 1,000 feet. Within the hanging wall and foot wall, fractures are most prominent along east-west trending trajectories that nearly parallel the strike of bedding planes and are least common along north-south trending trajectories. At depth there is little evidence of water movement through the fractures suggesting water movement in the bedrock is restricted to the upper few hundred feet of the bedrock.

Weathering studies described in the bedrock hydrogeology report show that the maximum vertical extent of weathered bedrock occurs within the Crandon Formation to a depth of about 1,100 feet. Figure 3.6-12 shows the location of several longitudinal weathering profiles within and north and south of the Crandon Formation. These weathering profiles are displayed in Figures 3.6-13 through 3.6-16. Weathering decreases in depth and intensity as one moves north into the hanging wall away from the Crandon Formation. At 400 feet north of the ore body, strong to moderate weathering is limited to near surface bedrock regions extending to a depth of about 250 feet. The depth of weathering is less in the foot wall rocks to the south of the Crandon Formation. Two hundred feet south of the ore body, strong to moderate weathering extends to a depth of about 250 feet. Table 3.6-7 provides a summary of weathering and bedrock permeability data for the footwall, Crandon formation and hanging wall.

Exploration drilling programs have delineated a fresh unweathered, post-mineralization gabbro dike south of the ore body. Locally named the Duck Lake gabbro dike, this unit, located immediately south of the ore body, as depicted in Figures 3.6-12 and 3.6-17, is likely to function as a low permeability barrier to potential lateral flow from the bedrock into the mine. The only potential for lateral flow across this formation into the mine would be the upper 200 to 300 feet where there is some evidence of water movement.

Table 3.6-7

Crandon Deposit Weathering and Permeability Data

Weathering Intensity Rating	Destructive Agent	Footwall				Crandon Formation				Hanging Wall			
		Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability
Strong: Strong development of two or more of the destructive processes, (oxidation, leaching, argillization, or fracturing. Rock will have low compressive strengths and workings would have to be supported at all times.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Uniform relatively horizontal zone with root like penetrations into underlying moderate zone.	Leaching breaks down sulfides, silicates, and carbonates, alters come to clay. May or may not increase permeability.	Similar throughout strong, moderate, and low zones. Gradual decrease with depth. Argillization tends to plug up porosity developed in leaching and reduces permeability.	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Irregular with several deeper spikes, and local isolated areas.	Varied internal stratigraphy controls irregular pattern and types of weathering. High sulfide, strong acid generation. Interbedded units, clay development from silicates. Fracturing. Solutions channel down beds.	Varied but commonly porous with higher permeability. More chlorite rich areas alter to clay with lower permeability. 255: 8.9x10-4 256: 2.5x10-4	Relatively homogeneous chlorotic tuff with local more siliceous material.	Broad gently undulating. Becomes less pronounced as move north from deposit.	Argillization due to chlorite tends to be pervasive. Little sulfide. Zone becomes deeper as approach Crandon Formation from north due to weathering of Crandon Deposit sulfides.	Near surface weathering and fractures. Clays plug up. 255: 1.7x10-5
Moderate: Strong development of one of the destructive processes (or moderate development of two) and weak to moderate development of at least one more. Rocks may or may not be strong enough to hold a back, depending upon which destructive processes have been active. Strong development of argillization or fracturing would make the rock very weak or unstable, whereas strong development of oxidation or leaching may not seriously affect its ability to hold a back.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Uniform relatively horizontal zone with root like penetrations less abundant into lower zones.	More limited leaching and development of clay. Similar but less intense than above.	Similar throughout strong, moderate, and low zones. Gradual decrease with depth. Argillization tends to plug up porosity developed in leaching and reduces permeability. 254: 3.4x10-6	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Irregular broad zone along strike with wider deeper protrusions to depth associated with stronger intensity spikes from above.	As above, with moderate zone adjacent to and surrounds strong weathered areas. Can follow along strike nearer surface.	Varied, moderate to high depending on horizon. 66: 1.8x10-5 213: 3.4x10-3 213: 3.4x10-4 213: 2.4x10-3 256: 9.8x10-5	Relatively homogeneous chlorotic tuff with local more siliceous material.	road gently undulating. Becomes less pronounced as move north from deposit.	Argillization due to chlorite tends to be pervasive. Little sulfide. Zone becomes deeper as approach Crandon Fm from north due to weathering of Crandon Deposit sulfides.	Permeability decreases, fewer fractures, some plugging due to clay. 66: 1.8x10-5 5AL: 1.0x10-7 253: 6.4x10-6 213: 2.7x10-5
Low: Moderate leaching with only minor other effects. The compressive strength of the rock is not seriously reduced.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Broad open poorly defined areas.	Very limited leaching and alteration effects.	Decreases due to depth and lack of weathering effects. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 254: 7.0x10-6 257: 7.6x10-6	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Broad smooth zone below moderate intensity zone.	Not significant at depth below moderate zone.	Moderate to locally lower permeability. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 213: 1.0x10-4	Relatively homogeneous chlorotic tuff with local more siliceous material.	Broad gentle, not significant zone below moderate zone.	Broad not significant.	Few fractures. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 213: 5.0x10-6 213: 2.0x10-5 213: 2.2x10-5 213: 3.8x10-5

Table 3.6-7, continued

Weathering Intensity Rating	Destructive Agent	Footwall				Crandon Formation				Hanging Wall			
		Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability
Weak: Weak development of leaching and/or oxidation. Rock strengths are not affected.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Broad open poorly defined areas.	Very limited leaching and alteration effects.	Decreases due to depth and lack of weathering effects. 91: 1.3x10-5 91: 1.9x10-5 165: 1.2x10-7	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Broad smooth zone below low intensity zone.	Not significant at depth below low zone.	91: 1.3x10-5 91: 1.9x10-5 77: 5.7x10-6 165: 5.8x10-7	Relatively homogeneous chlorotic tuff with local more siliceous material. (a) Leakage reported	Broad not significant.	Broad not significant.	9AL: 2x10-8 F 91: 1.3x10-5 e 5AU: 2x10-6 w 77: 5.7x10-6 253: 1.7x10-6 f 155: 5.8x10-7 r 155: 4.9x10-7 a 155: 4.4x10-7 c 155: 4.7x10-7 t 155: 3.9x10-7 u 155: 4.8x10-7 r 155: 5.4x10-7 e 155: 7.9x10-7 s 155: 3.8x10-5 155: 6.0x10-5a 155: 6.3x10-5a 165: 1.4x10-6

All permeability values reported in cm/s, multiply by 2834.6 to arrive at value in units of ft/d.

Prepared by: AJE
Checked by: SVD1

In the 1970s and 1980s, packer and slug tests were performed on 12 core holes open to the bedrock and three piezometers screened within the bedrock. The location of these core holes and piezometers are shown in Figure 3.6-18. The 1970s and 1980s packer and slug test data, summarized in Table 3.6-8, shows that the bulk hydraulic conductivity of the bedrock outside the area of influence of the Crandon Formation is likely to be in the range of 2.8E-2 ft/d (1E-5 cm/s) to 2.8 E-3 ft/d (1E-6 cm/s). Higher permeability bedrock is typically associated with weathered regions of the Crandon Formation and weathered zones along the Crandon Formation hanging wall contact. Given that fractures are oriented preferentially in an east west direction, it is likely that the bedrock is anisotropic with the east-west trending permeability being greater than the north-south permeability.

Two pump tests were also conducted on hole 214. The first test was conducted over an interval from 107 feet to 360 feet, and was able to produce water at a rate of only 0.36 gpm, perhaps derived from a fracture zone at 325 to 345 feet. When a larger interval was tested, 107 feet to 750 feet, water was produced at a slightly higher rate of two gpm indicating that other fracture zones were likely intersected. The low water yielding capacity of the rock in hole 214 suggests restricted water movement within the region tested.

Downhole temperature measurements in the boreholes shown on Figure 3.6-19 and summarized in Tables 3.6-9 and 3.6-10 show a smooth regional thermal gradient of 0.81 °F per 100 vertical feet. With the exception of several small temperature fluctuations of less than 0.5 °F in holes 139 and 155, there were no temperature deflections encountered in the boreholes that would indicate significant circulation of fresh water. Circulation of fresh water through the fractured bedrock should create widespread temperature fluctuations within the hole and destroy the thermal gradient trends. Alternatively, restricted circulation of water through infrequent fractures would tend to produce small deflections in down hole temperatures, which is what was recorded.

The fracture characterization studies discussed in the bedrock hydrogeology report (Appendix 3.5-15), indicate that limited circulation of water may take place in the upper 1,000 feet of the bedrock due to higher fracture frequency and more interconnected fractures. The temperature measurements indicate that this circulation, if present, is minor since no alteration of the thermal gradient or large water movement is evident. Below the upper 1,000 feet of bedrock, the fracture studies discussed above suggest that circulation of water is not likely taking place, except perhaps over geologic time scales. The temperature logs support this interpretation since there is no significant alteration in the thermal gradient.

Bedrock water chemistry data supports the above interpretation of restricted water movement within the upper reaches of the bedrock. Bedrock water samples from nine angled core holes that intersected the Crandon Formation and one vertical core hole in the hanging wall were sampled over discrete intervals. The location of the tested core holes are shown in Figure 3.6-20. The data is summarized in Table 3.6-11.

In core holes that intersected the Crandon Formation, the chloride concentration was less than 50 mg/L for those samples collected above 1,800 feet. Water samples collected from below 1,800 feet contained chloride concentrations ranging from about 2,000-5,000 mg/L. Similarly, the

Table 3.6-8

Summary Bedrock Permeability Tests

Hole #		Core Interval Tests											
		Collar Dip	Drill Depth (ft)			Vertical Depth (ft)		Horz to CrHW (ft)		Permeability		Tests(c)	Formations(d)
			From	To	Thick	From	To	From	To	ft/d	cm/sec		
1	EX-9AL	--	276.4	283.4	7	276.4	283.4	+1000	+1000	5.7x10-5	2x10-8	HW	Regional PC Bedrock
2	EX-5AL	--	183.9	191.9	8	183.9	191.9	+1000	+1000	2.8x10-4	1x10-7	HW	Regional PC Bedrock
3	EX-5AU	--	160.9	167.9	7	160.9	167.9	+1000	+1000	5.7x10-3	2x10-6	HW	Regional PC Bedrock
4	257	-90	246	360	114	246	360	833	833	2.1x10-2	7.6x10-6	FW	SL
5	254	-90	217	315	98	217	315	833	833	9.6x10-3	3.4x10-6	FW	SL
6	254	-90	315	435	120	315	435	98	115	2.0x10-2	7.0x10-6	FW	SL
7	256	-90	167	282	115	167	282	0	0	0.71	2.5x10-4	CR	CR
8	256	-90	282	394	112	282	394	0	0	2.8x10-1	9.8x10-5	CR	CR
9	213	-75	144	231	87	139	223	278	223	7.7x10-2	2.7x10-5	HW	UML
10	--	--	231	312	81	223	301	223	177	1.4x10-2	5.0x10-6	HW	UML
11	--	--	312	392	80	301	379	177	128	5.7x10-2	2.0x10-5	HW	UML
12	--	--	392	472	77	379	453	128	79	6.2x10-2	2.2x10-5	HW	LML
13	--	--	472	552	83	453	533	79	30	1.1x10-1	3.8x10-5	HW	LML
14	--	--	552	631	79	533	609	30	26	9.6	3.4x10-3	CR	CR
15	--	--	631	724	93	609	699	26	69	9.6	3.4x10-3	CR	CR
16	--	--	724	808	83	699	780	69	118	6.8	2.4x10-3	CR	CR
17	--	--	808	879	72	780	849	118	141	2.8x10-1	1.0x10-4	CR	CR

Table 3.6-8, continued

Hole #		Core Interval Tests											
		Collar Dip	Drill Depth (ft)			Vertical Depth (ft)		Horz to CrHW (ft)		Permeability		Tests(c)	Formations(d)
			From	To	Thick	From	To	From	To	ft/d	cm/sec		
18	91	-75	179	1415	1236	175	1025	635	400	3.7x10-2(b)	1.3x10-5(b)	HW/CR/FW	SK/RL/UML/LML/CR/SL
19	--	--	852	1415	563	735	1025	145	400	5.4x10-2(b)	1.9x10-5(b)	HW/CR/FW	LML/CR/SL
20	155	-90	161	3050	2889	161	3050	836	295	1.6x10-3	5.8x10-7	HW	SK/RL/UML
21	--	--	362	3050	2688	362	3050	771	295	1.4x10-3	4.9x10-7	HW	SK/RL/UML
22	--	--	562	3050	2488	562	3050	715	295	1.2x10-3	4.3x10-7	HW	SK/RL/UML
23	--	--	842	3050	2208	842	3050	656	295	1.3x10-3	4.7x10-7	HW	RL/UML
24	--	--	942	3050	2108	942	3050	633	295	1.1x10-3	3.9x10-7	HW	RL/UML
25	--	--	1042	3050	2008	1042	3050	623	295	1.4x10-3	4.8x10-7	HW	RL/UML
26	--	--	1372	3050	1678	1372	3050	561	295	1.5x10-3	5.4x10-7	HW	RL/UML
27	--	--	2102	3050	948	2102	3050	462	295	2.2x10-3	7.9x10-7	HW	UML
28	--	--	2202	2215	13	2202	2215	442	295	1.1x10-1	3.8x10-5	HW	RL/UML
29	--	--	2710	2723	13	2710	2723	360	295	1.8x10-1(a)	6.0x10-5(a)	HW	UML
30	--	--	2712	2725	13	2712	2725	360	295	1.9x10-1(a)	6.3x10-5(a)	HW	UML
31	70	-65	302	1334	1037	275	960	400	480	3.4x10-2	1.2x10-5	HW/CR/FW	RL/ML/CR/SL
32	--	--	552	1334	782	490	960	200	480	2.4x10-2	8.6x10-6	HW/CR/FW	UML/LML/CR/SL
33	255	-55	252	300	48	183	217	46	0	4.8x10-2	1.7x10-5	HW	LML
34	--	--	300	426	126	217	308	0	92	2.5	8.9x10-4	HW/FW/CR	LML/CR
35	165	-70	1600	2971	1371	1560	2585	400	590	4.0x10-3	1.4x10-6	HW/FW/CR	UML/LML/CR/SL

Table 3.6-8, continued

Hole #		Core Interval Tests											
		Collar Dip	Drill Depth (ft)			Vertical Depth (ft)		Horz to CrHW (ft)		Permeability		Tests(c)	Formations(d)
			From	To	Thick	From	To	From	To	ft/d	cm/sec		
36	--	--	2297	2971	674	2150	2585	23	590	1.6x10-3	5.8x10-7	HW/FW/CR	LML/CR/SL
37	--	--	2920	2971	51	2575	2585	560	590	3.4x10-4	1.2x10-7	HW/FW/CR	LML/CR/SL
38	66	-65	228	1078	850	205	750	340	350	5.1x10-2(b)	1.8x10-5(b)	HW/FW/CR	UML/LML/CR/SL
39	--	--	402	1078	676	351	750	230	350	2.6x10-2(b)	9.0x10-6	HW/FW/CR	UML/LML/CR/SL
40	253	-90	167	258	91	167	258	62	43	1.8x10-2	6.4x10-6	HW	LML
41	--	--	258	375	117	258	375	43	16	4.8x10-3	1.7x10-6	CR	LML/CR
42	77	-70	602	1049	447	575	930	130	160	1.6x10-2	5.7x10-6	HW	LML/SL

(a) Some leakage around packers on these tests because of open fractures. D&M 4/19/1978, Table 1.

(b) Possible leakage around uncemented casing from overlying glacial material. D&M 4/19/1978, p.7.

(c) HW = Hanging Wall, FW = Footwall, CR = Crandon Formation

(d) SL = Sand Lake Formation, CR = Crandon Formation, UML = Upper Mole Lake Formation, LML = Lower Mole Lake Formation, RL = Rice Lake Formation

Shaded values representative of regional bedrock unaffected by weathering of Crandon Formation.

Prepared by: AJE
Checked by: SVD1

Table 3.6-9

Crandon Deposit Down Hole Bedrock Temperature Data (EDCON-1978)
Holes 11, 15, 19, 22, 38 and 42

	Hole No. 11			Hole No. 15			Hole No. 19			Hole No. 22			Hole No. 38			Hole No. 42		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
1	250	240	52.5	200	200	51.1	250	260	52.1	250	240	52.2	250	245	52.2	200	200	51.6
2	300	289	52.9	250	250	51.5	300	305	52.5	300	271	52.5	300	290	52.6	250	249	52.0
3	350	338	53.2	300	301	52.0	350	350	52.9	350	320	52.9	350	338	53	300	300	52.4
4	400	380	53.6	350	350	52.5	400	395	53.3	400	362	53.2	400	390	53.4	350	345	52.7
5	450	430	53.9	400	395	52.9	450	445	53.7	450	410	53.6	450	430	53.8	400	395	53.1
6	500	476	54.3	450	450	53.3	500	495	54.1	500	451	53.9	500	470	54.3	450	445	53.5
7	550	521	54.7	500	498	53.8	550	538	54.5	550	500	54.2	550	530	54.7	500	500	53.8
8	600	565	55.1	550	545	54.2	600	585	54.9	600	550	54.5	600	575	55.1	550	550	54.2
9	650	602	55.4	600	595	54.7	650	630	55.3	650	570	54.9	650	626	55.5	600	595	54.4
10	700	649	55.8	650	645	55.1	700	685	55.7	700	620	55.3	700	671	55.9	650	648	54.6
11	750	696	56.2	700	695	55.5	750	720	56.0	750	661	55.6	750	721	56.2	700	700	54.8
12	800	745	56.5	750	740	55.9	800	780	56.4	800	695	56.0	800	769	56.6	750	745	55.0
13	850	775	56.9	800	790	56.3	850	820	56.7	850	722	56.3	850	810	57.0	800	795	55.3
14	900	811	57.2	850	844	56.7	900	870	57.1	900	759	56.6	900	859	57.3	850	849	55.6
15	950	854	57.5	900	991	57.1	950	910	57.5	950	799	56.9	950	900	57.7	900	895	55.9
16	1000	890	57.8	950	945	57.5	1000	945	57.8	1000	830	57.2	1000	945	58.1	950	945	56.3
17	1050	921	58.1	1000	991	57.9	1050	980	58.1	1050	859	57.5	1050	985	58.4	1000	995	56.7
18	1100	956	58.4	1050	1040	58.3	1100	1020	58.4	1100	888	57.7	1100	1025	58.7	1050	1045	57.0
19	1150	991	58.7	1100	1090	58.8	1150	1060	58.7	1150	915	57.9	1150	1058	59	1100	1095	57.4

Table 3.6-9, continued

	Hole No. 11			Hole No. 15			Hole No. 19			Hole No. 22			Hole No. 38			Hole No. 42		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
20	1200	1020	58.9	1150	1140	59.3	1200	1090	59.1	1200	945	58.2	1200	1100	59.3	1150	1140	57.7
21	1250	1050	59.1	1200	1183	59.8	1250	1120	59.4	1250	974	58.4	1250	1129	59.6	1200	1190	58.1
22	1300	1069	59.3	1250	1235	60.2	1300	1155	59.7	1300	1000	58.8	1300	1160	59.8	1250	1237	58.4
23	1350	1110	59.6	1300	1285	60.7	1350	1190	59.9				1350	1190	60.0	1300	1285	58.7
24				1350	1340	61.1	1400	1220	60.2				1400	1218	60.3	1350	1332	59.1
25				1400	1481	61.5	1450	1245	60.4				1450	1245	60.5	1400	1381	59.4
26				1450	1436	61.9	1500	1275	60.7				1500	1258	60.7	1450	1430	59.7
27				1500	1481	62.3	1550	1300	60.9				1550	1289	60.9	1500	1476	60.0
28				1550	1530	62.6	1600	1330	61.1				1600	1306	61.1	1550	1521	60.4
29				1600	1579	63.0	1650	1350	61.3				1650	1325	61.2	1600	1570	60.7
30				1650	1625	63.3	1700	1370	61.5				1700	1340	61.4	1650	1618	61.0
31				1700	1672	63.6	1750	1390	61.6							1700	1661	61.4
32				1750	1715	63.9	1800	1410	61.8							1750	1709	61.7
33				1800	1759	64.2	1850	1430	62.0							1800	1756	62.1
34				1850	1800	64.4	1900	1445	62.2							1850	1800	62.6
35				1900	1834	64.7										1900	1845	62.9
36				1950	1870	64.9										1950	1890	63.2
37				2000	1900	65.1										2000	1935	63.5
38				2050	1930	65.3										2050	1980	63.9
39				2100	1950	65.5										2100	2018	64.1
40				2150	1978	65.7										2150	2055	64.2
41				2200	2000	65.8										2200	2098	64.4

Table 3.6-9, continued

	Hole No. 11			Hole No. 15			Hole No. 19			Hole No. 22			Hole No. 38			Hole No. 42		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
42				2550	2028	66.0										2250	2137	64.5
43				2300	2045	66.1										2300	2175	64.8
44				2350	2066	66.3										2350	2210	65.0
45				2400	2082	66.4										2400	2244	65.3
46				2450	2100	66.6										2450	2279	65.5
47																2500	2314	65.7
48																2550	2341	66.0
49																2600	2372	66.2
50																2650	2400	66.3
51																2700	2430	66.6
52																2750	2455	66.8
53																2800	2470	67.1
54																		
55																		
56																		
57																		
58																		

Prepared by: AJE
Checked by: JCP

Table 3.6-10

Crandon Deposit Down Hole Bedrock Temperature Data (EDCON-1978)
Holes 60, 80, 91, 139 and 155

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
1	150	152	51.5	300	210	52.6	150	145	51.1	Frozen Pen Problems Top 500'			150	150	51.6
2	200	205	51.9	350	245	52.9	200	195	51.3				200	200	52.0
3	250	251	52.2	400	275	53.3	250	240	51.6				250	250	52.5
4	300	307	52.6	450	305	53.5	300	290	52.0				300	300	53.0
5	350	359	53.1	500	345	53.7	350	340	52.3				350	350	53.4
6	400	410	53.5	550	376	54.0	400	385	52.7				400	400	54.0
7	450	455	53.9	600	414	54.2	450	425	53.0				450	450	54.4
8	500	510	54.4	650	445	54.5	500	470	53.3				500	500	54.9
9	550	560	54.8				550	515	53.7	550	565	54.9	550	550	55.3
10	600	610	55.3				600	565	54.1	600	619	55.2	600	600	55.5
11	650	661	55.7				650	595	54.5	650	665	55.7	650	650	55.8
12	700	711	56.1				700	640	54.9	700	716	56.2	700	700	56.2
13	750	760	56.6				750	675	55.2	750	770	56.6	750	750	56.6
14	800	810	57.0				800	710	55.7	800	820	57.0	800	800	57.0
15	850	858	57.4				850	748	55.9	850	873	57.4	850	850	57.5
16	900	910	57.8				900	780	56.2	900	926	57.8	900	900	57.9
17	950	960	58.2				950	815	56.6	950	975	58.2	950	950	58.4
18	1000	1010	58.6				1000	845	56.9	1000	1029	58.6	1000	1000	58.8
19	1050	1056	59.1				1050	879	57.2	1050	1075	59.0	1050	1050	59.3
20	1100	1115	59.5				1100	900	57.4	1100	1130	59.3	1100	1100	59.7
21	1150	1160	59.9				1150	929	57.7	1150	1180	59.6	1150	1150	60.0

Table 3.6-10 (Continued)

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
22	1200	1215	60.4				1200	950	57.9	1200	1230	60.1	1200	1200	60.4
23	1250	1265	60.8				1250	974	58.2	1250	1276	60.5	1250	1250	61.0
24	1300	1315	61.2				1300	995	58.4	1300	1330	60.9	1300	1300	61.4
25	1350	1358	61.6				1350	1016	58.6	1350	1381	61.3	1350	1350	61.8
26	1400	1419	62.1				1400	1038	58.8	1400	1430	61.7	1400	1400	62.1
27	1450	1470	62.4							1450	1480	62.1	1450	1450	62.5
28	1500	1521	62.8							1500	1530	62.5	1500	1500	62.9
29	1550	15571	63.2							1550	1580	62.9	1550	1550	63.2
30	1600	1625	63.6							1600	1629	63.3	1600	1600	63.5
31	1650	1674	63.9							1650	1681	63.7	1650	1650	63.8
32	1700	1727	64.3							1700	1735	64.0	1700	1700	64.2
33	1750	1778	64.6							1750	1785	64.3	1750	1750	64.5
34	1800	1820	64.9							1800	1832	64.6	1800	1800	64.9
35	1850	1876	65.3							1850	1884	64.9	1850	1850	65.3
36	1900	1920	65.6							1900	1934	65.2	1900	1900	65.7
37	1950	1965	66.0							1950	1980	65.6	1950	1950	66.1
38	2000	2012	66.4							2000	2031	65.9	2000	2000	66.5
39	2050	2055	66.7							2050	2080	66.3	2050	2050	66.9
40	2100	2105	67.0							2100	2130	66.5	2100	2100	67.3
41	2150	2149	67.4							2150	2175	66.9	2150	2150	67.7
42	2200	2190	67.7							2200	2212	67.1	2200	2200	68.0
43	2250	2235	68.0							2250	2269	67.7	2250	2250	68.3
44	2300	2275	68.3							2300	2321	68.1	2300	2300	68.5
45	2350	2320	68.7							2350	2369	68.3	2350	2350	68.9

Table 3.6-10 (Continued)

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
46	2400	2360	69.0							2400	2416	68.6	2400	2400	69.3
47	2450	2400	69.2							2450	2460	68.8	2450	2450	69.6
48	2500	2440	69.5							2500	2503	69.0	2500	2500	69.9
49										2550	2550	69.1	2550	2550	70.2
50										2600	2590	69.6	2600	2600	70.5
51										2650	2640	69.8	2650	2650	71.0
52										2700	2690	70.1	2700	2700	71.5
53										2750	2731	70.4	2750	2750	71.8
54										2800	2774	70.8	2800	2800	72.0
55										2850	2810	71.0	2850	2850	72.2
56										2900	2850	71.0	2900	2900	72.5
57										2950	2886	71.3			
58										3000	2919	71.6			
59										3050	2957	71.8			
60										3100	2990	71.9			
61										3150	3020	72.1			
62										3200	3051	72.4			
63										3250	3085	72.6			
64										3300	3115	72.8			
65										3350	3145	72.9			
66										3400	3171	73.1			

Prepared by: AJE
Checked by: JCP

Table 3.6-11

Bedrock Water Chemistry Data

Core Hole	Downhole Interval (ft)	Depth[a] (ft)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
155	362-3050	362-3050	3,700	NA	NA	NA	NA
	562-3050	562-3050	4,200	NA	NA	NA	NA
	842-3050	842-3050	4,000	NA	NA	NA	NA
	942-3050	942-3050	3,600	404	127	1,670	25.8
	1042-3050	1042-3050	3,300	NA	NA	NA	NA
	1370-3050	1370-3050	2,900	NA	NA	NA	NA
	2102-3050	2102-3050	2,550	NA	NA	NA	NA
	2710-3050	2710-3050	2,100	NA	NA	NA	NA
	2202-2215	2202-2215	2,200	261	75.0	1,060	18.8
	2712-2725	2712-2725	2,250	NA	NA	NA	NA
66	402-1078	250-710	2	38.6	19.3	NA	NA
70	302-1334	235-935	6	39.5	22.8	NA	NA
	552-1334	470-935	8	39.1	23.4	NA	NA
77	602-1049	540-895	20	34.6	20.5	NA	NA
91	852-1415	730-1040	12	42.2	22.0	NA	NA
165	2300-2971	2120-2455	1,900	NA	NA	NA	NA
	2920-2971	2435-2455	2,650	468	185	1,090	18.8
181	1900-3405	1835-3110	4,850	850	221	1,810	3.5
190[b]	1700-2244	1340-1795	30	36.2	22.4	15.7	3.1
192[b]	2300-3219	2210-2960	5,100	1,060	298	2,450	50.5
194	800-1584	735-1335	46	34.2	20.1	21.4	3.3

NA Not Analyzed

[a]Vertical depth below ground surface.

[b]Intervals for Holes 190 and 192 were reversed on original laboratory report.

Prepared by: JET
Checked by: SVD1

common alkalies and alkaline earths (sodium, potassium, calcium, and magnesium) increased significantly below 1,800 feet. Collectively this data indicates that meteoric water may circulate in the weathered zones of the Crandon Formation to a depth of about 1,800 feet.

Within the hanging wall, samples were collected from 10 intervals within vertical core hole 155. The chloride concentration in all the samples was consistently above 2,000 mg/L from a depth of 362 feet to a depth of 3,050 feet. The high chloride concentrations indicate that meteoric water is not readily circulating below a depth of 362 feet in the hanging wall.

The fact that saline water was encountered in the hanging wall at shallow depths in hole 155 and that meteoric water was encountered at shallow depths in the Crandon Formation indicates that lateral movement of water between the hanging wall and Crandon Formation is likely restricted. Water chemistry data also suggests that water seeping into the mine workings from deep fractures within the hanging wall and footwall will likely be from pockets of saline water contained in, as identified by fractures studies, discontinuous fractures that do not extend to the bedrock surface, and therefore, would not, when drained, induce additional drawdown in the near bedrock surface. This general conclusion is consistent with work reported by Kelly, et. al. (1986), who performed an extensive analysis of saline waters at Precambrian mine sites in the Keweenaw Peninsula of Northern Michigan. Kelly, et. al. (1986) concludes that saline waters in the Precambrian rock are likely to be large fluid inclusions derived from Paleozoic brines that were sealed in the Precambrian rock under relatively high temperatures. Kelly et al (1986) notes that when encountered these saline waters emerge as seeps or flows that cease after periods ranging from days to years. These types of seeps are consistent with water derived from fractures of limited continuity at depth.

Vertical head differences between bedrock and the Pre- to Early Wisconsinan till were measured at the eight locations shown on Figure 3.6-21. Hydrographs of the nested wells at the eight locations are shown in Figures 3.6-22 through 3.6-24. The hydrographs were developed using data from the Crandon Project hydrologic database (Appendix 3.6-8). The hydrographs depicted in the figures are for wells screened completely within the upper bedrock or overlying Pre- to Early Wisconsinan till.

With the exception of several well nests over the ore body (BE-211-2U/2L and CMC-OWA1, 2, 3, and PWAR), the hydrographs show that over time there is very little head difference between the glacial overburden and the bedrock, indicating that there is very little flow between the bedrock and the glacial overburden outside of the ore body. Therefore, it is unlikely that the bedrock is acting as a sink or source of groundwater to the glacial overburden. This is consistent with the conceptual model of limited flow in the bedrock, in which case the water encountered in fractures at shallow bedrock depths would be in hydrostatic equilibrium with the glacial overburden, which is hydraulically connected to the bedrock.

Based on bedrock hydrogeologic conditions, the conceptual model for mine inflow for the Crandon Project consists of three components: 1) stored water within the ore body and surrounding bedrock, 2) vertical leakage from the glacial deposits into the bedrock consisting of and surrounding the ore body; and 3) lateral flow of water within the bedrock to the mine workings, with the greatest majority of inflow emanating from the first two components. No single piece of data provides irrefutable information to confirm with certainty with this conceptual model is correct, however the data presented here and in Appendix 3.5-15 provides check after check that supports and is consistent with a conceptual model of limited lateral flow of water within the bedrock to the mine and limited drawdown within the bedrock. This conclusion is based on the following:

- Extensive drilling programs totalling approximately 320,000 feet (60 miles) of core have shown that major structural offsets that would give rise to significant lateral flow are not present at the Crandon mine site.

- Fracture and rock mechanics studies show a clear pattern of reduced fracture frequency with depth and an increase in RQD. Fracture orientation is preferential to east-west orientation. These parameters are consistent with decreased water flow in the bedrock with depth, with higher east-west than north-south permeabilities.

- Two bedrock pump tests on hole 214 from depths of 107 to 360 feet and 107 to 750 feet yielded low flow from the intersected hanging wall rocks.

- Weathering studies indicate that strong and moderate weathering is most pronounced in the Crandon Formation and is less in the hanging wall and footwall. The weathering is preferentially developed along the east-west trend of the bedrock formations.

- An east-west trending gabbro dike in the footwall will tend to limit the south to north water flow in the bedrock toward the mine.

- Packer test data is consistent with the conceptual model of bedrock water flow being primarily in the weathered zones.

- Temperature logs and geothermal gradients at the site are consistent with limited flow of water in the bedrock.

- Bedrock water chemistry changes with depth suggesting limited flow at depth.

- Vertical gradients indicate little head difference between the glacial overburden and bedrock.

Collectively, this information provides strong support for the conceptual model of water movement in the bedrock at the Crandon Project site.

To verify the conceptual model of water movement in the bedrock and to further quantify the permeability of the bedrock, CMC completed additional bedrock packer tests in 1995 on core holes 254, 257, 155, and 246. The intent of the 1995 packer test program was to supplement historical bedrock permeability data with packer test data that targeted the strongly, moderately, and weakly weathered bedrock in the hanging wall, footwall, and Crandon Formation. The results of the 1995 packer tests are presented in Table 3.6-11a. The 1995 data shows a general pattern of decreasing permeability with depth and degree of weathering. In addition, the data shows that the Crandon Formation is more permeable than the surrounding hanging wall and footwall rock.

The 1995 packer test program is discussed in detail in a report prepared by Hydro-Geo Consultants, Inc. (Hydro-Geo, 1995). This report can be found in Appendix F of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3.

Table 3.6-11a

Summary of 1995 Bedrock Permeability Tests

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
254	377 - 400	23	8.25×10^{-7}	Footwall weakly weathered	—
	354 - 377	23	2.57×10^{-5}	Footwall weakly weathered	—
	330 - 353	23	2.24×10^{-4}	Footwall weakly weathered	—
	307 - 330	23	1.85×10^{-7}	Footwall weakly weathered	—
	295 - 306	11	3.88×10^{-5}	Footwall moderately weathered	—
	284 - 295	11	4.66×10^{-6}	Footwall moderately weathered	—
	273 - 284	11	3.41×10^{-5}	Footwall moderately weathered	—
	262 - 273	11	1.68×10^{-5}	Footwall moderately weathered	—
	251 - 262	11	3.30×10^{-6}	Footwall moderately weathered	—
	241 - 247.5	6.5	3.23×10^{-5}	Footwall moderately weathered	Leakage around packer
	235.5 - 242	6.5	4.23×10^{-4}	Footwall moderately weathered	Leakage around packer
	230.5 - 237	6.5	4.22×10^{-4}	Footwall moderately weathered	Leakage around packer
	225.5 - 232	6.5	3.57×10^{-4}	Footwall moderately weathered	Leakage around packer
257	337 - 360	23	7.96×10^{-6}	Footwall weakly weathered	—
	314 - 337	23	7.46×10^{-5}	Footwall weakly weathered	—
	291 - 314	23	4.17×10^{-6}	Footwall weakly weathered	—

Table 3.6-11a *(Continued)*

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
	268 - 291	23	$3.74x10^{-5}$	Footwall weakly weathered	—
	283.5 - 290	6.5	$8.31x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	278.5 - 285	6.5	$9.29x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	273.5 - 280	6.5	$8.29x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	265.5 - 272	6.5	$1.53x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	259 - 265.5	6.5	$7.15x10^{-6}$	Footwall weakly weathered	—
	252.5 - 259	6.5	$1.06x10^{-5}$	Footwall moderately weathered	—
155	1,975 - 1,997	22	$5.35x10^{-7}$	Hangingwall weakly weathered	—
	1,854 - 1,876	22	$3.18x10^{-7}$	Hangingwall weakly weathered	—
	1,575 - 1,597	22	$1.98x10^{-7}$	Hangingwall weakly weathered	—
	1,210 - 1,232	22	$1.49x10^{-7}$	Hangingwall weakly weathered	—
	1,000 - 1,022	22	$1.27x10^{-7}$	Hangingwall weakly weathered	—
	760 - 782	22	$2.13x10^{-6}$	Hangingwall weakly weathered	—
	550 - 572	22	$7.44x10^{-7}$	Hangingwall weakly weathered	—
	250 - 272	22	$8.56x10^{-8}$	Hangingwall weakly weathered	—
	140 - 162	22	$1.09x10^{-7}$	Hangingwall moderately weathered	—
	120 - 142	22	$3.04x10^{-8}$	Hangingwall moderately weathered	—

Table 3.6-11a *(Continued)*

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
246[1]	1,035 - 1,052	22	$1.86x10^{-7}$	Footwall weakly weathered	—
	981 - 998	22	$2.49x10^{-7}$	Footwall weakly weathered	—
	928 - 945	22	$1.86x10^{-7}$	Footwall weakly weathered	—
	897 - 914	22	$1.80x10^{-7}$	Crandon weakly weathered	—
	851 - 868	22	$2.99x10^{-5}$	Crandon moderately weathered	—
	821 - 837	22	$9.51x10^{-6}$	Crandon strongly weathered	—
	790 - 807	22	$9.97x10^{-6}$	Footwall moderately weathered	—
	779 - 792	22	$2.66x10^{-5}$	Footwall weakly weathered	—

[1]Test interval is listed as true depth, borehole is inclined at 50°.

Source: Hydro-Geo, 1995. Checked by: JWS

As part of the 1995 packer test program, Hydro-Geo Consultants, Inc. also evaluated all site bedrock permeability data to determine representative values and reasonable ranges of permeability for the various bedrock hydrostratigraphic units at the Crandon site. The summary of representative values and reasonable ranges of permeability for the bedrock is provided in Table 3.6-11b and confirms a trend of decreasing permeability with depth and degree of weathering that is consistent with the conceptual model described above.

3.6.4.2.2 Structured & Massive Saprolite

In 1981 Camp Dresser & McKee conducted two pump tests from angled core holes 211 and 213 that intersected the Crandon Formation. The purpose of the pump tests were to evaluate, the relative degree of hydraulic connection between the ore body and glacial overburden. Figures 3.6-25 and 3.6-26 show the location of observation wells and angle core holes used to monitor the drawdown from these two pump tests. The results of the two pump tests are summarized in Tables 3.6-12 and 3.6-13. Based on the results of the pump test it was inferred that a low permeability layer resided over the ore body, since very little drawdown was observed in the wells screened in the glacial overburden. The exception was the drawdown observed in wells BE-216-1, BE-216-2, and BE-211-1. Based on the drawdown observed at these three wells, it was inferred that a direct hydraulic connection between the ore body and glacial overburden occurred in these areas.

In 1994 the hydraulic and geologic characteristics of the contact between the ore body and glacial overburden was further evaluated. Upon review of archived core and soil samples in the CMC Rhinelander core shed, it was concluded that a massive saprolite and glacial till layer at the

Table 3.6-11b

Representative Hydraulic Conductivities for Bedrock Hydrostratigraphic Units

Hydrostratigraphic Unit	Representative Value (cm/sec)	Estimated Range of Variability (cm/sec)	Method of Estimation (Rep. Value / Range)
Hanging Wall strongly weathered	$1.7x10^{-5}$	$3.4x10^{-6}$ - $8.5x10^{-5}$	1 Test / Estimated
Hanging Wall moderately weathered	$5.0x10^{-6}$	$7.7x10^{-7}$ - $3.2x10^{-5}$	Geom. Mean / Confidence Interval
Hanging Wall weakly weathered	$3.3x10^{-7}$	$9.1x10^{-8}$ - $1.2x10^{-6}$	Geom. Mean / Confidence Interval
Footwall strongly weathered	$8.0x10^{-5}$	$1.6x10^{-5}$ - $4.0x10^{-4}$	Estimated / Estimated
Footwall moderately weathered	$1.0x10^{-5}$	$3.2x10^{-6}$ - $3.3x10^{-5}$	Geom. Mean / Confidence Interval
Footwall weakly weathered	$4.2x10^{-6}$	$1.2x10^{-6}$ - $1.4x10^{-5}$	Geom. Mean / Confidence Interval
Crandon strongly weathered	$1.6x10^{-4}$	$2.9x10^{-5}$ - $9.2x10^{-4}$	Geom. Mean / Confidence Interval
Crandon moderately weathered	$6.1x10^{-4}$	$1.2x10^{-4}$ - $3.0x10^{-3}$	Geom. Mean / Estimated
Crandon weakly weathered	$4.2x10^{-6}$	$8.4x10^{-7}$ - $2.1x10^{-5}$	Estimated / Estimated

Source: Hydro-Geo, 1995. Checked by: JWS

Table 3.6-12

211 Pump Test Well Data and Drawdowns

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
211-1	15	39	1.5' above bedrock
211-2U	2.2	20	130'-150' below land surface
211-2L	2.4	7	in overburden on top of bedrock
211-3U	1.2	10	183'-193' below land surface
211-3L	.44	10	18' below overburden/bedrock interface
213-1	0	25	in overburden just above bedrock
213-2	0	25	in overburden just above bedrock
213-3U	0	10	in overburden just above bedrock
213-3L	0.1	10	14' below overburden/ bedrock interface
216-1	2.8	20	in overburden just above bedrock
216-2	0.5	20	in overburden just above bedrock
WW-2	7.3	15	160 ft. below land surface
WW-4	0	10 ft. 4 in.	97 ft. 10 in. below land surface
DW-2L	0	5	top of screen 85' below land surface
DW-3	0.2	5	top of screen 28' below land surface
DMI-1	0	2.5	gravel pack from 52-109 ft., top of screen 106 ft. below land surface
DMS-1	0	10	sand pack from 50 ft. to 105 ft., top of screen at 95 ft.
DMS-2	0	10	top of screen 80' below land surface
STSB-1	0	10	top of screen 84.7 ft. below land surface
TW-1	0	15	55 ft. below land surface
195E	0.2	unknown	unknown
195W	NM	none	approximately 450' deep
209	0.9	180	25° off vertical-top of screen 1065' down hole, screened across hanging wall contact w/ore body
210	0.7	180	30° off vertical-top of screen 910' down hole, screened across hanging wall contact w/ore body
211 Pumping Well	308	none	980' open hole-from surface at 30° off vertical
213	0.5	none	880' open hole-from surface at 25° off vertical
216	1.5	none	1169' open hole-from surface at 25° off vertical

Table 3.6-12, continued

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
217	0.8	80	25° off vertical-top of screen 470' down hole, screened across hanging wall contact w/ore body
218	NM	60	15° off vertical-top of screen 840' down hole, screened across hanging wall contact w/ore body
219	258	105	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
220	223	160	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
221	0.8	211	25° off vertical-top of screen 489' down hole, screened across hanging wall contact w/ore body
222	0.8	232	25° off vertical-top of screen 442' down hole, screened across hanging wall contact w/ore body
223	0.9	200	25° off vertical-top of screen 324' down hole, screened across hanging wall contact w/ore body
224	0.8	80	25° off vertical-top of screen 374' down hole, screened across hanging wall contact w/ore body
226	2.1	106	25° off vertical-top of screen 689' down hole, screened across hanging wall contact w/ore body
227	1.9	127	25° off vertical-top of screen 503' down hole, screened across hanging wall contact w/ore body
228	3.2	100	25° off vertical-top of screen 595' down hole, screened across hanging wall contact w/ore body
229	2.2	100	25° off vertical-top of screen 384' down hole, screened across hanging wall contact w/ore body
230	229	127	25° off vertical-top of screen 537' down hole, screened across hanging wall contact w/ore body
232	1.1	200	40° off vertical-top of screen 480' down hole, screened across hanging wall contact w/ore body

NM = Not Measured

Prepared by: JCP
Checked by: LLA

Table 3.6-13

213 Pump Test Well Data and Drawdowns

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
211-1	0.8	39	1.5' above bedrock
211-2U	0.2	20	130'-150' below land surface
211-2L	2.3	7	in overburden on top of bedrock
211-3U	0.2	10	183'-193' below land surface
211-3L	4.2	10	18' below overburden/bedrock interface
213-1	3.1	25	in overburden just above bedrock
213-2	3.4	25	in overburden just above bedrock
213-3U	3.4	10	in overburden just above bedrock
213-3L	6.4	10	14' below overburden/ bedrock interface
216-1	49	20	in overburden just above bedrock
216-2	14	20	in overburden just above bedrock
WW-2	0.4	15	160 ft. below land surface
WW-4	3.9	10 ft. 4 in.	97 ft. 10 in. below land surface
DW-2L	0	5	top of screen 85' below land surface
DW-3	0	5	top of screen 28' below land surface
DMI-1	1.2	2.5	gravel pack from 52-109 ft., top of screen 106 ft. below land surface
DMS-1	0	10	sand pack from 50 ft. to 105 ft., top of screen at 95 ft.
DMS-2	0	10	top of screen 80' below land surface
STSB-1	4	10	boring terminated in bedrock at 103 ft., well set at 84.7 ft. below land surface
195E	3.3	unknown	unknown
195W	1.9	none	approximately 450' deep
209	124	180	25° off vertical-top of screen 1065' down hole, screened across hanging wall contact w/ore body
210	122	180	30° off vertical-top of screen 910' down hole, screened across hanging wall contact w/ore body
211	3.6	none	980' open hole-from surface at 30° off vertical
213 Pumping Well	221	none	880' open hole-from surface at 25° off vertical

Table 3.6-13, continued

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
216	28	none	1169' open hole-from surface at 25° off vertical
217	120	80	25° off vertical-top of screen 470' down hole, screened across hanging wall contact w/ore body
218	1.6	60	15° off vertical-top of screen 840' down hole, screened across hanging wall contact w/ore body
219	3.6	105	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
220	3.7	160	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
221	NM	211	25° off vertical-top of screen 489' down hole, screened across hanging wall contact w/ore body
222	94	232	25° off vertical-top of screen 442' down hole, screened across hanging wall contact w/ore body
223	92	200	25° off vertical-top of screen 324' down hole, screened across hanging wall contact w/ore body
224	91	80	25° off vertical-top of screen 374' down hole, screened across hanging wall contact w/ore body
226	70	106	25° off vertical-top of screen 689' down hole, screened across hanging wall contact w/ore body
227	71	127	25° off vertical-top of screen 503' down hole, screened across hanging wall contact w/ore body
228	60	100	25° off vertical-top of screen 595' down hole, screened across hanging wall contact w/ore body
229	67	100	25° off vertical-top of screen 384' down hole, screened across hanging wall contact w/ore body
230	4.2	127	25° off vertical-top of screen 537' down hole, screened across hanging wall contact w/ore body
232	8.8	200	40° off vertical-top of screen 480' down hole, screened across hanging wall contact w/ore body
TW-1	0	15 ft.	55 ft. below land surface

NM = Not Measured

Prepared by: JCP
Checked by: LLA

interface of the bedrock and glacial overburden was the low permeability layer that will control vertical seepage of groundwater from the glacial overburden into the mine. Section 3.5.3.1.5 described the results of an investigation to characterize the thickness and extent of the structured and massive saprolite in the vicinity of the ore body. As part of the saprolite investigation, a pump test and numerous slug tests were performed to evaluate the hydraulic conductivity of the structured saprolite, massive saprolite, and Pre- to Early Wisconsinan till. A description of the work performed and a discussion of the results were included in a February 23, 1995 report (Foth & Van Dyke, 1995a) submitted to the WDNR and USCOE. The report titled, *Investigation and Evaluation: Saprolite at the Crandon Site*, is the topic of continuing discussions between the two agencies and CMC. As described in the saprolite report, a specific objective of the investigation was to evaluate the hydraulic characteristics of the massive saprolite where, based on the 1981 ore body pump test, a direct hydraulic connection between the ore body and glacial overburden was inferred.

Results of the slug tests performed during the saprolite investigation are summarized in Table 3.6-14. Results of the 16 day pump test were principally analyzed through a numerical model that was calibrated to the pump test results. Calibrated hydraulic parameters from the pump test model are summarized in Table 3.6-15. The hydraulic conductivity of the massive saprolite was calibrated to 0.04 ft/d (1.4E-5 cm/s). As measured by slug tests (Table 3.16-14), the hydraulic conductivity of the massive saprolite ranged from 0.03 ft/d (1.3-5 cm/s) to 1.1 ft/d (3.8E-4 cm/s) and provides a reasonable estimate of the spacial variability for hydraulic conductivity of the massive saprolite.

The calibrated hydraulic conductivity of the structured saprolite ranged from 16 ft/d (5.6E-3 cm/s) along the strike of the ore body to 1.6 ft/d (5.6E-4 cm/s) perpendicular to the strike of the ore body. This anisotropy is likely attributed to east-west trending fractures that parallel bedding and foliation planes within the rock. The calibrated hydraulic conductivity of the structured saprolite from the pump test is reflective of the secondary permeability fracture features. In contrast, the slug tests, test a smaller zone of the structured saprolite measuring the primary permeability of the bedrock. Given that the pump test created a stress that was transmitted along nearly two-thirds of the ore body, the calibrated hydraulic conductivity from the pump test should provide a more representative estimate of the bulk hydraulic conductivity that will control flow within the structured saprolite.

Based on model calibration to drawdown in the Pre- to Early Wisconsinan till, the horizontal hydraulic conductivity of the till was estimated to be 0.8 ft/d (2.8E-4 cm/s), with an estimated vertical hydraulic conductivity of 0.16 ft/d (5.6E-5 cm/s). As measured by slug tests, the Pre- to Early Wisconsinan till over the ore body ranged from 3.4E-3 ft/d (1.2E-6 cm/s) to 0.77 ft/d (2.7E-4 cm/s).

Table 3.6-14

Saprolite Investigation Slug Test Permeability Data Summary

Well	Bouwer & Rice, 1976 Hydraulic Conductivity		Cooper, et. al. (1967) Transmissivity		Cooper, et. al. (1967) Hydraulic Conductivity		Formation
	ft/d	cm/s	ft^2/d	cm^2/s	ft/d	cm/s	
CMC-OWA1	0.01	4.2E-6	0.015	1.7E-4	1.3E-3	4.6E-7	Structured Saprolite
CMC-OWA2	0.15	5.2E-5	2.9	3.1E-2	0.24	8.5E-5	Structured Saprolite
CMC-OWA3	0.054	1.9E-5	1.3	1.4E-2	0.022	7.8E-6	Pre- to Early Wisconsinan Till
CMC-OWA4	0.048	1.7E-5	1.4	1.5E-2	0.028	9.8E-6	Pre- to Early Wisconsinan Till
CMC-OWA5	0.40	1.4E-4	8.1	8.7E-2	0.16	5.7E-5	Pre- to Early Wisconsinan Till
CMC-08	1.4	5.0E-4	--	--	--	--	Outwash
CMC-08P	0.028	1.0E-5	0.25	2.7E-3	7.8E-3	2.8E-6	Pre- to Early Wisconsinan Till
CMC-09	1.7	6.2E-4	--	--	--	--	Outwash

Table 3.6-14, continued

Well	Bouwer & Rice, 1976 Hydraulic Conductivity		Cooper, et. al. (1967)				Formation
			Transmissivity		Hydraulic Conductivity		
	ft/d	cm/s	ft^2/d	cm^2/s	ft/d	cm/s	
CMC-09P	0.021	7.5E-6	0.22	2.4E-3	3.4E-3	1.2E-6	Pre- to Early Wisconsinan Till
CMC-10	14.2	5E-3	--	--	--	--	Outwash/ Pre- to Early Wisconsinan Till
CMC-10P	0.77	2.7E-4	15.8	0.17	0.49	1.7E-4	Pre- to Early Wisconsinan Till
CMC-10PP	0.40	1.4E-4	3.7	0.040	0.57	2.0E-4	Massive Saprolite
CMC-11P	0.082	2.9E-5	1.86	0.020	0.12	4.2E-5	Massive Saprolite
CMC-12P	0.06	2.1E-5	1.5	1.6E-2	0.12	4.3E-5	Massive Saprolite
CMC-13P	0.07	2.5E-5	0.51	5.5E-3	0.03	1.29E-5	Massive Saprolite
CMC-14P	1.1	3.8E-4	13.0	0.14	0.88	3.1E-4	Massive Saprolite

--- Analysis by this method not used for wells screened in outwash.

Prepared by: SVD1
Checked by: JET

Table 3.6-15

Saprolite Investigation Calibrated Hydraulic Parameters

Layer #	Geologic Unit	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Specific Yield (Sy) (d)	Specific Storage (Ss) (1/ft.)	Thickness (ft)
Layer 1	Outwash	33.3*	33.3*	2.72*	0.1	N/A	34*
Layer 2	Upper Till	0.8	0.8	0.16	.01	1.00E-6	29*
Layer 3	Lower Till	0.8	0.8	0.16	N/A	1.00E-6	29*
Layer 4	Massive Saprolite	0.04	0.04	0.04	N/A	1.00E-6	11*
Layer 5	Structured Saprolite	16	1.6	16	N/A	5.00E-5	19*
Layer 6	Bedrock**	3.5/0.05/0.005	0.35/0.005/0.0005	3.5/0.05/0.005	N/A	1.00E-6	400

Notes:

* Average value of a variable parameter
** Three conductivity zones are ore body/hanging wall/footwall
(d) dimensionless
N/A Not Applicable

Prepared by: PFA
Checked by: SVD1

Three principal observations resulted from the saprolite investigation/pump test work. The first was that no evidence was found to support the inferred direct hydraulic connection between the ore body and the higher permeable glacial outwash materials. In fact borings placed in areas where such contacts were postulated actually showed that the materials overlying the ore body are massive saprolite and Pre- to Early Wisconsinan Till. In addition, the pump test did not show any evidence of areas of direct connection. The second observation is that the calibrated hydraulic conductivities of the massive saprolite and Pre- to Early Wisconsinan Till were found to be of the same order of magnitude with the massive saprolite being slightly lower, indicating that the two formations likely will act as a unit under stressed conditions. Third, the response of water levels to the pumping showed that vertical leakage will likely be the predominant source of mine inflow.

3.6.4.2.3 Glacial Till & Outwash

The hydraulic conductivity of the Pre- to Early Wisconsinan till, outwash sands and gravel and Late Wisconsinan till was evaluated by studies conducted by Dames & Moore (1982), Golder Associates (1981a) and STS Consultants Ltd. (1984b).

Dames & Moore performed slug tests on 36 monitoring wells screened in the glacial overburden the results of which are summarized in Table 3.6-16. Based on these results, the hydraulic conductivity of the Pre- to Early Wisconsinan and Late Wisconsinan till ranged from 3.1E-3 ft/d (1.1E-6 cm/s) to 1.13 ft/d (4.0E-4 cm/s). The outwash exhibited a higher permeability than both the Pre- to Early Wisconsinan till and Late Wisconsinan till ranging from 0.019 ft/d (6.7E-6 cm/s) to 16.44 ft/d (5.8E-3 cm/s). The data and supporting calculations are provided in Appendix 3.6-2.

Golder Associates (1981a) conducted a 24 day pump test from test well TW41 to evaluate the hydraulic characteristics of the glacial till and outwash deposits. The test was conducted at an average pumping rate of 1,420 gallons per minute using 13 primary observation wells and 16 secondary observation wells. Specific details on the pump test and analytical calculations for parameter estimates can be found in Golder Associates (1981a) which is provided in Appendix 3.6-4. The results of this pump test area summarized in Table 3.6-17. The measured horizontal hydraulic conductivity of the Pre- to Early Wisconsinan till was 0.8 ft/d with a vertical hydraulic conductivity of 0.3 ft/d. The non differentiated outwash horizontal hydraulic conductivity was 37.2 ft/d with a vertical hydraulic conductivity of 3.7 ft/d. The estimated hydraulic conductivity for the Late Wisconsinan till was equivalent to that of the Pre- to Early Wisconsinan till. The measured hydraulic conductivity of the tills compare favorable to the calibrated values derived from the saprolite pump test described above, indicating a strong degree of confidence in the estimated hydraulic characteristics of the glacial deposits.

STS Consultants Ltd. (1984) performed slug tests on EX-series wells and WP-series well points in addition to several wells installed by Golder Associates (1981b), Dames & Moore (1982) and Braun Engineering (CDM, 1982). The results of these tests are summarized in Table 3.6-18. Supporting data and calculations are provided in Appendix 3.6-5. The data is generally consistent with values measured by Dames & Moore (1978) and Golder Associates (1981a).

In all there were multiple tests conducted to evaluate the hydraulic characteristics of the glacial overburden. The results of the various investigations are generally in agreement indicating a high degree of confidence in the measured values.

Table 3.6-16

Slug Test Results for DM Series Wells

Boring Series	Number	Lithology	Permeability ft/d	Permeability cm/sec	Type of Test*
DMA	1-N	LWT	0.014	5.1×10^{-6}	FH
	1-S	LWT/CO	0.060	2.1×10^{-5}	FH
	3	LWT	0.028	1.0×10^{-5}	FH
	4	LWT	0.12	4.3×10^{-5}	FH
	19	CO/LWT	0.24	8.3×10^{-5}	FH
	43	LWT	0.019	6.6×10^{-6}	FH
DMB	1A	CO/LWT	1.73	6.1×10^{-4}	FH
	2	CO/LWT	0.016	5.8×10^{-6}	FH
	3	CO	0.54	1.9×10^{-4}	RH
	3	CO	1.67	5.9×10^{-4}	FH
	4	LWT/CO	0.34	1.2×10^{-4}	FH
	5	CO/LWT	0.0031	1.1×10^{-6}	FH
	5A	LWT/CO	0.057	2.0×10^{-5}	FH
	6	LWT	0.0031	1.1×10^{-6}	FH
	7	CO	1.62	5.7×10^{-4}	FH
	8	LWT	0.074	2.6×10^{-5}	FH
	9A	EWT/FO	1.08	3.8×10^{-4}	FH
	9B	FO	0.060	2.1×10^{-5}	FH
	9C	FO/CO	0.43	1.5×10^{-4}	FH
	10	LWT/FO	0.45	1.6×10^{-4}	FH
	10	LWT/FO	0.10	3.7×10^{-5}	RH
	12	LWT	1.13	4.0×10^{-4}	RH
	13	LWT	0.45	1.6×10^{-4}	FH
	14	CO	3.12	1.1×10^{-3}	FH
	15	CO	3.97	1.4×10^{-3}	FH
	15	CO	3.12	1.1×10^{-3}	FH

Table 3.6-16, continued

Boring Series	Number	Lithology	Permeability ft/d	Permeability cm/sec	Type of Test*
DMB	15	CO	3.69	$1.3x10^{-3}$	FH
	18	CO	0.51	$1.8x10^{-4}$	FH
	18	CO	1.19	$4.2x10^{-4}$	RH
	19	CO	3.40	$1.2x10^{-3}$	FH
	19	CO	0.12	$4.2x10^{-5}$	RH
	20	CO	1.50	$5.3x10^{-4}$	FH
	20	CO	0.11	$3.8x10^{-5}$	RH
	20A	CO	2.81	$9.9x10^{-4}$	FH
	21	CO	8.50	$3.0x10^{-3}$	FH
	21	CO	7.37	$2.6x10^{-3}$	FH
	22	CO	5.95	$2.1x10^{-3}$	FH
	23	FO	2.04	$7.2x10^{-4}$	RH
	23	FO	1.39	$4.9x10^{-4}$	FH
	23	FO	0.85	$3.0x10^{-4}$	FH
	24	CO	2.47	$8.7x10^{-4}$	FH
	25	CO	0.019	$6.7x10^{-6}$	FH
	26	CO	0.031	$1.1x10^{-5}$	FH
	27	CO	0.021	$7.4x10^{-6}$	FH
	28	CO	16.44	$5.8x10^{-3}$	FH
	29	LWT/CO	0.10	$3.5x10^{-5}$	FH

FH = Falling Head Slug Test
RH = Rising Head Slug Test
LWT = Late Wisconsinan Till
EWT = Pre- to Early Wisconsinan Till
CO = Coarse Outwash
FO = Fine Outwash
▒ = Raw data not available

Prepared by: SVD1
Checked by: XXC

Table 3.6-17

Hydraulic Parameter Summary From 1981 Glacial Overburden 24 Day Pump Test[a]

Geologic Unit	Horizontal Hydraulic Conductivity Kh		Vertical Hydraulic Conductivity Kh		Specific Storage Ss	Specific Yield Sy
	ft/d	cm/s	ft/d	cm/s	ft^{-1}	%
Late Wisconsinan Till	0.8	$2.8x10^{-4}$	0.27	$9.4x10^{-5}$	$4.6x10^{-6}$	5.4
Outwash	37.2	$1.3x10^{-2}$	3.7	$1.3x10^{-3}$	$4.6x10^{-6}$	7.0
Pre- to Early Wisconsinan Till	0.8	$2.8x10^{-4}$	0.27	$9.4x10^{-5}$	$4.6x10^{-6}$	5.4

[a] Obtained from Golder, 1981.

Prepared by: SDV1
Checked by: XXC

Table 3.6-18

1984 Slug Test Results

Well	Test Type	Geologic Unit	Permeability	
			ft/d	cm/sec
EX 1AL	Fall	EWT	0.3	9×10^{-5}
	Rise		0.1	4×10^{-5}
EX 1AU	Fall	CO/EWT	17	6×10^{-3}
	Rise		11	4×10^{-3}
EX 1BL	Fall	CO	17	6×10^{-3}
	Rise		17	6×10^{-3}
EX 2AL	Fall	FO	2.0	7×10^{-4}
	Rise		1.7	6×10^{-4}
EX 2AU	Fall	CO	11	4×10^{-3}
	Rise		14	5×10^{-3}
EX 3AL	Fall	EWT	0.9	3×10^{-4}
EX 3AU	Fall	FO	2.8	1×10^{-3}
	Rise		2.3	8×10^{-4}
EX 3BL	Fall	CO	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}
EX 3BU	Fall	FO	5.7	2×10^{-3}
	Rise		2.8	1×10^{-3}
EX 4AL	Fall	EWT	2.0	7×10^{-4}
	Rise		1.7	6×10^{-4}
EX 4AU	Fall	FO	2.8	1×10^{-3}
EX 4BL	Fall	CO	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}
EX 4BU	Fall	LWT	2.0	7×10^{-4}
	Rise		0.9	3×10^{-4}
EX 5BL	Fall	CO	28	1×10^{-2}
EX 6AL	Fall	EWT	0.9	3×10^{-4}
	Rise		0.3	1×10^{-4}
EX 6AU	Fall	CO	8.5	3×10^{-3}
	Rise		11	4×10^{-3}
EX 6BL	Fall	FO	5.7	2×10^{-3}
	Rise		2.8	1×10^{-3}
EX 7AL	Fall	EWT	2.6	9×10^{-4}
	Rise		2.0	7×10^{-4}
EX 7BL	Fall	EWT	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}
EX 7BU	Fall	CO	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}

Table 3.6-18, continued

Well	Test Type	Geologic Unit	Permeability	
			ft/d	cm/sec
EX 8AL	Fall	EWT	0.3	1×10^{-4}
	Rise		0.2	7×10^{-5}
EX 8AU	Fall	EWT	0.6	2×10^{-4}
	Rise		0.6	2×10^{-4}
EX 8BL	Fall	FO	5.7	2×10^{-3}
	Rise		2.8	1×10^{-3}
EX 8BU	Fall	CO	2.8	1×10^{-3}
EX 9AU	Fall	FO	17	6×10^{-3}
	Rise		8.5	3×10^{-3}
EX 9BL	Fall	CO	0.3	1×10^{-4}
	Rise		5.7	2×10^{-3}
EX 10AL	Fall	LA	0.006	2×10^{-6}
	Rise		0.3	1×10^{-5}
EX 10AU	Fall	FO	2.8	1×10^{-3}
EX 10BL	Fall	LWT	0.06	2×10^{-5}
	Rise		0.06	2×10^{-5}
EX 11AL	Fall	LA/CO	5.7	2×10^{-3}
	Rise		2.8	1×10^{-3}
EX 11AU	Fall	FO	2.8	1×10^{-3}
	Rise		0.6	2×10^{-4}
EX 11BL	Fall	CO	14	5×10^{-3}
	Rise		17	6×10^{-3}
EX 11BU	Fall	LWT	0.3	1×10^{-4}
	Rise		0.09	3×10^{-5}
EX 12AL	Fall	LA	0.2	7×10^{-5}
	Rise		0.6	2×10^{-4}
EX 12AU	Fall	EWT	2.8	1×10^{-3}
	Rise		8.5	3×10^{-3}
EX 12BL	Fall	CO	0.03	1×10^{-5}**
	Rise		0.2	6×10^{-5}
EX 13AL	Fall	EWT	1.1	4×10^{-4}
	Rise		1.4	5×10^{-4}
EX 13BL	Fall	EWT/FO	0.6	2×10^{-4}
	Rise		2.3	8×10^{-4}*
EX 13BU	Fall	CO	2.6	9×10^{-4}
	Rise		8.5	3×10^{-3}
EX 13CL	Fall	LWT	0.2	6×10^{-5}
	Rise		0.09	3×10^{-5}
EX 14AL	Fall	LA	0.09	3×10^{-5}
	Rise		0.2	7×10^{-5}

Table 3.6-18, continued

Well	Test Type	Geologic Unit	Permeability	
			ft/d	cm/sec
EX 14AU	Fall	FO	5.7	2×10^{-3}
	Rise		5.7	2×10^{-3}
EX 14BL	Fall	LWT	0.14	5×10^{-5}
	Rise		0.057	2×10^{-5}
EX 15AL	Fall	EWT	0.6	2×10^{-4}
	Rise		0.6	2×10^{-4}
EX 15AU	Fall	CO	11	4×10^{-3}
	Rise		11	4×10^{-3}
EX 16AL	Fall	FO	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}
EX 16AU	Fall	CO	11	4×10^{-3}
	Rise		17	6×10^{-3}
EX 16BL	Fall	LWT/FO	0.03	9×10^{-6}
	Rise		0.0028	1×10^{-6}
WP-1L	Fall	FO***	5.7	2×10^{-3}
	Rise		11	4×10^{-3}
WP-2L	Fall	CO***	0.014	5×10^{-6}
	Rise		0.6	2×10^{-4}
WP-3L	Fall	CO***	20	7×10^{-3}
	Rise		26	9×10^{-3}
WP-4L	Fall	CO***	0.017	6×10^{-6}
WP-5L	Flowing well	Coarse drift		
WP-6L	Fall	CO***	11	4×10^{-3}
WP-7L	Fall	CO***	0.014	5×10^{-6}
	Rise		0.11	4×10^{-5}
G40-M15	Fall	EWT	0.3	1×10^{-4}
	Rise		0.2	8×10^{-5}
G40-S17	Fall	EWT/FO	1.1	4×10^{-4}
	Rise		2.3	8×10^{-4}
G41-E17	Fall	EWT/UDB	2.8	1×10^{-3}
	Rise		2.8	1×10^{-3}
G41-E19A	Fall	CO/FO	1.7	6×10^{-4}
	Rise		5.7	2×10^{-3}
G41-E22A	Fall	LWT	1.7	6×10^{-4}
	Rise		2.6	9×10^{-4}
G41-M11	Fall	FO	5.7	2×10^{-3}
	Rise		2.8	1×10^{-3}
G41-P16	Fall	LWT/CO/EWT	0.11	4×10^{-5}
	Rise		0.14	5×10^{-5}
G41-P18	Fall	LWT/CO	6×10^{-4}	2×10^{-7}

Table 3.6-18, continued

Well	Test Type	Geologic Unit	Permeability	
			ft/d	cm/sec
DMS-1	Fall	EWT	0.14	5×10^{-5}
	Rise		0.06	2×10^{-5}
DMI-2L	Fall	UDB	0.3	1×10^{-4}
DW-1L	Rise	EWT	3×10^{-4}	1×10^{-7}
DW-1U	Rise	EWT	9×10^{-4}	3×10^{-7}
DW-1A	Fall	EWT	9×10^{-3}	3×10^{-6}
DW-3U	Fall	EWT	2.3	8×10^{-4}
DW-3L	Rise	EWT	0.03	1×10^{-5}
BE 211-1	Rise	SS/MS/EWT	0.06	2×10^{-5}
BE 211-1 (Test #2)	Rise	SS/MS/EWT	0.09	3×10^{-5}
BE 211-2L	Rise	SS/MS	0.006	2×10^{-6}
BE 211-3U	Rise	MS/EWT	0.03	1×10^{-5}
BE 211-3L	Rise	SS/MS	0.06	2×10^{-5}
BE 213-1	Rise	SS/MS/EWT/CO	0.14	5×10^{-5}
BE 213-2	Rise	SS/MS/EWT/CO	0.3	1×10^{-4}
BE 213-3L	Rise	SS	0.20	7×10^{-5}
BE 216-1	Rise	MS/EWT/SS	0.06	2×10^{-5}
BE 216-2	Rise	MS/EWT/SS	0.011	4×10^{-6}
BE 216-3U	Rise	MS/EWT	0.02	7×10^{-6}
BE 216-3L	Rise	SS	0.03	1×10^{-5}

LWT = Late Wisconsinan Till
LA = Lacustrine
CO = Coarse Outwash
FO = Fine Outwash
EWT = Pre- to Early Wisconsinan Till
MS = Massive Saprolite
SS = Structural Saprolite
UDB = Undifferentiated Bedrock

* (EX Wells) Well not stabilized at time of report.
** Did not use data in statistical analysis - well plugged.
*** (WP Wells) No split-spoon samples taken. Geologic unit estimated from drill cuttings and adjacent stratigraphy.

Prepared by: SVD1
Checked by: XXC

3.6.4.2.4 Lake Bed and Wetland Deposits

The hydraulic conductivity of the lake beds of Little Sand, Oak, Deep Hole, Duck and Skunk Lakes and selected wetlands were evaluated based on laboratory permeability tests and in situ field permeability tests. Table 3.6-19 summarizes the lake bed and wetland data which can be found in Appendices 3.5-26, 3.5-27 and 3.5-28. The hydraulic conductivity of the lake beds as measured during three different drilling programs was consistently on the order of 2.8E-4 ft/d (1E-7 cm/s). The consistency of the measured permeability for the lake beds is likely attributed to the uniform nature of the lake bed deposits.

Wetlands in upland areas such as the Burr Oak, Duck Lake and Skunk Lake wetlands, exhibit consistently low permeability values due to the lacustrine clay and silt that underlies the wetland. In contrast, wetlands associated with discharge areas such as the wetlands around Swamp Creek are consistently of a sandy nature and thus would be expected to yield moderate to fairly high permeabilities as were measured from slug tests conducted on the WP-series well points summarized above in Table 3.6-18.

3.6.4.3 Study Area Groundwater Flow System

The groundwater flow system within the glacial overburden has been evaluated based on groundwater level measurements dating back to the late 1970s from monitoring wells shown in Figures 3.6-1 and 3.6-2. Hydrographs for these wells are presented and contained in Appendix 3.6-8.

Figures 3.6-27, 3.6-28, and 3.6-28a show water table contour maps for October 1984, August 1986, and June 1995 respectively. The October 1984 water table map depicts the water table configuration during a period of relatively normal precipitation and thus is considered to represent an average water table elevation and configuration. The August 1986 water table map represents the record high water table during which groundwater inflow to Little Sand Lake could occur. The June 1995 water table map displays current water table conditions. Cross-sections shown in Figures 3.5-26 through 3.5-32 show the elevation of the water table based primarily on the October 1984 data.

The water table is defined as the surface at which fluid pressure in the pores of a porous medium is equal to the atmospheric pressure and is indicated by the level at which water stands in a shallow well that penetrates just deep enough to encounter standing water. A well that extends deeper than the water table will have a static water level that represents an integrated average of hydraulic heads within the screened interval, and that is weighted by differences in transmissivity in the interval. Such a well would best represent the true water table when the vertical hydraulic gradient and permeability differences are minimal.

The first step in preparing the water table maps was to select site wells that are reasonably open to the shallowest groundwater. Although some wells have screens that span the water table, others do not. Therefore, it was necessary to set acceptance criteria for depths of screened intervals below the static water table. Because of the variability of well construction, it was assumed that the portion of the well open to the groundwater was the filter-packed interval. The wells were then evaluated to determine the distances between the tops of the filter packs and the October 1984 static water level in each well. Maximum distances of 20 feet and 40 feet, respectively, were used to accept wells as being representative of water table conditions. These criteria are considered reasonable considering the very low vertical gradients observed at the site

Table 3.6-19
Lake Bed and Wetland Soil Testing and Permeability Data

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Little Sand Lake	1982	STS-LSL-1	Dark gray silty clay (CL)	30 - 32	---	---	---	14	99.2	1.4×10^{-7}	4.0×10^{-4}	1583.37		
			Dark gray silty clay (CL)	44.5 - 47	---	---	---	19	94.4	1.7×10^{-7}	4.8×10^{-4}			
	1982	STS-LSL-2	Dark gray silty clay (CL)	24.5 - 26.5	---	---	---	11.5	97.7	7.3×10^{-7}	2.1×10^{-3}	1584.68		
			Brown medium sand (SP)[c]	39 - 40.5	---	---	---		4.6	---	---			
	1982	STS-LSL-3	Dark gray silty clay (CL)	28 - 30	---	---	---	19	99	3.7×10^{-7}	1.0×10^{-3}	---		
			Dark gray silty clay (CL)	37 - 39	---	---	---	15	99.5	1.5×10^{-7}	4.3×10^{-4}			
			Brown to medium sand (SP)[c]	43.5 - 45	---	---	---	---	4.2	---	---			
	1982	STS-LSL-4	Dark gray silty clay (CL)	30.5 - 32.5	---	---	---	15	96.8	1.1×10^{-7}	3.1×10^{-4}	1583.63		
			Brown to medium sand (SP)[c]	45.5 - 47	---	---	---	---	18.7	---	---			
	1982	STS-LSL-5	Dark gray silty clay (CL)	20 - 22	---	---	---	17	98.4	1.6×10^{-4a}	0.45	---		
			Dark gray silty clay (CL)	28 - 30	---	---	---	19	96.8	1.5×10^{-7}	4.3×10^{-4}			

Table 3.6-19, continued

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Little Sand Lake	1982	STS-LSL-6	Dark gray silty clay (CL)	16 - 18	---	---	---	8	93.3	3.7×10^{-7}	1.0×10^{-3}	1584.28		
			Dark gray silty clay (CL)	28 - 30	---	---	---	9	98.3	1.6×10^{-6}	4.5×10^{-3}			
	1994	CMC-LSL-101	Dark gray silty clay (CL)	14 - 16	0	4	70.6	25.4	96	1.8×10^{-7}	5.1×10^{-4}	---		
			Dark gray silty clay (CL)	20 - 22	0	4.9	75.3	19.8	95.1	---				
	1994	CMC-LSL-102	Dark gray silty clay (CL)	11 - 13	0	18.5	57.1	24.4	81.5	2.5×10^{-7}	7.1×10^{-4}	---		
	1994	CMC-LSL-102A	Dark gray silty clay (CL-ML)	16 - 18	0	12.8	67.6	19.6	87.2	---	---	1590.65	2.3×10^{-3}	8.1×10^{-7}
	1994	CMC-LSL-102B	Dark gray silty clay (CL)	12 - 14	0	10.9	63.1	26	89.1	3.0×10^{-7}	8.5×10^{-4}	1587.83	0.12	4.2×10^{-5}
			Dark gray silty clay (CL)	16 - 18	0	5.8	67.0	27.2	94.2	1.8×10^{-7}	5.1×10^{-4}			
			Dark gray silty clay (CL)	24 - 26	0	17.7	56.1	26.2	82.3	2.3×10^{-7}	6.5×10^{-4}			
			Brown silty clay (CL)	28 - 30	0	2.2	58.0	39.8	97.8	4.5×10^{-7}	1.3×10^{-3}			
			Brown clayey sand (SC)[c]	32 - 34	17.7	58.8	11.6	11.9	23.5	---	---			

Table 3.6-19, continued

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Little Sand Lake	1994	CMC-LSL-103	Dark gray silty clay (CL-ML)	30 - 33	0	10.4	72.8	16.8	89.6	1.2×10^{-7}	3.4×10^{-4}	---		
			Dark gray silty clay (CL)	33 - 35	0	6.6	72.3	21.1	93.4	8.8×10^{-8}	2.5×10^{-4}			
	1994	CMC-LSL-103	Dark gray silty clay (CL)	18 - 19.6	0	27.6	55.8	16.6	72.4	---	---			
	1994	CMC-LSL-104A	Dark gray silty clay (CL)	15.4 - 17.4	0	6.6	70.4	23.0	93.4	2.3×10^{-7}	6.5×10^{-4}	1589.07	2.3×10^{-3}	8.0×10^{-7}
	1994	CMC-LSL-104B	Dark gray silty clay (CL)	17 - 19	0	7.7	65.2	27.1	92.3	2.4×10^{-7}	6.8×10^{-4}	1579.96	0.20	7.1×10^{-5}
			Dark gray silty clay (CL)	12 - 14	0	2.5	70.0	27.5	97.5	---	---			
			Brown sand (SP-SM)[c]	24 - 26	29.1	62.0	8.9		8.9	---	---			
	1994	CMC-LSL-105	Dark gray silty clay (CL)	6 - 8	0	10.2	65.2	24.6	89.8	2.1×10^{-7}	6.0×10^{-4}	---		
			Dark gray silty clay (CL)	8 - 10	0	4.9	64.7	30.4	95.1	---	---			
			Dark gray silty clay (CL)	12 - 14	0	19.7	55.2	25.1	80.3	2.4×10^{-7}	6.8×10^{-4}			
Duck Lake	1984	STS-DL-1	Dark gray silty clay (CL)	25.5 - 28	---	---	---	--	78	1.3×10^{-6}	3.7×10^{-3}	1594.75		
			Dark gray silty clay (CL)	38 - 40	---	---	---	--	93	1.0×10^{-7}	2.8×10^{-4}			
Skunk Lake	1984	STS-SL-½	Dark gray silty clay (CL)	9.1 - 10	---	---	---	--	93	4.3×10^{-8}	1.2×10^{-4}	1594.19		

Table 3.6-19, continued

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Oak Lake	1984	STS-OL-1	Dark gray silty clay (CL)	37.5 - 39.5	---	---	---	--	88	2.3×10^{-6}	6.5×10^{-3}	Dry		
			Dark gray silty clay (CL)	42.5 - 44.5	---	---	---	--	93	3.5×10^{-7}	9.9×10^{-4}			
Deep Hole Lake	1984	STS-DHL-1	Dark gray silt (ML)	21 - 23	---	---	---	--	95	6.8×10^{-7}	1.9×10^{-3}	1587.93		
			Dark gray silt (ML)	33.5 - 35.2	---	---	---	--	88	6.8×10^{-8}	1.9×10^{-4}			
Burr Oak Swamp	1994	CMC-BO-101B	Sand (SC-SM)	4 - 6	0	53.7	32.5 Brown	13.8 Silty Clayey		1.1×10^{-6}	3.1×10^{-3}			
			Brown Clay (CL)	12 - 14	0	4.4	73.3	22.3		2.9×10^{-6}	8.2×10^{-3}			
			Brown Coarse Sand (SP)	36 - 38	1.8	95.6	2.6			---	---			
		CMC-BO-101A	Brown Clay (CL)	14 - 16	0.4	23.3	53.6	22.7		---	---		0.20	7.1×10^{-5}
		CMC-BO-102	Brown Clayey Sand (SC)	16 - 18	17.6	62.4	20			---	---			
			Brown Silty Sand (SM)	35 - 37	0	82.9	17.1			---	---			
Skunk Lake Wetland	1994	CMC-SL-103A	Gray Silty Clayey Sand (SC-SM)	6 - 8.5	0.1	57.4	19.6	22.9		4.2×10^{-7}	1.2×10^{-3}		1.7	6.1×10^{-4}
		CMC-SL-103B	Gray Clay (CL)	26 - 28	0	14.8	61.1	24.1		3.5×10^{-6}	9.9×10^{-3}			
			Brown Sand (SP)	38 - 40	25.5	70.1	4.4			---	---		2.3	8.1×10^{-4}

Table 3.6-19, continued

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Skunk Lake Wetland, Continued		CMC-SL-104	Brown Silty Clayey Sand (SC-SM)	4 - 6	0	69.7	15.6	14.7		1.8×10^{-6}	5.1×10^{-3}			
			Gray Sandy Silty Clay (CL-ML)	16 - 19	0	30.5	56.0	13.5		6.4×10^{-7}*	1.8×10^{-3}			
			Brown Sand (SW-SM)	34 - 36	16.3	74.7	9			---	---			
Duck Lake Wetland	1994	CMC-DL-103A	Brown Silty Clayey Sand (SC-SM)	4 - 6	11.8	53.5	21.0	13.7		9.3×10^{-8}	2.6×10^{-4}			
		CMC-DL-103B	Brown Sand (SM)	20 - 22	0	67.4	27.6	5		---	---		2.2	7.6×10^{-4}
Swamp Creek Cedars Wetland	1994	CMC-SCC-101	Brown Clayey Sand (SC)	6 - 8	21.2	58.7	8.9	11.2		---	---			
		CMC-SCC-102A	Brown Silty Clayey Sand (SC-SM)	2 - 4	5.9	53.3	24.4	16.4		3.3×10^{-7}	9.3×10^{-4}			
			Gray Clayey Sand (SC)	8 - 10	14.6	57.7	27.7			---	---			
		CMC-SCC-102B	Brown Silty Fine Sand (SM)	16 - 18	13.2	67.9	11.6	7.3		---	---			

Table 3.6-19, continued

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity		Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity	
										Kv (cm/s)	Kv (ft/d)		Kh ft/d	Kh cm/s
Swamp Creek Wetland	1994	CMC-SC-101	Gray Coarse Sand (SP)	12.5 - 14.5	0	98.6	1.4			---	---			
		CMC-SC-102	Gray Coarse Sand (SP)	10 - 12	6.5	90.5	3.0							

[a] Probable side channeling was noted in this test.
[b] Represents hydraulic head within the outwash/till deposits below the lake bed of the Lake. Note that the ordinary high water marks (feet MSL) of Little Sand Lake = 1591.96, Oak Lake = 1633.17, Deep Hole Lake = 1605.83, Duck Lake = 1611.09 and Skunk Lake = 1598.09.
[c] Outwash/till soil sample from beneath lake bed.
* Note sample was jarred when tube was removed from the hole.
--- Not Tested

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Checked by: XXC

(STS, 1984b). Vertical gradients at the 16 EX series well nests are minimal as indicated on the geologic cross sections shown in Figures 3.5-26 to 3.5-32. Vertical gradients are higher immediately around lakes that discharge to the groundwater. Therefore, acceptance criteria were shortened to 10 feet and 20 feet within 500 feet of these lakes. The shallow WP-series wells were used in water table wells and meet the above criteria. If available, the same wells were used to construct the 1986 water table map.

On a macro basis the water table maps compare favorably with the regional potentiometric surface map shown in Figure 3.6-11. The regional potentiometric surface map displays a generalized horizontal distribution of head within the glacial overburden, depicting the unconfined distribution of head within upland areas and the confined distribution of head beneath the lake beds in upland areas (the lake beds function as a semi-confining layer). The connection of the upland lakes to the water table is not apparent in the potentiometric surface map, whereas the water table maps show the connection of the lakes to the groundwater system. The water table maps reflect the condition in which the surface elevation of the upland lakes are held above the surrounding groundwater due to the low permeability of the lake beds. This results in the lakes acting as sources of recharge to the groundwater system.

Figures 3.6-28b and 3.6-28c display potentiometric surface maps of the glacial outwash and Pre- to Early Wisconsinan till, respectively, based on October 31, 1984 data. October 1984 was selected based on available data and to provide a comparison to the October 1984 water table map shown in Figure 3.6-27. The outwash potentiometric surface is based on wells screened in the outwash deposits and in some instances both the outwash and the Pre- to Early Wisconsinan till or lacustrine deposits. The Pre- to Early Wisconsinan till potentiometric surface is based on wells screened in the Pre- to Early Wisconsinan till and in some instances both the Pre- to Early Wisconsinan till and bedrock. The potentiometric surface maps are similar to the water table maps except in the vicinity of the lakes where the potentiometric surface maps reflect the distribution of head within the outwash and till beneath the lake beds. It should be noted that in many areas the potentiometric surface map of the outwash and water table maps are synonymous since the water table frequently resides within the outwash.

In general, the water table and potentiometric surface maps are a reflection of the surface topography. The water table and potentiometric high of about 1,595 occurs at the groundwater divide centered in the vicinity of the TMA. From this groundwater high, groundwater flows radially. Groundwater flow to the north and northwest eventually discharges to Swamp Creek. Groundwater flowing east and northeast discharges to Hemlock Creek and Ground Hemlock Lake. Groundwater flowing to the south is inferred, based on the regional water table map and regional potentiometric surface map, to discharge to Crane and Pickerel Lakes. Groundwater flow to the southwest and west eventually discharges to Pickerel Creek and Rolling Stone Lake. Other known discharge areas include Hoffman Springs which feeds into Swamp Creek, and Martin Springs which feeds into Rolling Stone Lake.

Horizontal gradients are typically moderate across most of the study area. The exception to this is in the vicinity of the lakes and near Hemlock Creek and the confluence of Swamp and Hemlock Creeks where steep horizontal gradients are observed. The cross sections shown in Figures 3.5-26 through 3.5-32 also display the groundwater flow system from a vertical perspective. In general vertical gradients are minimal as summarized in Appendix 3.6-8. However, in the vicinity of the TMA, downward vertical gradients exist as groundwater enters the system as recharge in this area and migrates down into the glacial deposits. The steepest downward gradients exist in the vicinity of the lakes and are attributed to the permeability contrast between the silty clay lake beds and underlying outwash/till. In the vicinity of the creeks, upward gradients exist as groundwater flows toward and discharges to the creeks that function as sinks to the system. Based on the vertical gradients on either side of Hemlock,

Swamp, and Pickerel Creeks, the creeks appear to be fully penetrating in the sense that significant underflow beneath the creeks is not likely to take place.

Cross-sections show that across the study area the water table resides within various geologic formations. In the vicinity of the TMA and north of the plant site, the water table typically resides in the Late Wisconsinan till. Whereas in the southern part of the study area, the water table typically resides within the outwash deposits. In the immediate vicinity of the plant site, the water table resides within the Pre- to Early Wisconsinan till over the center part of the ore body. Along the eastern and western sides of the ore body, the water table resides within the overlying outwash deposits. The study area water table is a topic of ongoing discussions with the WDNR and USCOE. Upon completion of these discussions, a current water table map will be developed.

Golder Associates (1982) performed a water budget analysis to estimate net recharge to the groundwater system. The analysis was based on precipitation data from Laona and Swamp Creek base flow measurements. Golder Associates estimated that out of the 7.56E-3 ft/d (33.1 in/yr) of precipitation, 2.19E-10 ft/d (9.6 in/yr) or 29 percent of the total precipitation entered the groundwater system as recharge. Sensitivity analysis identified that the net annual recharge could vary between 1.96E-3 ft/d (8.58 in/yr) and 2.42E-3 ft/d (10.59 in/yr).

In the vicinity of the plant site, Swamp Creek and Hemlock Creek function as the principle groundwater discharge area that could be impacted by mine dewatering. A component of the groundwater modeling studies is to evaluate the potential reduction in groundwater discharge to these streams. To aid in this evaluation, the stream bed material which will influence the rate of groundwater discharge to the streams was evaluated. Figure 3.6-29 shows the results of the 1994 stream bed survey for Hemlock or Swamp Creeks. The survey was conducted visually, either on foot or by canoe. The stream bed of Hemlock Creek is predominantly silt and muck overlying sand. The stream bed of Swamp Creek ranges from predominantly sand to a mixture of sand, gravel, boulders and cobbles. The sandy stream beds reflect regions where the streams incise outwash deposits of sand. Whereas the mixture of sand, gravel, boulders and cobbles reflect regions where the streams incise deposits of glacial till in which the flowing stream has washed away the silt and clay component of the till.

Perched groundwater has been encountered at several locations across the study as identified in Figure 3.6-29a. In addition, many of the wetlands in upland areas are due to shallow perched water tables as discussed in Section 3.6.4.3.2. Perched groundwater occurs either near the land surface or deeper within the glacial deposits. The shallow perched groundwater is an integral part of wetlands and is created by low permeability fine grained soils and runoff. The deeper perched groundwater systems are also due to fine grained soils that intercept and retard percolating water.

The perched groundwater systems were identified based on an examination of boring logs and surrounding groundwater levels. In most instances the screened intervals of wells monitoring perched groundwater intersect fine grained deposits. In addition, nested or nearby water table wells that are deeper measure a phreatic surface substantially below the shallow groundwater which is indicative of perched conditions.

3.6.4.3.1 Groundwater/Lake Interactions

Cross-sections shown in Figures 3.5-26 through 3.5-32 show the general relationship between the groundwater system and upland lakes including Oak, Little Sand, Deep Hole, Duck and Skunk Lakes. Well STS-OL-1 installed beneath Oak Lake went dry soon after installation indicating that this lake is perched. As such, Oak Lake will not be subject to impacts on the lake's water budget due to mine dewatering activities. However, wells installed immediately beneath Little Sand, Deep Hole, Duck, and Skunk Lakes all produced static water levels that were above the bottom of the silt/clay and silt lake beds, but lower than the lake surface. This indicates that

these hydraulically connected lakes are primarily recharging the groundwater system. The rate of recharge out of the lakes is a function of the hydraulic gradient across the lake bed and the permeability of the lake bed. As such the recharging nature of these lakes is head dependent. Thus Little Sand, Deep Hole, Duck, and Skunk Lakes are classified as head dependent recharge lakes.

Dames & Moore (1985) performed an annual water budget analysis of the lakes to quantify the various components that make up the water budget of Oak, Little Sand, Deep Hole, Duck and Skunk Lakes. The Dames & Moore report is provided in its entirety in Appendix 3.6-9. The annual water budgets were based on field determined estimates of surface runoff to the lakes, precipitation, evaporation, and surface water inflow and outflow. Recharge to the groundwater system was computed as the difference between all surface inputs and outputs to the lake surface. The results of the water budget analysis are summarized in Table 3.6-20. The results of water budget analysis indicate that net movement of water through the lake beds of the head dependent recharge lakes is to the groundwater system.

Given the elevation of the lake beds with respect to the surrounding groundwater system, the potential for regional groundwater inflow to the lakes appears to be plausible only for Little Sand Lake. On the upgradient side of Little Sand Lake, i.e., the north and northeast side of the lake, the recorded groundwater elevations are in close proximity to the lake surface. A comparison of lake stage to groundwater elevations shown in Figure 3.6-30 shows that typically lake elevations are above the groundwater elevations. On two occasions the groundwater elevations in wells G40-Y15A and DMA-19 were above the lake stage of Little Sand Lake. Given that these wells are located on the upgradient side of Little Sand Lake and that head is decreasing in a southwesterly direction, it is unlikely that regional groundwater inflow into Little Sand Lake is a significant component of the seepage component of the lakes water budget.

This interpretation was corroborated in December 1994 through the installation of sand points along the north and northeast sides of Little Sand Lake. Groundwater elevations from the sand points with respect to the lake stage of Little Sand Lake are summarized in Table 3.6-21. With the exception of water levels in the F10 wetland, shown on Figures 3.6-3 and 3.10-1, the water levels on the north side of the lake were below the lake stage.

The flow of water between the lakes and the groundwater system is three-dimensional in nature. To better visualize the flow of water between the lakes and the groundwater system a series of hydraulic cross sections were prepared (Foth & Van Dyke, 1994d). These cross-sections are shown in Figures 3.6-31 through 3.6-36. Little Sand and Duck Lakes were selected based on data availability and because they are representative of the conditions around other head dependent recharge lakes. Of the four head dependent recharge lakes in the area, Duck and Little Sand Lakes reside at the highest and lowest topographic elevations, respectively.

All lake profiles show downward gradients beneath the lakes. A transition zone is present at the edges of the lakes where flow changes from primarily vertical to primarily horizontal. This is most evident around Duck Lake and along the down gradient side of Little Sand Lake. On Little Sand Lake flow is out of the lake with stronger downward gradients along the south side of the lake than along the north side of the lake. Hydraulic head data for October 1984 indicates that appreciable groundwater inflow into the lake is unlikely under normal steady state conditions. However, under high groundwater conditions, as in 1986 and 1994, hydraulic head contours indicate that the potential exists for a small amount of lateral groundwater inflow along the northeast side of Little Sand Lake.

Based on the 1994 sand point data from around Little Sand Lake, the area for potential groundwater inflow to the lake is likely limited to the F10 and possibly F9 wetlands. These wetlands are runoff fed. Since downward gradients are observed at well DMA-19/CMC-SP-09,

Table 3.6-20

Summary of Annual Water Balance

	Gains			Losses					Lake Level			
	Precipitation	Runoff	TOTAL	Evaporation	Outflow	TOTAL	Lake Storage	Recharge	Start (May) (ft)	Maximum (ft)	Minimum (ft)	Range (ft)
Little Sand Lake												
Wet	41.23	49.39	90.62	22.77	55.10	77.86	4.76	-8.00	1591.7820	1592.2	1591.4	0.8
Dry	22.80	28.95	51.75	29.06	18.37	47.44	-3.69	-8.00	1591.7820	1591.8	1591.3	0.5
Average	30.71	37.28	67.99	25.69	34.30	59.99	.00	-8.00	1591.7820	1591.8	1591.5	0.3
Oak Lake												
Wet	41.23	32.57	73.80	22.77	37.80	60.57	4.11	-9.10	1633.1930	1633.6	1632.8	0.8
Dry	22.80	19.08	41.88	29.06	5.41	34.47	-1.69	-9.10	1633.1930	1633.2	1632.8	0.4
Average	30.71	24.58	55.29	25.69	20.49	46.17	.00	-9.10	1633.1930	1633.4	1633.1	0.3
Duck Lake												
Wet	41.23	25.11	66.34	22.77	15.90	38.67	6.37	-21.30	1611.0580	1611.7	1611.0	0.7
Dry	22.80	14.71	37.51	29.06	0.26	29.33	-13.11	-21.30	1611.0580	1611.1	1610.1	1.0
Average	30.71	18.95	49.66	25.69	2.67	28.36	.00	-21.30	1611.0580	1611.2	1610.9	0.3
Skunk Lake												
Wet	41.23	46.08	87.31	22.77	0.00	22.77	24.74	-39.80	1598.0900	1599.7	1598.1	1.6
Dry	22.80	27.00	49.80	29.06	0.00	29.06	-19.06	-39.80	1598.0900	1598.1	1596.7	1.4
Average	30.71	34.78	65.49	25.69	0.00	25.69	.00	-39.80	1598.0900	1598.3	1598.1	0.2
Deep Hole Lake												
Wet	41.23	44.37	85.60	22.77	50.49	73.25	4.35	-8.00	1606.5145	1606.9	1606.2	0.7
Dry	22.80	26.01	48.81	29.06	15.11	44.18	-3.37	-8.00	1606.5145	1606.5	1606.0	0.5
Average	30.71	33.49	64.20	25.69	30.51	56.20	.00	-8.00	1606.5145	1606.6	1606.2	0.4

General Notes:
1. Units are inches of lake level except as indicated.
2. Negative lake storage values indicate fall in water level.
3. Negative recharge values indicate outward seepage.
4. Derivation of values is explained in Appendix 3.6-9.

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Table 3.6-21

Summary of December 1994 Little Sand Lake Sand Point Data

Sand Point/ Private Well	East	North	Screened Interval or Bottom Elevation (ft.)	December 1994 Water Elevation (ft.)
CMC-SP-01	2279412.2	114244.4	1589.50-1592.50	1592.99
CMC-SP-02	2279306.4	114181.3	1589.20-1592.20	1592.55
CMC-SP-03A	2278974.6	114628.8	1589.41-1592.41	1592.53
CMC-SP-03B	2278975.8	114672.6	1573.07-1576.07	NS
CMC-SP-04	2279029.3	114726.9	1588.49-1592.49	1592.80
CMC-SP-05A	2278578.4	114907.4	1589.51-1592.51	1592.41
CMC-SP-05B	2278580.5	114908.8	1572.35-1575.35	NS
CMC-SP-06	2278619.2	114977.8	1589.76-1592.76	1591.95
CMC-SP-07	2278023.5	115104.1	1589.89-1592.89	1591.94
CMC-SP-08	2278024.2	115222.1	1589.15-1592.15	1591.07
CMC-SP-09	2279719.9	115000.5	1590.17-1593.17	1592.40
Little Sand Lake	---	---	---	1592.45

NS = Not Stabilized

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Checked by: SGL

the source of potential groundwater inflow to the lake from these wetlands is from surface water runoff to the wetland and is, for all practical purposes, equivalent to surface water runoff.

Reviewers from the WDNR have expressed concern that the monthly and quarterly groundwater and lake stage measurements do not account for short term transient hydrologic changes due to recharge events for Little Sand Lake and perched wetlands such as Bur Oak Swamp. It has been hypothesized that these short term recharge events, such as the spring snow melt and subsequent heavy precipitation events, could result in transient changes to the hydrologic relationship between the groundwater system and surface water bodies in question.

Specific hypotheses have envisioned short term spring and summer recharge events increasing groundwater levels on the upgradient side of Little Sand Lake whereby groundwater seepage to the lake for a short period of time could account for a significant percentage of the water budget for the lake. With respect to perched wetlands (discussed in Section 3.6.4.3.2), such as Bur Oak Swamp, hypotheses have envisioned these same recharge events increasing the water table elevation to the point that the water table is coupled to the lacustrine clay layer that underlies the wetland. Under the coupled hypothesis, the hydraulic gradient across the clay layer would be reduced, thus increasing the duration of ponded water in the wetland.

Drawdown of the water table due to mine inflow could preclude these hypothesized transient events. In the case of Little Sand Lake, this would result in less water input to the lake which could impact lake stage. In the case of perched wetlands such as Bur Oak Swamp, the reduced duration of ponded water in the wetland could affect the wetlands ecology.

In late February 1995, prior to the spring thaw, CMC initiated an investigation of the short term transient hydrologic relationships between the regional groundwater system and head dependent recharge lakes and perched wetlands. This program, implemented at the request of the WDNR and described in a CMC letter dated February 16, 1995 (CMC, 1995), was intended to assess the spring runoff and recharge event impact on: 1) the potential for groundwater inflow into Little Sand Lake, and 2) the coupling of perched wetlands, such as Bur Oak Swamp, to the groundwater system.

Six sand points (CMC-SP-03A, -03B, -05A, -05B, -11A, and -11B) along the north side of Little Sand Lake and two monitoring wells in Bur Oak Swamp (CMC-BO-101A and -101B) were instrumented with pressure transducers and electronic data loggers. The data loggers were programmed to record, via the pressure transducers, the water level in the well at a frequency of at least once every hour. The equipment was installed in late February and early March of 1995 and was initially scheduled to run until June 1995. At WDNR's request the monitoring was extended and the equipment was left in place until September 7, 1995 to assess changes during summer rain events. Concurrent with the data logger measurements, frequent manual measurements of water levels in the instrumented wells were recorded to check the accuracy of the pressure transducers. In addition, frequent manual water level measurements were recorded in non-instrumented "CMC-SP" series sand points and well DMA-19 which are distributed around the northern part of Little Sand Lake. Lake stage measurements of Little Sand Lake were also frequently recorded from a surveyed staff gage.

Sand points CMC-SP-03A, -03B, -05A, -05B, -11A, and -11B shown on Figure 3.6-3 were monitored via data loggers around the upgradient, northeast, side of Little Sand Lake. The "A" sand points are shallow, screened approximately 1 to 4 feet below land surface. The "B" sand

points are deeper, screened at a depth of approximately 19 to 22 feet below land surface. The remaining non-instrumented "CMC-SP" series sand points shown on Figure 3.6-3 are all screened at the water table, whereas well DMA-19 is a piezometer measuring head within the regional aquifer that extends beneath the silty clay lake bed. Note that based on the slow rate of recovery after development, the "B" sand points are presumed to be screened within the lacustrine silty clay layer that comprises the lake bed. Sand points CMC-SP-03A & B and CMC-SP-11A & B are located in head dependent recharge wetlands (F9 and F10) adjacent to Little Sand Lake. Sand point CMC-09 and well DMA-19 are adjacent to the northern boundary of the F10 wetland. The lake stage of Little Sand Lake had been measured frequently since ice out in mid April of 1995 through the time the sand points were in place.

The potential sources of water input to a surface water body such as a lake include direct precipitation, precipitation generated runoff or overland flow, and subsurface stormflow (interflow) and groundwater flow. The continuous monitoring of the shallow sand points along the northeast side of Little Sand Lake provides insight into the overland flow, interflow and baseflow processes that affect the stage of the lake.

Figures 3.6-36A through 3.6-36C show the transient groundwater levels (measured via data loggers and manually) along the upgradient side of Little Sand Lake, daily precipitation, and lake stage from March 1, 1995 until September 7, 1995. In comparison to the deeper sand points, the shallow sand points show greater and more frequent transient fluctuations suggestive of short lived responses to precipitation events as opposed to longer temporal changes in the regional groundwater regime.

Comparison of water levels in the shallow sand points provides insight into the transient lateral exchange of water between the lake and groundwater system that is affected by overland and groundwater flow phenomena. From the point of ice out on Little Sand Lake in April, 1995, until the fall of 1995, the lake stage of Little Sand Lake, ranges from being less than the shallow water table to greater than the shallow water table. This indicates that there are transient exchanges of water from the lake to the shallow water table and from the shallow water table to the lake. As measured by CMC-SP-03A and CMC-SP-11A, the periods where the shallow water table is greater than the lake stage range from several days to several weeks, with the shallow water table being anywhere from about one tenth to half a foot above the lake stage. However, this phenomena occurred primarily in the wetlands. Outside the wetlands, as measured by CMC-SP-05A, the water table elevation routinely remained several tenths to half a foot below the lake stage. This suggests that the infrequent short term increases of the water table in the wetland above the lake stage are related to a phenomena other than regional groundwater flow.

With respect to the vertical component of flow between the lake and the groundwater system, Figures 3.6-36a through 3.6-36c show a definite downward vertical gradient between the shallow sand points and nested deeper sand points through the duration of monitoring. This pattern is consistent with previous field data and interpretations that have noted strong downward vertical gradients across the lake bed of Little Sand Lake and other head dependent recharge lakes. Based on the trends of the deep and shallow sand points, it seems evident that reversal of the vertical component of flow between the silty clay lake bed and groundwater system does not occur.

Figures 3.6-36A through 3.6-36C also display concurrent manual measurements of water levels in the sand points around Little Sand Lake. Acquired to verify the accuracy of the pressure

transducers, the manual measurements compare favorably to the pressure transducers. In the shallow sand points the manual measurements agree with the pressure transducers to within several hundredths to approximately two tenths of a foot. The deviation between the deeper sand points and the pressure transducers is between approximately one to three tenths of a foot.

Figures 3.6-36d through 3.6-36g display hydrographs of groundwater elevations versus lake stage, based on manual measurements from the non-instrumented wells for 1995. Although based on non-continuous monitoring data, the hydrographs show a similar trend to that observed in the instrumented wells discussed above. Outside the wetland areas, as measured by CMC-SP-06, -07, and -08, the water levels are continuously below the lake stage indicating lateral movement of water from the lake to the shallow water table. Within the F10 wetland and between the F10 and F9 wetland, the water table is periodically above the lake as measured by CMC-SP-01, -02, and -04. Again, these periods of a high shallow water table versus lake stage range from several days to several weeks or more and appear driven by runoff, precipitation, and the head dependent recharge nature of the wetland.

Well CMC-SP-09 shows a sustained water table elevation above the lake stage. Located approximately 800 feet north of Little Sand Lake, the water levels in CMC-SP-09 are representative of the water table in and near the north side of the F10 head dependent recharge wetland as opposed to the regional groundwater table and is not indicative of a continuous lateral influx to Little Sand Lake. This opinion is supported by the fact that shallow water table sand point CMC-SP-03A, downgradient of CMC-SP-09, is frequently below the lake stage. Moreover, given that the F10 wetland is a head dependent recharge wetland, it is to be expected that the local water table within and around the wetland would be slightly higher than the regional water table and lake.

The F9 and F10 wetlands receive considerable runoff from the surrounding area. Consequently, it is likely that the slight increase of water levels in these wetlands above the lake stage is reflective of the runoff ponding in the wetlands, thus the head dependent recharge nature of the wetlands. Note that during the spring, when the ground is frozen and runoff to wetlands is greatest, the shallow groundwater levels in the wetlands (see CMC-SP-03A and -11A) are one-quarter to one foot greater than the shallow groundwater outside the wetland (CMC-SP-05A, -06, -07, and -08). This indicates a more prolonged surface input to the wetlands where it is stored. The resulting seepage from the wetlands to the lake over these short periods of time is thus more representative of an overland flow and interflow phenomena as opposed to regional groundwater flow to the lake. The transient nature of the wetland water level elevations being greater than the lake stage support the inference of this input being comprised of overland flow during runoff and high precipitation events. This was observed during the month of August 1995, a period of very high precipitation.

During August 1995, the water levels in shallow wells CMC-SP-03A and -11A increased slightly above the lake stage and fluctuated significantly over short periods of time in response to each precipitation event. A more gradual increase and decline than what was observed would be expected if the input were derived from regional groundwater flow. Overall, the preponderance of data suggests a localized groundwater system exists in the vicinity of the F9 and F10 wetlands near Little Sand Lake that occasionally contributes water laterally to the lake. Furthermore, this localized groundwater system appears to be controlled via direct precipitation and runoff to the wetland, and the head dependent nature of the wetlands, as opposed to the regional groundwater influx. The localized groundwater system resides above the silty clay layer that forms the lake

bed of Little Sand Lake. Since it is unlikely that runoff to these wetlands will be affected by drawdown of the regional water table due to mine inflow, it is also unlikely that the wetland derived local groundwater system and infrequent short term transient seepage from these wetland areas to the lake will be impacted.

Figure 3.6-36h displays the monthly precipitation record from December 1994 through August 1995. Recharge and runoff during the spring (March through May) is comprised of two components: 1) precipitation as rainfall, and 2) melted snow and ice that accumulated during the winter months (December through March). Precipitation from December 1994 through May 1995 was approximately 73 percent of the long term average for these months. June was approximately 50 percent of the long term average. July experienced near normal precipitation. Precipitation in August was more than twice the long term monthly average and made up for the deficit from lower winter and spring precipitation. Although the precipitation during winter and spring months was below normal, the capture of the intense recharge event in August 1995 indicates that it is unlikely that transient recharge events lead to a significant groundwater contribution to Little Sand Lake.

An analysis of lake and groundwater chemistry data provides an additional means of assessing groundwater and lake interactions. As summarized in Section 3.7.7.1, all of the upland lakes (Oak, Little Sand, Deep Hole, Duck, and Skunk) have low hardness, alkalinity, and total dissolved solids (TDS). As summarized below, the groundwater in the study area has alkalinity, hardness, and TDS concentrations that are approximately an order of magnitude higher than that of head dependent recharge lakes. In contrast, groundwater fed lakes in the study area, such as those discussed in Section 3.7.7.1, have water chemistries that are very similar to the groundwater.

Oak Lake has no direct contact with the groundwater system. Consequently the groundwater system has no impact on the water chemistry of Oak Lake. The fact that the water chemistry of Little Sand, Deep Hole, Duck, and Skunk Lakes have water chemistries that are nearly identical to Oak Lake, and significantly different than the groundwater and groundwater fed lakes is nearly conclusive evidence that the head dependent recharge lakes, receive no groundwater inflow. However, as Figure 3.6-34 suggests, short term transient recharge events may take place in which groundwater discharges to Little Sand Lake on the north and northeast sides. This possibility is being investigated through continuous water level measurements in sand points on the northeast side of the lake. Once available, these data will be provided in an addendum to this report.

During the late 1980s the region experienced a drought. Additional insight into the interaction of the lakes with the groundwater system is gained by examining the reaction of the lakes and the groundwater system to the drought. Figures 3.6-37 through 3.6-40 show hydrographs of the head dependent recharge lakes compared to nearby groundwater monitoring wells. During the drought, groundwater levels in the vicinity of the upland lakes declined by about four to five feet. However, the lakes did not respond in a similar fashion and showed little response to the drought. The ratio of lake level decline to groundwater decline is about 0.3 for Skunk Lake and 0.1 for Duck Lake. The hydrographs for Little Sand and Deep Hole Lakes show no discernable response to the drought and groundwater level declines. This response is consistent with the hydraulic conductivity and lake bed characterization studies. These studies, described above, indicate that the lake beds consist of a low permeability continuous silty clay/silt layer.

In addition to precipitation, runoff, evapotranspiration, and seepage, the lake stage of Little Sand, Duck, and Deep Hole Lakes are also influenced by outlet creeks on these lakes. In 1996, CMC completed outlet flow and lake stage monitoring for Little Sand, Duck, and Deep Hole Lakes to evaluate the stage-discharge relationship of these water bodies. Results from this field investigation are described in a memorandum contained in Appendix 3.6-9a (Foth & Van Dyke, 1996a).

In summary, the memorandum concluded that the 1996 flow and stage monitoring data confirm that beaver populations can have a substantial influence on lake elevations. This is evident by the stage decline in Little Sand Lake when the beaver dam was breached which emphasizes the transient nature of the stage-discharge relationship. Given the beaver induced morphological changes that have occurred over the years to the outlets of the lakes, it is to be expected that the stage-discharge relationships have changed slightly and will continue to change provided a beaver population remains. The rating equations developed for the 1996 data support this hypothesis. Although the flow from the lakes is comparable to that measured in the late 1970's, the rating equations indicate that the outflow is controlled by a broader more diffuse outlet structure than existed previously. Overall, the rating curves as currently measured are consistent with the past data. However, they have changed slightly and will continue to fluctuate in the future because of the beaver activity downstream from the discharge.

3.6.4.3.2 Groundwater Wetland Interactions

Wetlands can be classified as either discharge or recharge based on their relationship with the groundwater system. Situations in which the wetland is lower than the water table surrounding it results in groundwater discharging to the wetland. These are referred to a discharge wetlands (Mitsch & Gosslink, 1993; and Todd, 1967). Discharge wetlands are commonly associated with groundwater discharge points such as gaining streams. The use of the term discharge wetland here will be used as described above for the classification of wetlands with respect to the groundwater system.

When a wetland exists above the surrounding water table, water infiltrates the wetland soils and flows to the underlying groundwater system. This is referred to as a recharge wetland (Mitsch & Gosslink, 1993; and Todd, 1967).

Several types of recharge wetlands exist in the study area. If an unsaturated zone exists between the wetland and the underlying groundwater system, the wetland is perched and will not be subjected to impacts from groundwater drawdown provided the wetland is not connected laterally to a head dependent recharge lake. These wetlands are referred to here as Type 1 recharge wetlands.

Wetlands that are perched but are connected laterally to head dependent recharge lakes may be subject to drawdown related impacts due to their connection to the lake. These wetlands, which also recharge the groundwater system, are referred to here as Type 2 recharge wetlands. Type 3 recharge wetlands are head dependent wetlands that exist slightly above the regional water table and contain continuously saturated soils from the wetland surface down to the regional aquifer and are therefore hydraulically connected vertically to the groundwater system.
Schematic diagrams of the various types of wetlands are provided in Figures 3.6-41 through 3.6-44. Within the study area, all wetlands were classified as being either discharge or one of three types of recharge wetlands. These classified wetlands are shown in Figure 3.6-45.

Wetlands that were considered were delineated wetlands within the study area and major wetland systems associated with groundwater discharge areas. The criteria used to classify the wetlands are discussed below.

Discharge wetlands are those that are associated and in close proximity to groundwater discharge points such as Swamp, Hemlock, and Pickerel Creeks. Type 1 recharge wetlands are those wetlands that exist in upland areas, occur in isolated topographic depressions not associated with head dependent recharge lakes and are roughly 15 feet or more above the water table. Figure 3.6-46 shows an inferred depth to groundwater map for the study area that was derived from using the regional potentiometric surface map as representative of the water table with the condition that the head dependent recharge lakes reflect the water table. Type 2 recharge wetlands are those that exist in upland areas, contain an unsaturated zone beneath them, are more than 15 feet above the inferred water table, but are connected laterally to head dependent recharge lakes. Type 3 recharge wetlands were classified based on their association with head dependent recharge lakes. The second criterion used for these wetlands is that the wetland surface resides at a topographic elevation that is less than approximately ten feet above the surrounding groundwater elevation. Study area wetlands are listed by hydrogeological classification in Table 3.6-22. These designations will be used as input to the project's regional groundwater modeling effort.

As described in Section 3.6.4.3.1, continuous monitoring of water levels in Bur Oak Swamp, a Type I recharge wetland, was performed from March 1995 through June 1995 to assess the potential for the regional water table to couple the wetland soils. Figure 3.6-47 shows the transient groundwater elevations in wells installed at the Bur Oak Swamp. Well CMC-BO-101A is installed in the shallow clay deposit that forms the wetland base. Well CMC-BO-101B is screened below the clay deposit in the outwash sands and gravel. As shown by the figure, during the spring, the perched water table increases in response to infiltration from the spring melt and rainfall. However, the water level in the deep well remains nearly constant over time. The deep well is screened in unsaturated outwash deposits and resides about three feet above the regional water table. The water level measured in the well represents stagnant water in the well sump (the unslotted portion of the casing below the slotted well screen). Thus it can be inferred that the water table below the wetland fluctuated during this period of time by no more than approximately three feet. More importantly, it is evident that the water table did not couple to the clay layer that forms the wetland base. Although this data is not conclusive for all perched wetlands, it provides a strong indication that the duration of ponded water in perched wetlands at the site is not affected by short term transient events that couple the regional groundwater system to the perched wetlands. Thus mining induced drawdown of the water table should not alter the ecology of these environments.

In 1996 the WDNR requested that CMC conduct additional studies on the hydrology of Bur Oak Swamp. Specifically, the WDNR requested that CMC conduct studies to evaluate the potential for interflow acting as a significant contributor of water to the wetland. In 1996, CMC completed test pits and initiated a second hydrologic monitoring program in Bur Oak Swamp to assess the potential occurrence of interflow contributions to the wetland. A detailed memorandum describing the 1996 wetland investigation is contained in Appendix 3.6-9b (Foth & Van Dyke, 1996b). In summary, the results of the 1996 investigation, in addition to data collected in 1995, support a conceptual model of a wetland in which water input is derived primarily from direct precipitation and runoff. Moreover, the work concluded that it is unlikely that interflow is a significant contributor to the Bur Oak Swamp water balance and that the regional groundwater system does not couple to the wetland.

3.6.5 Groundwater Quality

This section of the report addresses groundwater quality from a regional perspective, followed by a discussion of study area groundwater quality. A comparison of water quality data from the 1970/1980 period to the 1994/1995 study is also presented.

3.6.5.1 Regional Groundwater Quality

Information regarding regional groundwater quality is general and described by Olcott (1968) and Oaks and Hamilton (1973). Groundwater in the Fox River - Wolf River Basin and Menominee River - Oconto River Basin is described as being of good quality, derived primarily from coarse grained glacial deposits. The groundwater is hard to very hard and of the calcium-magnesium-bicarbonate type. Total dissolved solids generally range from 175 to 300 mg/L. Iron can be high locally.

Table 3.6-22

Wetland Type by Hydrogeology

Wetland Number	Wetland Type
A1	Recharge Wetland Type 1
A2	Recharge Wetland Type 1
A3	Recharge Wetland Type 1
B1	Recharge Wetland Type 1
B2	Recharge Wetland Type 1
B3	Recharge Wetland Type 1
B4	Recharge Wetland Type 1
B5	Recharge Wetland Type 1
B8	Recharge Wetland Type 1
D1	Discharge
D2	Recharge Wetland Type 1
D3	Recharge Wetland Type 1
D4	Recharge Wetland Type 1
D4A	Recharge Wetland Type 1
D5	Recharge Wetland Type 1
D8	Recharge Wetland Type 1
D18	Recharge Wetland Type 1
F1	Discharge
F2	Recharge Wetland Type 3
F4	Recharge Wetland Type 3
F5	Recharge Wetland Type 3
F6	Recharge Wetland Type 3
F7	Recharge Wetland Type 3
F8	Recharge Wetland Type 1
F9	Recharge Wetland Type 3
F10	Recharge Wetland Type 3
F11	Recharge Wetland Type 3

Table 3.6-22, continued.

Wetland Number	Wetland Type
F12	Recharge Wetland Type 3
F13	Recharge Wetland Type 1
F15	Recharge Wetland Type 1
F16	Recharge Wetland Type 1
F17	Recharge Wetland Type 1
F18	Recharge Wetland Type 2
F19	Recharge Wetland Type 2
F21	Recharge Wetland Type 2
F22	Recharge Wetland Type 2
F23	Recharge Wetland Type 2
F24	Recharge Wetland Type 1
F25	Recharge Wetland Type 1
F26	Recharge Wetland Type 1
F27	Recharge Wetland Type 1
F28	Recharge Wetland Type 2
F29	Recharge Wetland Type 2
F30	Recharge Wetland Type 1
F31	Recharge Wetland Type 1
F32	Recharge Wetland Type 1
F33	Recharge Wetland Type 1
F34	Recharge Wetland Type 1
F35	Recharge Wetland Type 1
F36	Recharge Wetland Type 1
F37	Recharge Wetland Type 2
F38	Recharge Wetland Type 1
F39	Recharge Wetland Type 1
F40	Recharge Wetland Type 3
F42	Recharge Wetland Type 1
F43	Recharge Wetland Type 1

Table 3.6-22, continued.

Wetland Number	Wetland Type
F45	Recharge Wetland Type 1
F46	Recharge Wetland Type 1
F48	Recharge Wetland Type 1
F50	Recharge Wetland Type 1
F51	Recharge Wetland Type 1
F52	Recharge Wetland Type 1
F53	Recharge Wetland Type 1
F54	Recharge Wetland Type 1
F55	Recharge Wetland Type 1
F57	Recharge Wetland Type 1
F58	Recharge Wetland Type 1
F60	Recharge Wetland Type 1
F61	Recharge Wetland Type 1
F62	Recharge Wetland Type 1
F63	Recharge Wetland Type 1
F64	Recharge Wetland Type 1
F65	Recharge Wetland Type 1
F66	Recharge Wetland Type 1
F69	Recharge Wetland Type 1
F70	Recharge Wetland Type 1
F72	Recharge Wetland Type 1
F81	Recharge Wetland Type 1
F86	Recharge Wetland Type 1
F87	Recharge Wetland Type 1
F90	Recharge Wetland Type 1
F114	Recharge Wetland Type 1
F116	Recharge Wetland Type 1
F119	Recharge Wetland Type 3
F121	Recharge Wetland Type 1

Table 3.6-22, continued.

Wetland Number	Wetland Type
F122	Recharge Wetland Type 1
F122A	Recharge Wetland Type 1
F125	Recharge Wetland Type 1
F126	Recharge Wetland Type 1
F127	Recharge Wetland Type 1
G1	Recharge Wetland Type 1
H1	Recharge Wetland Type 1
I1	Recharge Wetland Type 1
J1	Recharge Wetland Type 1
K1	Recharge Wetland Type 1
K2	Recharge Wetland Type 1
K3	Recharge Wetland Type 1
K4	Recharge Wetland Type 1
K5	Recharge Wetland Type 1
L1	Recharge Wetland Type 3
M1	Recharge Wetland Type 3
M2	Recharge Wetland Type 1
M3	Recharge Wetland Type 1
M4	Recharge Wetland Type 1
M5	Recharge Wetland Type 1
M6	Recharge Wetland Type 1
N1	Recharge Wetland Type 3
O1	Discharge
O3	Recharge Wetland Type 1
P1	Discharge
P2	Recharge Wetland Type 1
R1	Recharge Wetland Type 1
R1A	Recharge Wetland Type 1
R3	Recharge Wetland Type 1

Table 3.6-22, continued.

Wetland Number	Wetland Type
R7A	Recharge Wetland Type 1
R5	Recharge Wetland Type 1
R7	Recharge Wetland Type 1
R8	Recharge Wetland Type 1
T1	Recharge Wetland Type 3
T2	Recharge Wetland Type 3
T3	Recharge Wetland Type 3
T4	Discharge
T5	Recharge Wetland Type 3
W1	Discharge
W2	Discharge
X2	Recharge Wetland Type 1
X3	Recharge Wetland Type 1
X4	Recharge Wetland Type 1
Z1	Recharge Wetland Type 1
Z2	Recharge Wetland Type 1
Z3	Recharge Wetland Type 1
Z4	Recharge Wetland Type 1
Z5	Recharge Wetland Type 1
Z6	Recharge Wetland Type 3
Z7	Recharge Wetland Type 1
Z8	Recharge Wetland Type 3
Z9	Recharge Wetland Type 3
Z10	Recharge Wetland Type 3
Z11	Discharge
Z12	Recharge Wetland Type 3
Z13	Recharge Wetland Type 3
Z14	Discharge
Z15	Discharge

Table 3.6-22, continued.

Wetland Number	Wetland Type
Z16	Recharge Wetland Type 3
Z17	Discharge
Z18	Discharge
Z19	Discharge
Z20	Recharge Wetland Type 1
Z21	Recharge Wetland Type 1
Z22	Recharge Wetland Type 1
Z23	Discharge
Z24	Discharge
Z25	Discharge
Z26	Recharge Wetland Type 1
1	Recharge Wetland Type 1
2	Recharge Wetland Type 1
3	Recharge Wetland Type 1
4	Recharge Wetland Type 1
5	Recharge Wetland Type 1
6	Recharge Wetland Type 1
7	Recharge Wetland Type 1
8	Recharge Wetland Type 1
9	Recharge Wetland Type 1
10	Recharge Wetland Type 1
11	Recharge Wetland Type 1
12	Recharge Wetland Type 1
13	Recharge Wetland Type 1
14	Recharge Wetland Type 1
15	Recharge Wetland Type 1
16	Recharge Wetland Type 1
17	Recharge Wetland Type 1
18	Recharge Wetland Type 1

Table 3.6-22, continued.

Wetland Number	Wetland Type
19	Recharge Wetland Type 1
20	Recharge Wetland Type 1
21	Recharge Wetland Type 1
PC-1[1]	Discharge
MS-1	Discharge
CR 129-1	Discharge
UN-1	Discharge
HC-1	Discharge
OC-1	Recharge Wetland Type 3
RL-1	Discharge
ML-1	Discharge

[1]Wetlands PC-1 through ML-1 were mapped based on interpretation of 1993 color aerial photograph and field verification. These wetlands are outside the boundaries of the wetland study area, but were added for the groundwater modeling studies.

Prepared by: SVD1
Checked by: RFS

3.6.5.2 Study Area Groundwater Quality

In the 1970s and 1980s, groundwater quality data was collected for an area reaching approximately one-quarter mile north of Swamp Creek including monitoring well DMA-16 and approximately one-half mile east of Ground Hemlock Lake including monitoring well DMA-22B. To the south, the area of investigation extended to DMB-24 on the northeast shore of Rolling Stone Lake. On the west, the study area extended to DMA-13 approximately two miles west of Little Sand Lake.

Table 3.6-23 is a list of all wells used in the 1977 through 1980 groundwater quality evaluation. Note that the last six wells on the list are private wells. These wells are not included on Figures 3.6-1 and 3.6-2, which show the location of all environmental monitoring wells.

Table 3.6-24 provides a statistical summary of groundwater quality data for the 1977 to 1980 period for the study area bounded by the features described above. Appendix 3.6-10 contains a summary by well of the 1977 through 1980 groundwater quality data.

Approximately 15 years after the 1977-1980 investigation, another study was initiated by CMC in support of Crandon Project permitting work. The additional study was conducted from May 1994 to May 1995. The data for this study incorporates analyses of samples from 22 groundwater monitoring wells, each for a period of eight months. Eight months (or eight data points) is considered statistically significant for comparison of the 1994/1995 database to the earlier 1977-1980 database. Note that for wells CMC-04, -05, -07, DMB-1A, and -08P an additional round of field and laboratory mercury analyses were performed in February 1995. A list of the wells included in the study was previously presented in Table 3.6-2. Laboratory reports for analytical data for these monitoring wells is included in Appendix 3.6-11. A database for the 1994/1995 data is included in Appendix 3.6-12.

The information in the 1994/1995 database has undergone several levels of review during the course of the project. As a result of these reviews, the laboratory was asked to verify certain laboratory results. In most cases, the laboratory verified the results as originally reported, while in a limited number of cases the reported results were corrected. The database in Appendix 3.6-12 contains the verified and corrected laboratory results, while the laboratory results sheets in Appendix 3.6-11 do not. A summary of those data which were corrected is included at the beginning of Appendix 3.6-11.

The locations of the groundwater monitoring wells in the 1994/1995 program are shown on Figures 3.6-2 and 3.6-2a. A summary of the 1994/1995 groundwater quality database is presented in Table 3.6-25. This data, like the 1977-1980 data, has been evaluated statistically (Appendix 3.6-13). Taken together, the groundwater quality analytical results presented in Tables 3.6-24 and 3.6-25 establish an historical (15 years past) and current (1994/1995) baseline for the proposed project. Note that the statistical comparisons of the 1977-1980 database to the 1994/1995 database consider dissolved metals. During the 1994 monitoring program analyses also included total metals for the June and October 1994 rounds. These data are also included in Table 3.6-25.

Table 3.6-23

List of Groundwater Monitoring Wells Used in 1977-1980 Groundwater Quality Evaluation

WW-1	DMB-5A	G41-E13
WW-2	DMB-24	G41-G14A
TW-1	DMB-25	G41-G14B
DMA-10	DMB-27	G41-G14C
DMA-13	DMB-28	G41-G15A
DMA-17	DMB-20A	G41-G15B
DMA-19	DMB-29	G41-P18B
DMB-32A	DMA-4	G41-P24
DMA-48	DMC-1	Walentowski
DMB-1A	DMC-2	Fox
DMB-4	DMC-3	McGeshick
DMB-7	DMA-22B	Reynolds Resort
DMB-8	G40-J15	Simonsen
DMB-18	G40-K13	Vollmar
DMB-20	G40-L23	
DMB-21	G40-Q7	
DMB-23	G40-R23	
DMA-16	G41-C15	

Prepared by: WJS
Checked by: SVD1

Table 3.6-24

Summary of Groundwater Quality for Principal Aquifers in the Study Area for the Period July 1977 through August 1980

Parameter	Units	Range	Mean (x)	Standard Deviation	Number of Samples
Field temperature	°C	3.0 - 12.0	7.1	1.8[a]	220
Total laboratory alkalinity	mg/L[b]	14 - 453	123	50	234
Total field alkalinity	mg/L[b]	11 - 487	127	53	221
Specific conductance	μmhos/cm	50 - 1,300	237	107	235
Field conductivity	μmhos/cm[c]	29 - 1,150	178	92	218
Laboratory pH	standard units	6.09 - 11.02	7.6	0.69	204
Field pH	standard units	5.5 - 12.2	7.7	1.0	222
Total hardness	mg/L[b]	16 - 452	125	53	236
Total dissolved solids	mg/L	14 - 836	166	84	235
Chemical oxygen demand	mg/L	<1 - 365	<29	<56	143
Total phosphorus (P)	mg/L	<0.01 - 0.84	<0.06	<0.10	135
Anions					
Arsenic	mg/L	<0.001 - 0.004	<0.001	<0.001	236
Chloride	mg/L	<1 - 78	<4	<10	236
Cyanide, total	mg/L	<0.001 - 0.004	<0.001	<0.001	236
Fluoride	mg/L	<0.12 - 0.57	<0.20	<0.09	142
Nitrate nitrogen (N)	mg/L	<0.01 - 11.0	<0.37	<1.04	235
Phosphate (PO_4)	mg/L	<0.01 - 0.31	<0.06	<0.06	101
Sulfate	mg/L	<0.01-0.31	<0.06	<0.06	101
	mg/L	<1 - 86	<9	<9	232
Cations					
Aluminum	mg/L	<0.01 - 9.09	<0.53	<1.12	169
Barium	mg/L	<0.01 - 0.24	<0.02	<0.03	142
Cadmium	mg/L	<0.001 - 0.015	<0.002	<0.002	169
Calcium	mg/L	4.9 - 92.4	29.8	12.6	94
Chromium, total	mg/L	<0.001 - 0.021	<0.002	<0.003	169
Cobalt	mg/L	<0.01	<0.01	0	169
Copper	mg/L	<0.001 - 0.09	<0.007	<0.011	232
Iron	mg/L	<0.01 - 38.9	<1.74	<4.34	236
Lead	mg/L	<0.01 - 0.10	<0.01	<0.01	235
Magnesium	mg/L	0.279 - 29.6	12.00	5.12	169
Manganese	mg/L	<0.001 - 10.2	<0.423	<0.989	236
Mercury	mg/L	<0.0001 - 0.0010	<0.0001	<0.0001	169
Molybdenum	mg/L	<0.01 - 0.03	<0.01	<0.01	169
Nickel	mg/L	<0.01 - 0.04	<0.01	<0.01	169
Selenium	mg/L	<0.001 - 0.001	<0.001	0	142
Silver	mg/L	<0.001	<0.001	0	142
Zinc	mg/L	<0.001 - 2.60	<0.052	<0.214	235

[a] Reflects seasonal temperature variation.

[b] All alkalinity and hardness values listed in text are as $CaCO_3$, although the "as $CaCO_3$" has been eliminated to make the text more readable.

[c] Varies with temperature (USEPA, 1976).

* Table derived from the 1985 EMC Environmental Impact Report (EMC, 1985)

Prepared by: LLA
Checked by: AWZ

Table 3.6-25

Summary of Study Area Groundwater Quality
May 1994 - May 1995

Parameter	Units	Total Samples(1)	Total Detections(1)	Minimum(1)	Maximum(1)	Mean(1)(2)	Standard Deviation(1)(2)	Mean(1)(3)	Standard Deviation(1)(3)
pH (Field)	S.U.	182	182	5.98	8.1	7.253	0.534	7.253	0.534
Conductivity (Field)	µmhos/cm	182	182	145	1356	390.2	194.5	390.2	194.5
Temperature (Field)	Degrees C	182	182	5.6	13	9.031	1.451	9.031	1.451
Alkalinity	mg/L	176	176	60	290	147.4	48.9	147.4	48.9
Hardness	mg/L	162	162	36	410	149.8	69.8	149.8	69.8
Total Dissolved Solids	mg/L	176	176	81	544	202.2	92.3	202.2	92.3
Chemical Oxygen Demand	mg/L	175	34	<10	65	9.41	8.09	4.15	9.92
Nitrate + Nitrite	mg/L	175	110	<0.5	2.6	0.736	0.500	0.643	0.597
Nitrogen, Total Kjeldahl	mg/L	175	89	<0.2	1.82	0.307	0.308	0.258	0.343
Chloride	mg/L	176	110	<1	8	1.256	1.216	1.069	1.351
Fluoride	mg/L	176	105	<0.1	1	0.109	0.101	0.088	0.115
Sulfate	mg/L	176	174	<2	200	21.25	32.20	21.24	32.21
Cyanide, total	mg/L	176	0	<0.02	<0.2	0.011	0.010	0	0
Calcium, dissolved	mg/L	176	176	14	98	34.31	16.43	34.31	16.43
Calcium, total	mg/L	43	43	14	94	35.50	15.84	35.50	15.84
Arsenic, dissolved	mg/L	176	11	<0.005	0.086	0.0036	0.0088	0.0013	0.0091
Arsenic, total	mg/L	43	3	<0.005	0.007	0.0027	0.0009	0.0004	0.0016
Barium, dissolved	mg/L	176	175	<0.01	0.11	0.028	0.018	0.028	0.018
Barium, total	mg/L	43	43	0.01	0.151	0.051	0.040	0.051	0.040
Iron, dissolved	mg/L	176	17	<0.05	0.63	0.051	0.064	0.018	0.071
Iron, total	mg/L	43	29	<0.05	19.2	2.844	4.952	2.831	4.959

Table 3.6-25, continued

Parameter	Units	Total Samples(1)	Total Detections(1)	Minimum(1)	Maximum(1)	Mean(1)(2)	Standard Deviation(1)(2)	Mean(1)(3)	Standard Deviation(1)(3)
Manganese, dissolved	mg/L	176	81	<0.01	1.9	0.096	0.273	0.093	0.274
Manganese, total	mg/L	43	29	<0.01	1.11	0.171	0.270	0.170	0.271
Molybdenum, dissolved	mg/L	176	13	<0.02	0.088	0.0116	0.0073	0.0023	0.0095
Molybdenum, total	mg/L	43	4	<0.02	0.043	0.0120	0.0069	0.0030	0.0097
Selenium, dissolved	mg/L	176	0	<0.005	<0.005	0.0025	0	0	0
Selenium, total	mg/L	43	0	<0.005	<0.005	0.0025	0	0	0
Silver, dissolved	mg/L	176	2	<0.01	0.032	0.0052	0.0022	0.0003	0.0027
Silver, total	mg/L	43	0	<0.01	<0.01	0.005	0	0	0
Chromium, dissolved	mg/L	176	2	<0.005	0.13	0.0033	0.0096	0.0008	0.0098
Chromium, total	mg/L	43	14	<0.005	0.085	0.0109	0.0192	0.0092	0.0199
Cobalt, dissolved	mg/L	176	2	<0.01	0.14	0.0058	0.0102	0.0009	0.0106
Cobalt, total	mg/L	43	1	<0.01	0.01	0.0051	0.0008	0.0002	0.0015
Nickel, dissolved	mg/L	176	3	<0.03	0.13	0.0158	0.0088	0.0010	0.0102
Nickel, total	mg/L	43	3	<0.03	0.082	0.0185	0.0135	0.0046	0.0173
Antimony, dissolved	mg/L	176	4	<0.005	0.052	0.037	0.037	0.00040	0.00399
Antimony, total	mg/L	43	0	<0.05	<0.2	0.063	0.038	0	0
Magnesium, dissolved	mg/L	176	176	5.33	43.2	16.229	7.913	16.229	7.913
Magnesium, total	mg/L	43	43	6.8	42.9	17.163	7.459	17.163	7.459
Aluminum, dissolved	mg/L	176	13	<0.05	0.347	0.069	0.059	0.016	0.061
Aluminum, total	mg/L	43	25	<0.05	22.2	2.621	4.785	2.597	4.798
Cadmium, dissolved	mg/L	175	28	<0.0001	0.0015	0.00030	0.00024	0.00006	0.00018
Cadmium, total	mg/L	43	9	<0.0001	0.002	0.00037	0.00035	0.00012	0.00036
Copper, dissolved	mg/L	176	1	<0.03	0.11	0.0155	0.0072	0.0006	0.0083
Copper, total	mg/L	43	3	<0.03	0.079	0.0176	0.0110	0.0037	0.0145

Table 3.6-25, continued

Parameter	Units	Total Samples(1)	Total Detections(1)	Minimum(1)	Maximum(1)	Mean(1)(2)	Standard Deviation(1)(2)	Mean(1)(3)	Standard Deviation(1)(3)
Lead, dissolved	mg/L	176	39	<0.001	0.017	0.0014	0.0017	0.0007	0.0019
Lead, total	mg/L	43	19	<0.001	0.015	0.0025	0.0032	0.0020	0.0035
Mercury, dissolved	mg/L	181	39	<0.0002	0.001	0.00016	0.00015	0.00008	0.00019
Mercury, total	mg/L	43	15	<0.0002	0.0007	0.00021	0.00017	0.00015	0.00022
Zinc, dissolved	mg/L	176	12	<0.02	0.15	0.012	0.011	0.002	0.013
Zinc, total	mg/L	43	14	<0.02	0.078	0.018	0.014	0.011	0.018

(1) Includes data from the following monitoring wells: CMC-01P, CMC-01R, CMC-02P, CMC-02R, CMC-03P, CMC-03RR, CMC-04, CMC-05, CMC-06P, CMC-07, CMC-08, CMC-08P, CMC-09, CMC-09P, CMC-10, CMC-10P, DMB-1A, DMB-6, EX-13BU, EX-9BL, EX-9BU, G41-H18B

(2) All non-detects replaced with one-half the detection limit.

(3) All non-detects replaced with zero.

Prepared by: SGL
Checked by: AWZSVD1

3.6.5.3 Monitoring Well DMB-1A Baseline Data

Groundwater monitoring well DMB-1A, located at the southwest corner of the TMA, is the one groundwater quality monitoring well which has been sampled through both the 1977-1980 and 1994/1995 monitoring periods. Groundwater quality results from DMB-1A have been evaluated to determine whether the most recent results (July 1994 through February 1995) statistically differ from past results (July 1978 through August 1980). Parameters common to both time periods are included in Table 3.6-26. Summary statistics of the data for each time period are presented in Table 3.6-27.

A review of the data show that cyanide, molybdenum, selenium, silver, cobalt and nickel were not detected in either the 1978 through 1980 samples or the 1994/1995 samples. Parameters that were detected in the 1978 through 1980 samples but not in the 1994 samples include COD, iron, manganese, chromium, cadmium, copper, mercury and zinc. These parameters typically had higher detection limits for the 1994/1995 study.

Lead was detected in the 1994/1995 samples but not the 1978 through 1980 samples. However, the detection limits of the two time periods were again different. The two detected values in the 1994 data were below the 1978 through 1980 detection limit.

The parameters which had detectable values during both time periods were statistically tested by the Mann-Whitney U test. This is the recommended nonparametric statistical test for two samples given by the USEPA guidance document "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, 1992 Addendum to Interim Final Guidance" (USEPA, 1992). A summary of the statistical test results along with boxplots of the data are provided in Appendix 3.6-14. Note that for aluminum, the June and July 1994 data were removed from the test due to the relatively high detection limits. All other nondetected values for all tests were replaced with a common value just below the lowest detected value.

Only five of the twelve analytical parameters which were tested had statistically different results between the two time periods. These were conductivity, alkalinity, magnesium, fluoride and aluminum. The 1978 to 1980 average conductivity value was 187.5 compared to an average 1994/1995 value of 327.7. The average alkalinity value between 1978 and 1980 was 130.1 while the average 1994/1995 alkalinity value was 157.3. The average magnesium value between 1978 and 1980 was 11.43 while the average 1994/1995 magnesium value was 18.09. The average fluoride value between 1978 and 1980 was 0.184 while the average 1994/1995 fluoride value was 0.0625. The average aluminum value between 1978 and 1980 was 0.216 while the average 1994/1995 aluminum value was 0.0660.

The differences observed in conductivity, alkalinity and magnesium values between the two sampling periods is considered to be related to the difference in magnesium value alone. Calculations included in Appendix 3.6-14 show that the difference in magnesium concentrations could account for the observed changes in conductivity and alkalinity. The small differences observed between the two sampling periods for fluoride and aluminum are likely related to differences in analytical techniques.

Table 3.6-26

Historical and Current Groundwater Quality Analytical Results for Well DMB-1A

Parameter	Units	Jul-78	Sep-78	Oct-78	Jan-79	Apr-79	Nov-79	Feb-80	May-80	Aug-80	Jun-94	Jul-94	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94	Jan-95	Feb-95
pH (Field)	S.U.	6.9	7.2	6.9	7.4	7.4	8.3	8.4	8.3	7.2	7.79	6.50	6.43	7.07	7.30	8.02	7.86	7.78	8.05
Conductivity (Field)	µmhos	266	270	177	147	173	180	147		140	358	339	322	361	306	225	324	382	332
Temperature (Field)	Degrees C	6.5	7.0	5.5	4.0	7.5	6.5	7.0	7.0	8.0	9.6	11.2	11.3	9.8	8.5	7.2	8.3	6.7	7.9
Alkalinity	mg/L	206	118	140	134	128	118	100	112	115	164	158	156	160	160	150	150	160	
Hardness	mg/L	216	248	146	142	108	118	132	116	116	168	162	169		170	160	160	170	
Total Dissolved Solids	mg/L	272	146	157	184	186	180	132	103	116	171	186	167	180	200	230	240	200	
Chemical Oxygen Demand	mg/L			39	31	7	<1	<1	<1	23	<10.0	<10.0	<10.0	<20	<20	<10	<10	<10	
Chloride	mg/L	<1	2	<1	<1	<1	4	<1	<1	4	1	1	1	<1	<1	<1	<1	<1	
Fluoride	mg/L			0.15	0.45	0.20	0.23	0.14	<0.12	<0.12	<0.100	<0.100	<0.100	<0.1	0.1	0.1	<0.1	<0.1	
Sulfate	mg/L	<1	8	9	6	14	13	6	8	11	9.00	9.70	12.0	12	13	12	11	10	
Cyanide, total	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.020	<0.020	<0.020	<0.02	<0.020	<0.020	<0.020	<0.020	
Calcium, dissolved	mg/L	56.5	37.1	36.1	37.2	26.8					38.0	38.0	35.9	36	35	33	36	37	
Arsenic, dissolved	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.085	
Barium, dissolved	mg/L			<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.025	0.021	0.020	0.019	0.019	0.019	0.020	0.019	
Iron, dissolved	mg/L	1.09	0.74	0.43	0.17	0.18	0.29	0.30	0.06	0.05	<0.100	<0.100	<0.100	<0.050	<0.050	<0.050	<0.050	<0.050	
Manganese, dissolved	mg/L	1.36	0.238	0.323	0.269	0.169	0.114	0.130	0.097	0.07	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Molybdenum, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	
Selenium, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	
Silver, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Chromium, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	0.004	0.002	<0.001	<0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	
Cobalt, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Nickel, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	
Magnesium, dissolved	mg/L			13.5	11.8	9.9	8.9	12.0	11.5	12.4	19.0	17.6	18.1	19	18	17	18	18	
Aluminum, dissolved	mg/L			0.25	0.09	0.21	0.22	0.35	0.34	0.05	<0.200	<0.200	0.203	<0.050	<0.050	<0.050	<0.050	<0.050	
Cadmium, dissolved	mg/L			0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Copper, dissolved	mg/L	0.005	0.008	<0.001	0.003	0.005	0.009	<0.001	<0.001	<0.001	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	
Lead, dissolved	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.003	0.002	<0.001	<0.0020	<0.0020	<0.0030	<0.0020	<0.020	
Mercury, dissolved	mg/L			0.0001	0.0006	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.00020	<0.00020	<0.00020	<0.0002
Zinc, dissolved	mg/L	0.023	0.03	0.010	0.011	0.009	0.010	0.007			<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	

Note: Blank space means no data was collected.

Prepared by: WJS/SGL
Checked by: SVD1

Table 3.6-27

Statistical Comparison of Historical and Current Groundwater Quality Analytical Results for Well DMB-1A

Parameter	Units	Jul 1978 - Aug 1980						Jun 1994 - Feb 1995					
		Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean(1)	Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean(1)
pH (Field)	S.U.	9	9	100%	6.9	8.4	7.56	9	9	100%	6.43	8.05	7.42
Conductivity (Field)	µmhos	8	8	100%	140	270	187.5	9	9	100%	225	382	327.7
Temperature (Field)	Degrees C	9	9	100%	4	8	6.56	9	9	100%	6.7	11.3	8.94
Alkalinity	mg/L	9	9	100%	100	206	130.1	8	8	100%	150	164	157.3
Hardness	mg/L	9	9	100%	108	248	149.1	7	7	100%	160	170	165.6
Total Dissolved Solids	mg/L	9	9	100%	103	272	164.0	8	8	100%	167	240	196.8
Chemical Oxygen Demand	mg/L	7	4	57%	<1	39	14.50	8	0	0%	<1	<20	6.25
Chloride	mg/L	9	3	33%	<1	4	1.44	8	3	38%	<1	1	0.6875
Fluoride	mg/L	7	5	71%	<0.12	0.45	0.184	8	2	25%	<0.1	0.1	0.0625
Sulfate	mg/L	9	8	89%	<1	14	8.39	8	8	100%	9	13	11.09
Cyanide, total	mg/L	9	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.02	<0.02	0.01
Calcium, dissolved	mg/L	5	5	100%	26.8	56.5	38.74	8	8	100%	33	38	36.11
Arsenic, dissolved	mg/L	9	0	0%	<0.001	<0.001	0.0005	8	1	13%	<0.005	0.086	0.0129
Barium, dissolved	mg/L	7	2	29%	<0.01	0.02	0.00929	8	8	100%	0.019	0.025	0.0203
Iron, dissolved	mg/L	9	9	100%	0.05	1.09	0.368	8	0	0%	<0.05	<0.1	0.0344
Manganese, dissolved	mg/L	9	9	100%	0.07	1.36	0.308	8	0	0%	<0.01	<0.01	0.005
Molybdenum, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.02	<0.02	0.01
Selenium, dissolved	mg/L	7	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.005	<0.005	0.0025
Silver, dissolved	mg/L	7	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.01	<0.01	0.005
Chromium, dissolved	mg/L	7	2	29%	<0.001	0.004	0.00121	8	0	0%	<0.005	<0.005	0.0025
Cobalt, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.01	<0.01	0.005
Nickel, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.03	<0.03	0.015

Table 3.6-27, continued

Parameter	Units	Jul 1978 - Aug 1980						Jun 1994 - Feb 1995					
		Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean(1)	Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean(1)
Magnesium, dissolved	mg/L	7	7	100%	8.9	13.5	11.43	8	8	100%	17	19	18.09
Aluminum, dissolved	mg/L	7	7	100%	0.05	0.35	0.216	8	1	13%	<0.05	0.203	0.0660
Cadmium, dissolved	mg/L	7	1	14%	<0.001	0.008	0.00157	8	0	0%	<0.0001	<0.001	0.00022
Copper, dissolved	mg/L	9	5	56%	<0.001	0.009	0.00356	8	0	0%	<0.03	<0.03	0.015
Lead, dissolved	mg/L	9	0	0%	<0.01	<0.01	0.005	8	2	25%	<0.001	0.003	0.00138
Mercury, dissolved	mg/L	7	3	43%	<0.0001	0.0006	0.00014	8	0	0%	<0.0002	<0.0002	0.0001
Zinc, dissolved	mg/L	7	7	100%	0.007	0.03	0.01429	8	0	0%	<0.02	<0.02	0.01

(1) Nondetects Replaced With One-Half the Detection Limit.

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Checked by: AWZ/SVD1

Monitoring well DMB-1A is screened in a calcareous sand (see log in Appendix 3.5-1). Magnesium concentrations in wells installed in carbonate-rock aquifers typically range from 12 to 60 mg/L with standard deviations ranging from 30-100% of the means (Freeze and Cherry, 1979, p. 263). The difference in magnesium concentration between the two sampling periods can be attributed to normal variations observed in groundwater influenced by carbonate materials.

Twenty-nine parameters were sampled from monitoring well DMB-1A from July 1978 to August 1980, and then again from June 1994 to February 1995. Of these 29 analytical parameters, only conductivity, alkalinity, fluoride, aluminum and magnesium were determined to have statistically different concentrations between the two time periods. The differences observed in magnesium, alkalinity and conductivity values between the two sampling periods can be attributed to normal variations expected in magnesium concentrations. Overall, the analysis shows that the data collected in the 1978-1980 time period and that collected in the 1994/1995 study are comparable.

3.6.5.4 Evaluation of Data in Comparison to Drinking Water Standards

The groundwater quality data should be placed into a context which reflects the relative significance of natural groundwater quality. This objective is achieved by comparing the 1977-1980 data set maximum values (Table 3.6-24) and the 1994/1995 data set maximum values (Table 3.6-25) to the NR 809 Drinking Water Standards. The comparison, shown in Table 3.6-28, indicates that the actual concentration values of eleven groundwater quality parameters naturally met or exceeded the primary or secondary NR 809 Drinking Water Standards on one or more occasion during the 1978-1980 or 1994/1995 monitoring activities. These parameters include TDS, Nitrate + Nitrite, total chromium, total iron, total manganese, total arsenic, total antimony, total aluminum, total cadmium, total lead and total nickel.

Particular note should be made of the fact that measured total iron, total manganese, and total aluminum concentrations exceeded an established standard by a factor of 50 or more. This reflects the naturally high iron and manganese content of groundwater in northern Wisconsin. The database presented in Tables 3.6-24 and 3.6-25 and the analysis presented in Table 3.6-28 are based upon laboratory analyses for the wells listed in Tables 3.6-2 and 3.6-23.

Table 3.6-28

Comparison of NR 809 Drinking Water Standards to Study Area Groundwater Quality

Parameter	Units	NR 809 Drinking Water Standards		1977-1980	1994-1995
		Primary	Secondary	Max	Max
Total Dissolved Solids	mg/L		500*	836[b]	544[b]
Nitrate + Nitrite	mg/L	10		11[a]	2.6
Chloride	mg/L		250	78	8
Fluoride	mg/L	4	2	0.57	1
Sulfate	mg/L		250	86.0	200
Cyanide, total	mg/L	0.2		0.004	<0.2
Arsenic, dissolved	mg/L			0.004	0.086[a]
Arsenic, total	mg/L	0.05			0.007
Barium, dissolved	mg/L			0.24	0.11
Barium, total	mg/L	2			0.151
Iron, dissolved	mg/L				0.63[b]
Iron, total	mg/L		0.3	38.9[b]	19.2[b]
Manganese, dissolved	mg/L				1.9[b]
Manganese, total	mg/L		0.05	10.2[b]	1.11[b]
Selenium, dissolved	mg/L				<0.005
Selenium, total	mg/L	0.05		0.001	<0.005
Silver, dissolved	mg/L				0.032
Silver, total	mg/L		0.01	<0.001	<0.01
Chromium, dissolved	mg/L				0.13[a]

Table 3.6-28, continued

Parameter	Units	NR 809 Drinking Water Standards		1977-1980	1994-1995
		Primary	Secondary	Max	Max
Chromium, total	mg/L	0.1		0.021	0.085
Nickel, dissolved	mg/L				0.13[a]
Nickel, total	mg/L	0.1		0.04	0.082
Antimony, dissolved	mg/L				0.052[a]
Antimony, total	mg/L	0.006			<0.2
Aluminum, dissolved	mg/L				0.347[b]
Aluminum, total	mg/L		0.05-0.2	9.09[b]	22.2[b]
Cadmium, dissolved	mg/L				0.0015
Cadmium, total	mg/L	0.005		0.015[a]	0.002
Copper, dissolved	mg/L				0.11
Copper, total	mg/L	1.3	1.0	0.09	0.079
Lead, dissolved	mg/L				0.017[a]
Lead, total	mg/L	0.015		0.10[a]	0.015[a]
Mercury, dissolved	mg/L				0.001
Mercury, total	mg/L	0.002		0.001	0.0007
Zinc, dissolved	mg/L				0.15
Zinc, total	mg/L		5	2.6	0.078

* Standard for residue.
[a] Equal to or exceeds primary standard.
[b] Equal to or exceeds secondary standard.

Prepared by: SGL/SVD1
Checked by: AWZ/JWS

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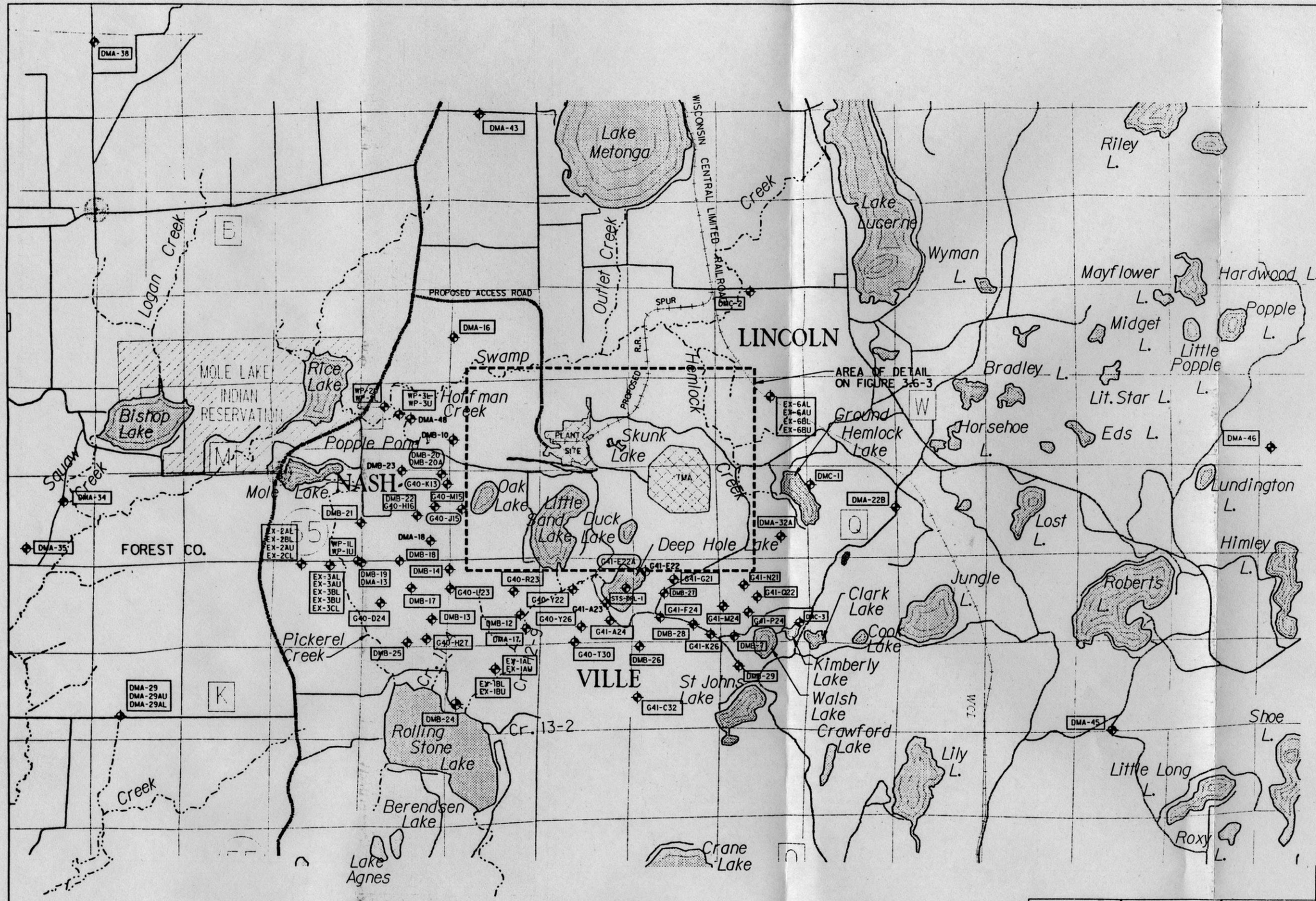
FIGURES FOR SECTION 3.6



NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	JWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-1

MONITORING WELL LOCATION MAP 1

Scale: 0 3000' 6000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JOW

93C049

2,275,000 E
2,280,000 E
2,285,000 E
2,290,000 E
120,000 N
115,000 N
110,000 N
N
SHERMAN LN
SWAMP
CREEK
HEMLOCK CREEK
19
20
21
25
30
29
28
36
31
33
6
5
4
1
NASH-
LINCOLN
AINSWORTH
VILLE
FOREST COUNTY
LANGLADE COUNTY
OAK LAKE
LITTLE SAND LAKE
SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
KIMBERLY LAKE
WALSH LAKE
GROUND HEMLOCK LAKE
W SHORE LN
DEEP HOLE LAKE RD
SAND LAKE RD
WALSH LAKE RD
WP-4U
WP-4L
WP-5L
WP-5U
EX-4CL
EX-4AL
EX-4AU
EX-4BL
EX-4BU
EX-5AL
EX-5AU
EX-5BL
EX-5BU
EX-5CL
DMA-20
DMA-47
G40-X1A
G40-X1
G40-Q7
G40-P10A
G40-P20
G40-S17A
G40-S17
G40-Y1
G40-Y1A
G40-Y2I
DMA-1
DMA-1N
DMA-1S
DMA-3
DMA-4
DMA-10
DMA-12
DMA-19
DMA-31
DMB-1
DMB-1A
DMB-2
DMB-3
DMB-4
DMB-5
DMB-5A
DMB-6
DMB-8
DMB-9A
DMB-9B
DMB-9C
DMB-11
DMB-15
DMB-16
DMP-1
DMP-2
DMP-3
DMS-1
DMS-2
CDM-15
CDM-16
CDM-17
CDM-18
CDM-19
CDM-20
WW-1
WW-2
WW-4
TW-1
TW-2
TW-41
STS-B1
STS-EVS
STS-WVS
STS-OL-1
STS-OL-2
STS-DL-1
STS-DL-2
STS-DL-3
STS-DL-4
STS-DL-5
STS-DL-6
STS-LSL-1
STS-LSL-2
STS-LSL-4
STS-LSL-6
STS-SL-1
STS-SL-3
STS-SL-4
STS-SL-5
BE-211-1
BE-211-2L
BE-211-2U
BE-211-3L
BE-211-3U
BE-213-1
BE-213-2
BE-213-3L
BE-213-3U
BE-216-1
BE-216-2
BE-216-3L
BE-216-3U
DW-1A
DW-1H
DW-1L
DW-2L
DW-2U
DW-3L
DW-3U
DMI-2L
DMI-2U
CMC-01
CMC-01P
CMC-01R
CMC-02
CMC-02P
CMC-02R
CMC-03P
CMC-03R
CMC-03RR
CMC-04
CMC-05
CMC-06P
CMC-07
CMC-08
CMC-08P
CMC-09
CMC-09P
CMC-10
CMC-10P
CMC-10PP
CMC-11P
CMC-12P
CMC-13P
CMC-14P
CMC-OWA1
CMC-OWA2
CMC-OWA3
CMC-OWA4
CMC-OWA5
CMC-PWA
CMC-PWB
CMC-PWR
CMC-SCC-102A
CMC-SCC-102B
CMC-SL-103A
CMC-SL-103B
CMC-BO-101A
CMC-BO-101B
CMC-DL-103A
CMC-DL-103B
CMC-LSL-102A
CMC-LSL-102B
CMC-LSL-104A
CMC-LSL-104B
CMC-SP-01
CMC-SP-02
CMC-SP-03A
CMC-SP-03B
CMC-SP-04
CMC-SP-05A
CMC-SP-05B
CMC-SP-06
CMC-SP-07
CMC-SP-08
CMC-SP-09
CMC-SP-10
CMC-SP-11A
CMC-SP-11B
G41-B12
G41-C15
G41-C15A
G41-C15B
G41-C15C
G41-E13
G41-E13A
G41-E17
G41-E19A
G41-G12
G41-G13
G41-G14A
G41-G14B
G41-G14C
G41-G15
G41-G15A
G41-G15B
G41-H7
G41-H9
G41-H11
G41-H18
G41-H18A
G41-H18B
G41-J18
G41-K13
G41-K13A
G41-K13B
G41-P16
G41-P18
G41-P18B
EX-7AL
EX-7BL
EX-7BU
EX-7CL
EX-8AL
EX-8AU
EX-8BL
EX-8BU
EX-9AL
EX-9AU
EX-9BL
EX-9BU
EX-10BL
EX-10BU
EX-10AL
EX-10AU
EX-11BL
EX-11BU
EX-11AL
EX-11AU
EX-11CL
EX-12AL
EX-12AU
EX-12BL (B)
EX-12BU
EX-13BL
EX-13BU
EX-13AL
EX-13CL
EX-13DL
EX-14AL
EX-14AU
EX-14BL
EX-14BU
EX-15AL
EX-15AU
EX-15BL
EX-16AL
EX-16AU
EX-16BL
WP-6L
WP-6U
WP-7L
WP-7U

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- WP-7L — ABANDONED WELLS NUMBER AND LOCATION
- DMB-2 — TEMPORARY ABANDONED WELLS NUMBER AND LOCATION
- G41-K13 — ACTIVE WELLS NUMBER AND LOCATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

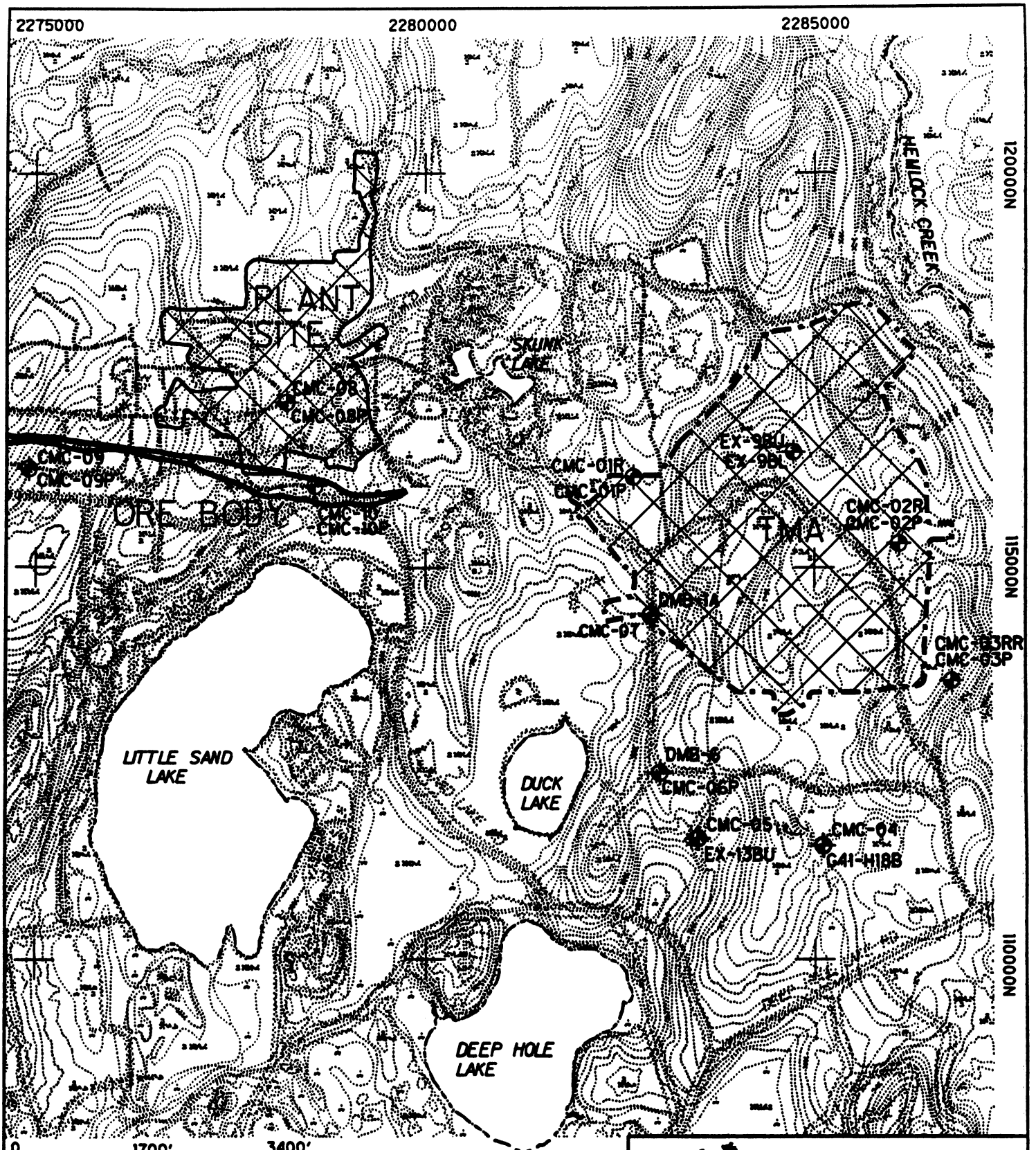
Crandon Mining Company

FIGURE 3.6-2
MONITORING WELL LOCATION
MAP 2

Scale: 0 1000' 2000' | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: JOW

/c3/d1/users/gam/4c33f89.dgn

93C049



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS	DATE: DEC, '96
APPROVED BY:	SVDI	DATE: DEC, '96
APPROVED BY:	JWS	DATE: DEC, '96

Crandon Mining Company

FIGURE 3.6-2A

LOCATION OF 1994 GROUNDWATER QUALITY VERIFICATION WELLS

Scale:	SEE BAR SCALE	Date:	DECEMBER, 1996
Prepared By:	Foth & Van Dyke	By:	JRB2

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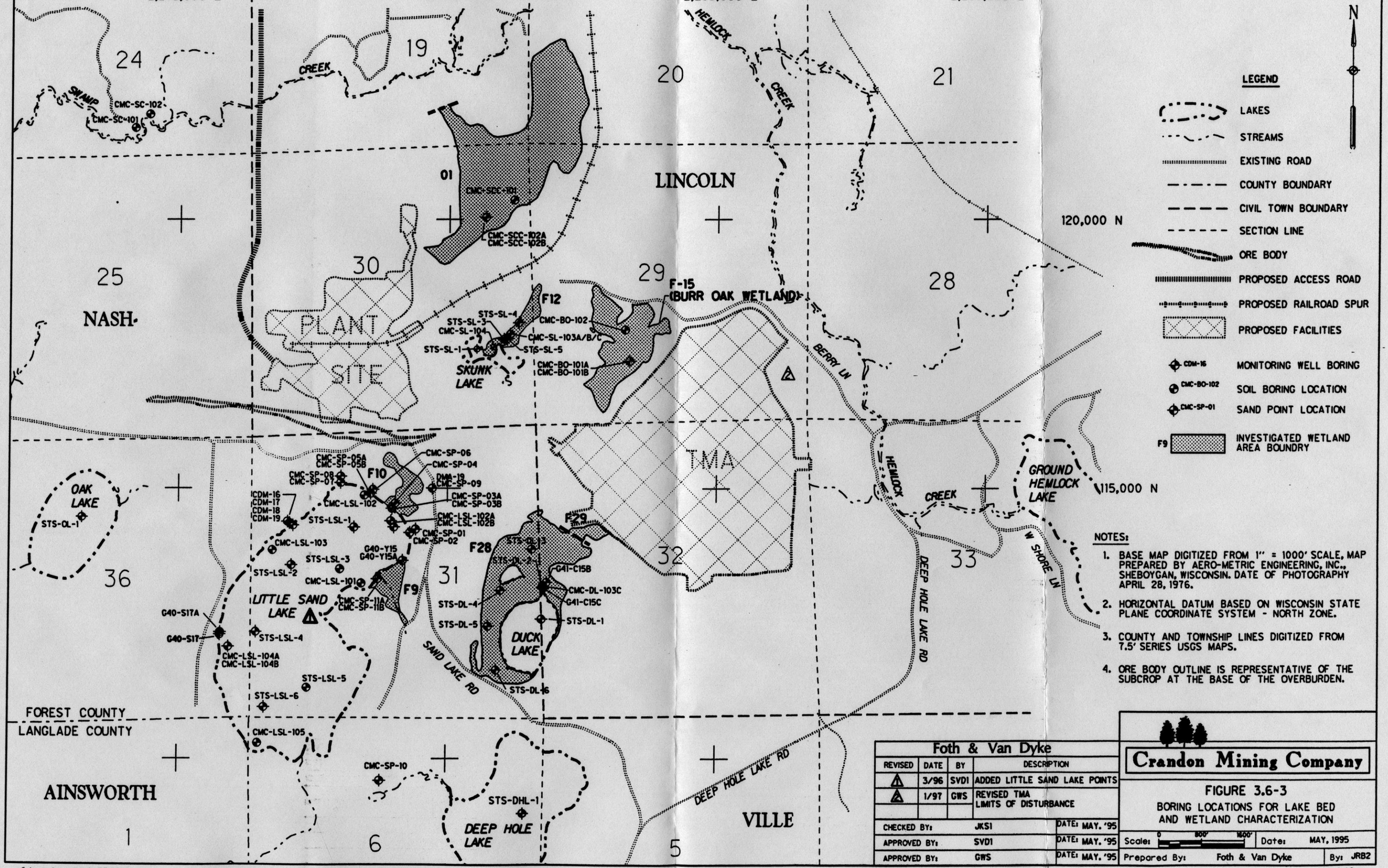
93C049



NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	3/96	SVD1	ADDED LITTLE SAND LAKE POINTS
2	1/97	GWS	REVISED TMA LIMITS OF DISTURBANCE

CHECKED BY:	JKS1	DATE: MAY. '95
APPROVED BY:	SVD1	DATE: MAY. '95
APPROVED BY:	GWS	DATE: MAY. '95

Crandon Mining Company

FIGURE 3.6-3

BORING LOCATIONS FOR LAKE BED AND WETLAND CHARACTERIZATION

Scale: 0 800' 1600' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JRB2

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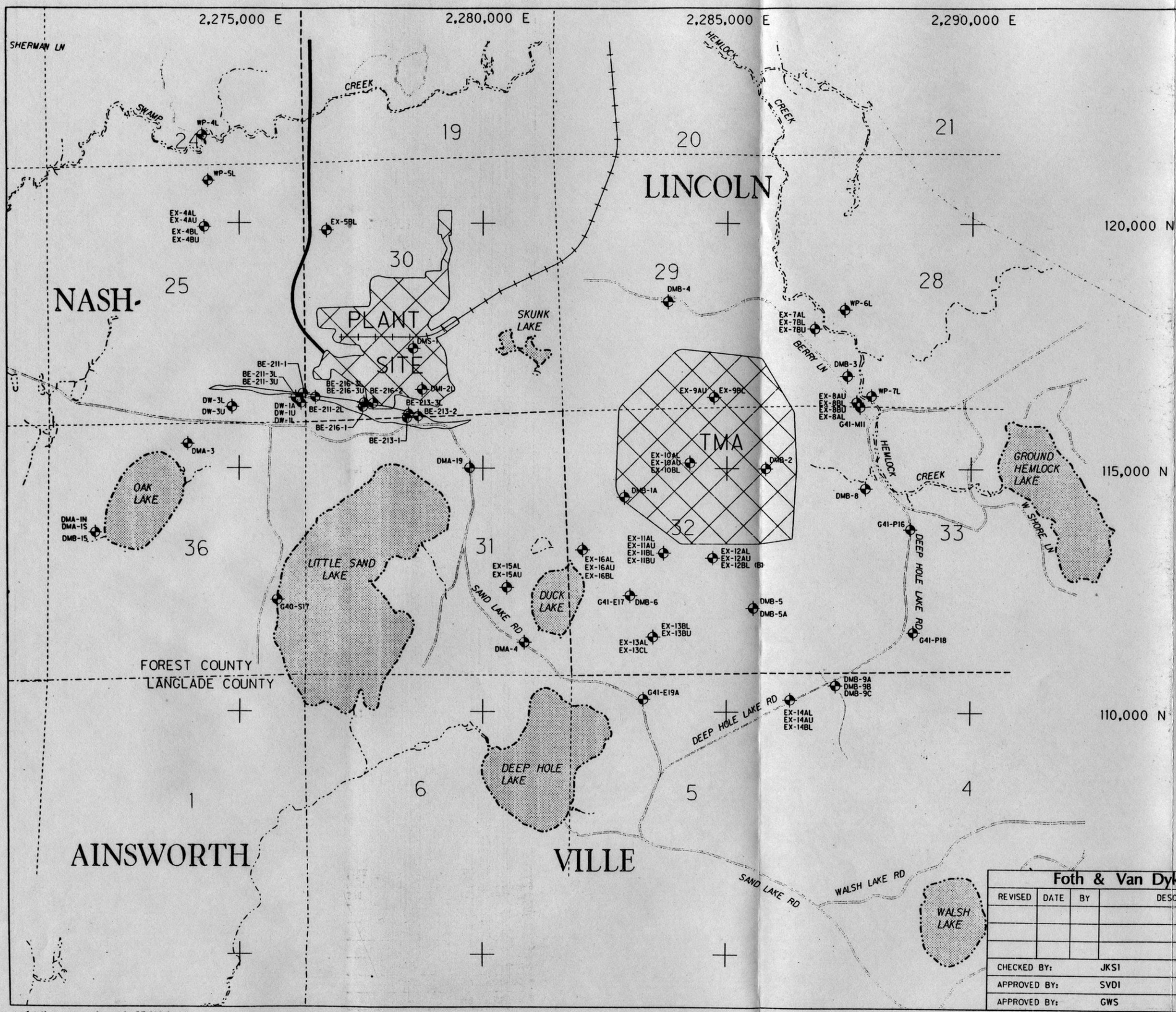
N

Lake Metonga
Riley L.
Lake Lucerne
Wyman L.
Mayflower L.
Hardwood L.
Popple L.
Midget L.
Little Popple L.
Bradley L.
Lit. Star L.
Horsehoe L.
Eds L.
Ground Hemlock Lake
Lundington L.
Lost L.
Roberts L.
Himley L.
Clark Lake
Cook Lake
Jungle Lake
Kimberly Lake
Walsh Lake
St Johns Lake
Crawford Lake
Lily Lake
Little Long L.
Shoe L.
Roxy L.
Crane Lake
Deep Hole Lake
Duck Lake
Little Sand Lake
Oak Lake
Skunk Lake
Rice Lake
Bishop Lake
Mole Lake
Popple Pond
Rolling Stone Lake
Berendsen Lake
Lake Agnes
Swamp Creek
Hoffman Creek
Logan Creek
Squaw Creek
Pickerel Creek
Outlet Creek
Hemlock Creek
Creek
Creek



N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-12A — WELL USED FOR SLUG TESTS

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-5

LOCATION OF GLACIAL OVERBURDEN WELLS USED FOR SLUG TESTS-MAP 2

Scale: 0 1000' 2000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW

/c3/dl/users/jow/4c33f104.dgn

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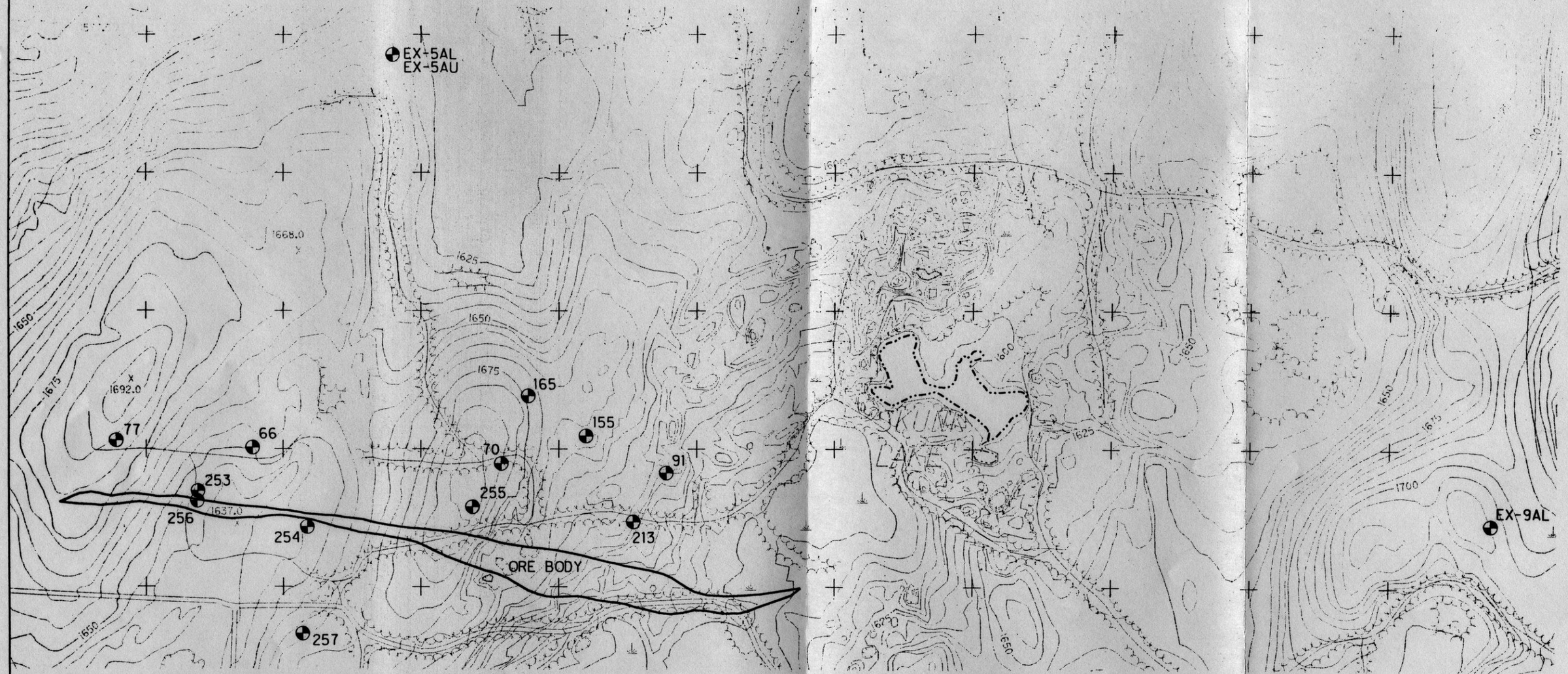

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON WISCONSIN STATE PLANE DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

⚠ 77	EXPLORATION HOLE / BEDROCK PIEZOMETER USED FOR BEDROCK PERMEABILITY TEST. SYMBOL DENOTES COLLAR LOCATION AT SURFACE
	LAKES
1600	EXISTING CONTOUR
x 1677.0	SPOT ELEVATION
	ORE BODY
	ROADWAY
	TRAIL
	MARSH

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-6

LOCATION OF BEDROCK PACKER AND SLUG TESTS

Scale: 0 375' 750' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: GAM

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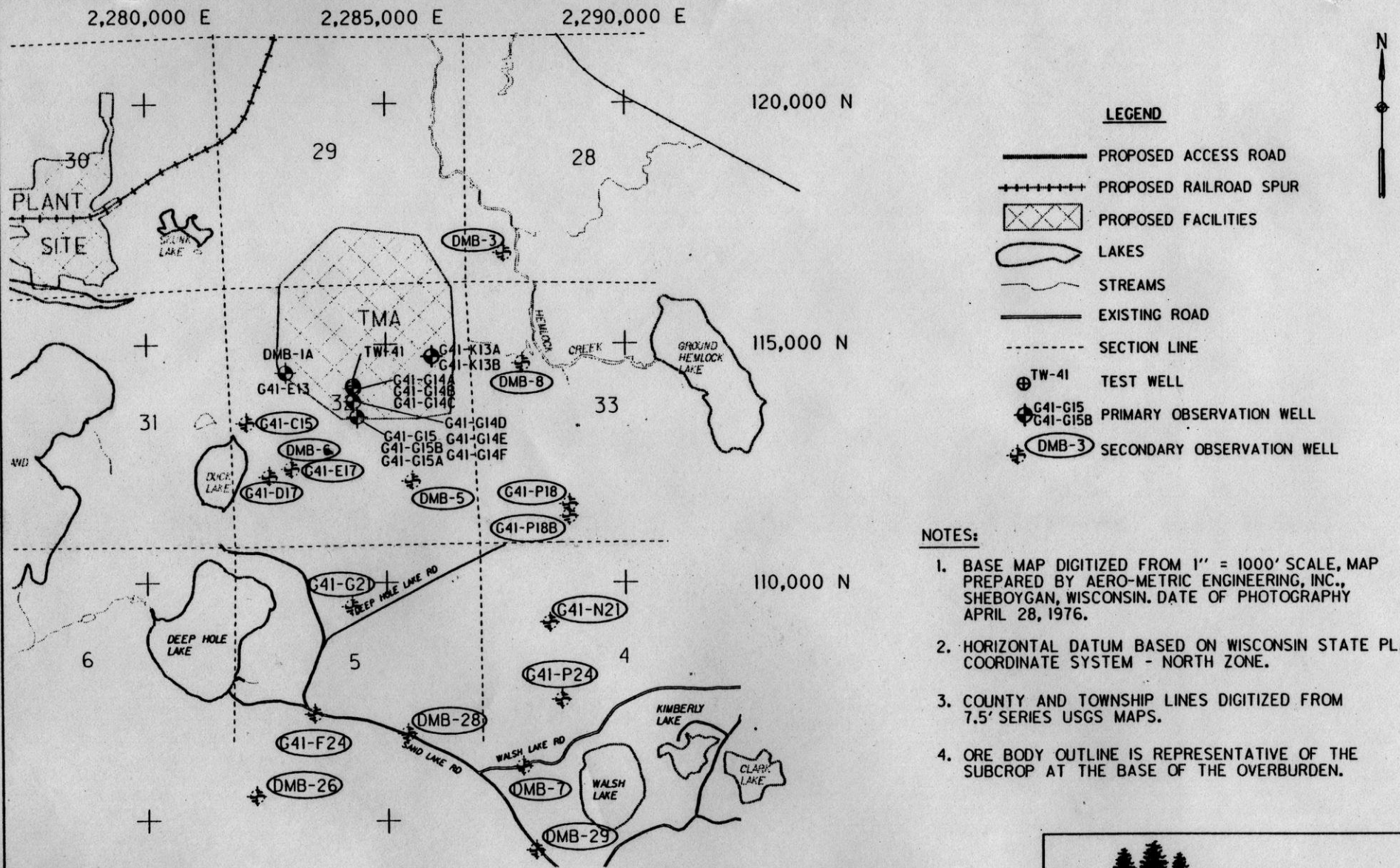
93C049



NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-7

PUMP TEST SETUP FOR 24 DAY GLACIAL OVERBURDEN PUMP TEST

Scale: 0 1500' 3000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: KMP

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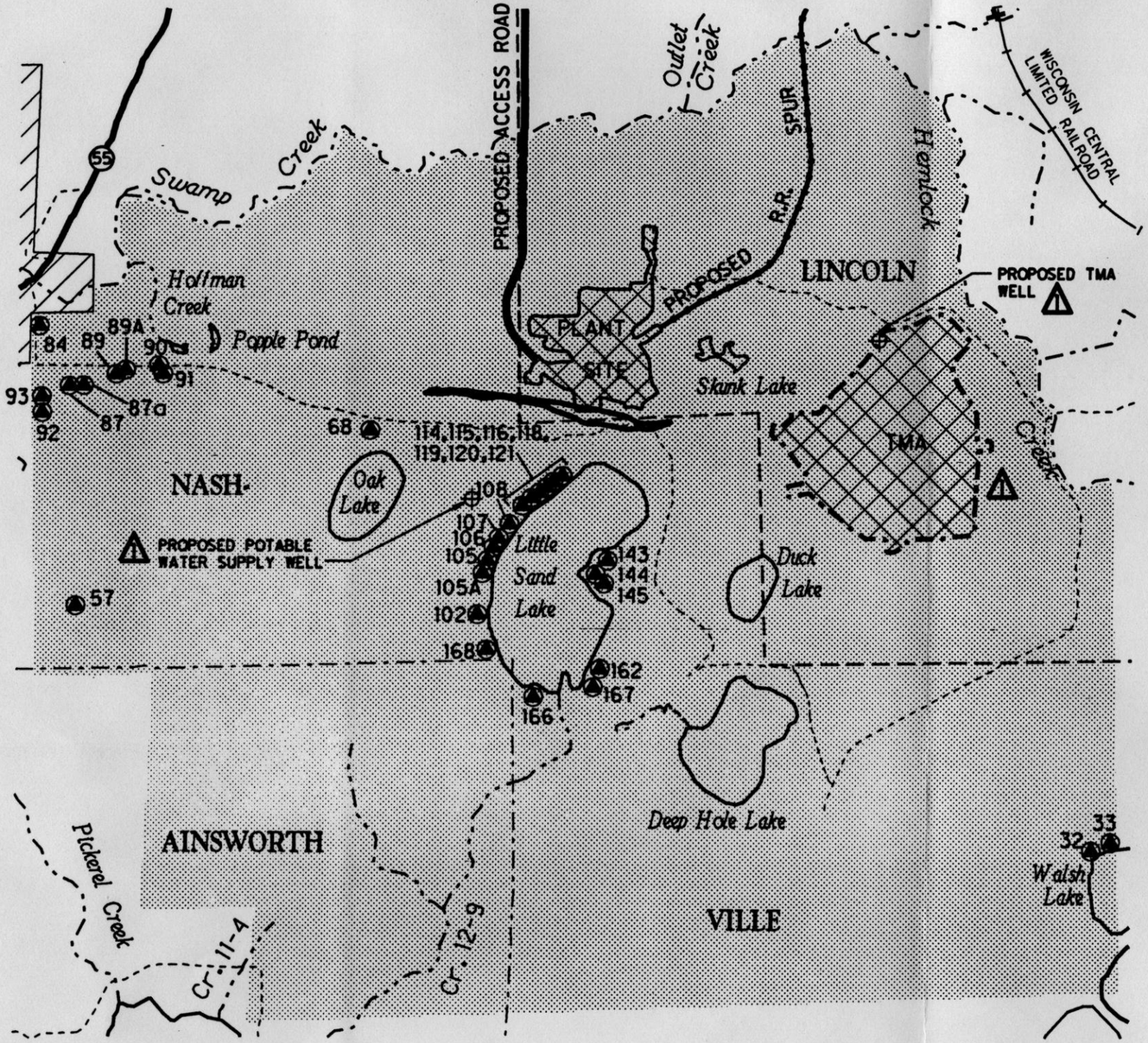
93C049



N

LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- (47) STATE HWY NO.
- [W] COUNTY HWY LETTER
- SURVEY AREA
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- 68 DOMESTIC WELL NUMBER AND LOCATION
- PROPOSED WATER SUPPLY WELL

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/96	GWS	ADDED CMC WELL LOCATIONS AND REVISED TMA LIMITS OF DISTURBANCE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	PAE	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-8
DOMESTIC WATER WELL
SURVEY AREA

Scale: 0 1500' 3000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW

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93C049

PLANT SITE

25 30 29 32 31 36 1 6 5

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED FACILITIES
- CMC PROPERTIES
- 143 DOMESTIC WATER WELL NUMBER AND LOCATION

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

DEEP HOLE LAKE

SAND LAKE RD

PUBLIC ACCESS

134 135 136 137 138 139 140 141

68

115 YEAGER
120
116
118
117
119
111
121 MANTEY
DIETZLER
PALLEN
BETTERS
DIX
WALENTOWSKI

110
108 BECKER
107
106 FRISTSCHE
105 HAFERMAN
KELCHNER
105A
104
103 SEAWELL
WEBB
102
PIERITZ
168
KLOEHN

ROBERT KELCHNER
HAROLD PRYOR
WILLIAM BECKER

143 PARKER
144 LUEWSKI
145 SCHALLOCK
SCHALLOCK
VERLOTTA

FOREST COUNTY
LANGLADE COUNTY

162 G. JOHNSON
ARCHIE JOHNSON
167 G. BUCKLEY
G. BUCKLEY
166
L. DILLEY
MIHALKO, et. al.
MAUREEN NOTEBOOM
DHUEY

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

	DATE	BY	DESCRIPTION
1	10/95	GWS	ADDED CMC PROPERTIES

REVISED

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY. '95
APPROVED BY:	GWS	DATE: MAY. '95

Crandon Mining Company

FIGURE 3.6-9
LITTLE SAND LAKE
DOMESTIC WATER WELLS

Scale: 0 400' 800' | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: JOW

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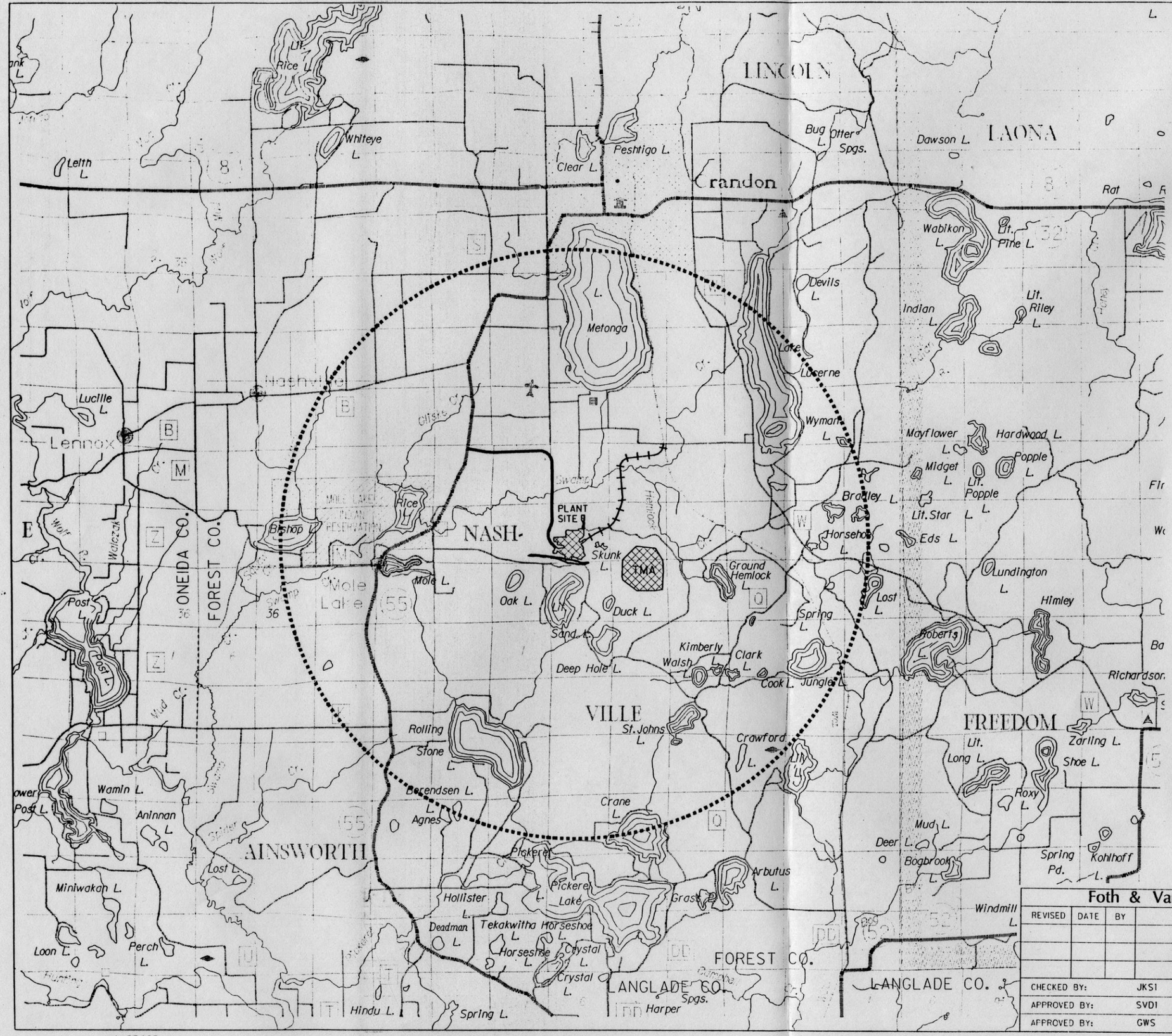

LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- U.S. HWY NO.
- STATE HWY NO.
- COUNTY HIGHWAY LETTER
- NATIONAL & STATE FOREST BOUNDARY
- CORPORATE LIMITS
- UNINCORPORATED VILLAGE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- 5 MILE RADIUS AROUND PLANT SITE
- Zarling L. LAKES
- STREAMS

N

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-10
REGIONAL AREA
5 MILE RADIUS FROM SITE

Scale: 0 4500' 9000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JRB2

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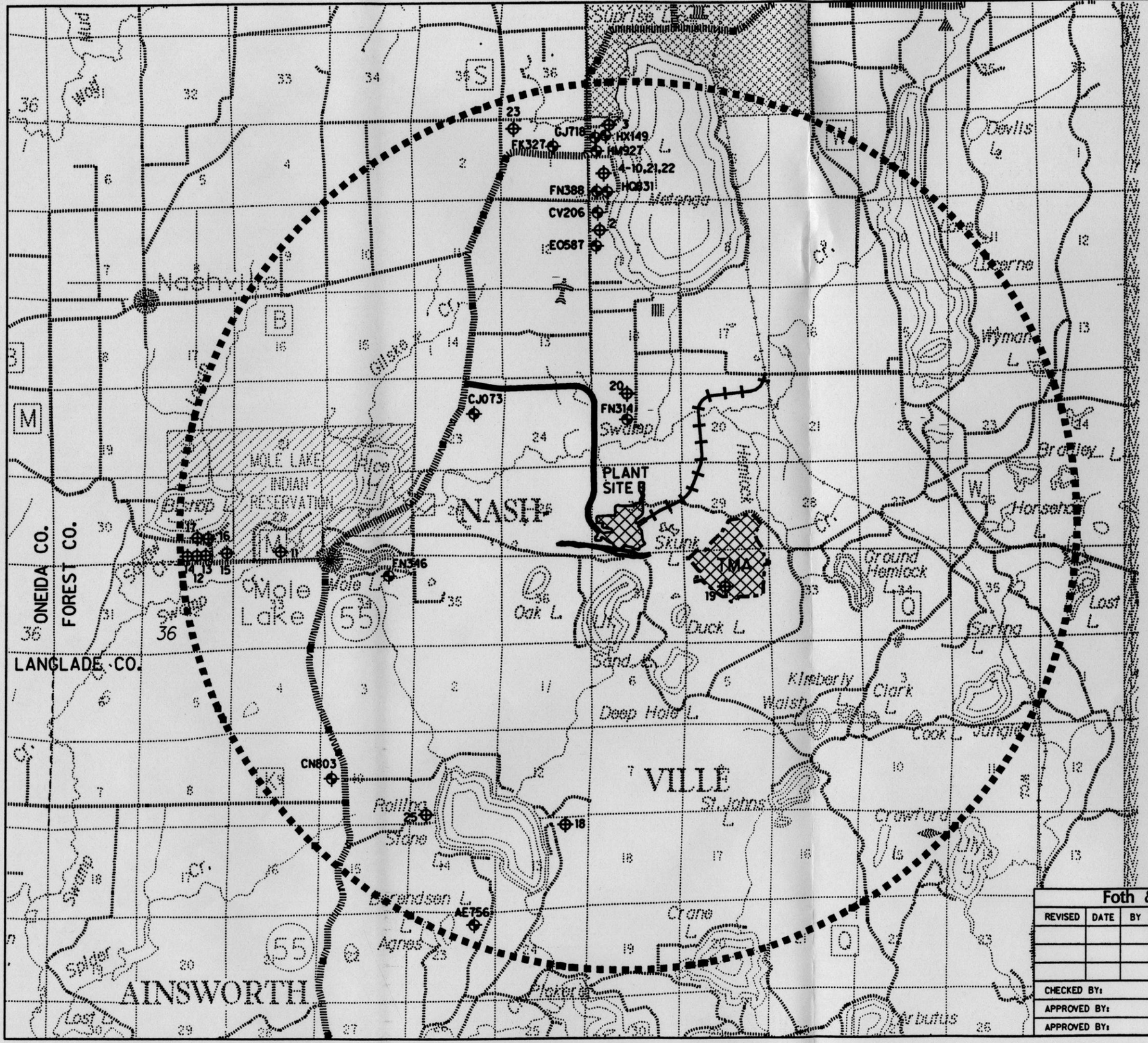

LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- (8) U.S. HWY NO.
- (17) STATE HWY NO.
- (B) COUNTY HIGHWAY LETTER
- NATIONAL & STATE FOREST BOUNDARY
- CORPORATE LIMITS
- UNINCORPORATED VILLAGE
- ORE BODY
- Zarling L. LAKES
- STREAMS
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- 20 PRE - 1988 WELLS COMPLETED IN BEDROCK
- FN314 WELLS COMPLETED IN THE BEDROCK SINCE 1988
- 5 MILE RADIUS AROUND PLANT SITE

N

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: DEC. '96
APPROVED BY:	GWS	DATE: DEC. '96
APPROVED BY:		DATE:

Crandon Mining Company

FIGURE 3.6-10A

WELLS COMPLETED IN BEDROCK

Scale: 0 3000' 6000' Date: DECEMBER, 1996

Prepared By: Foth & Van Dyke By: JRB2

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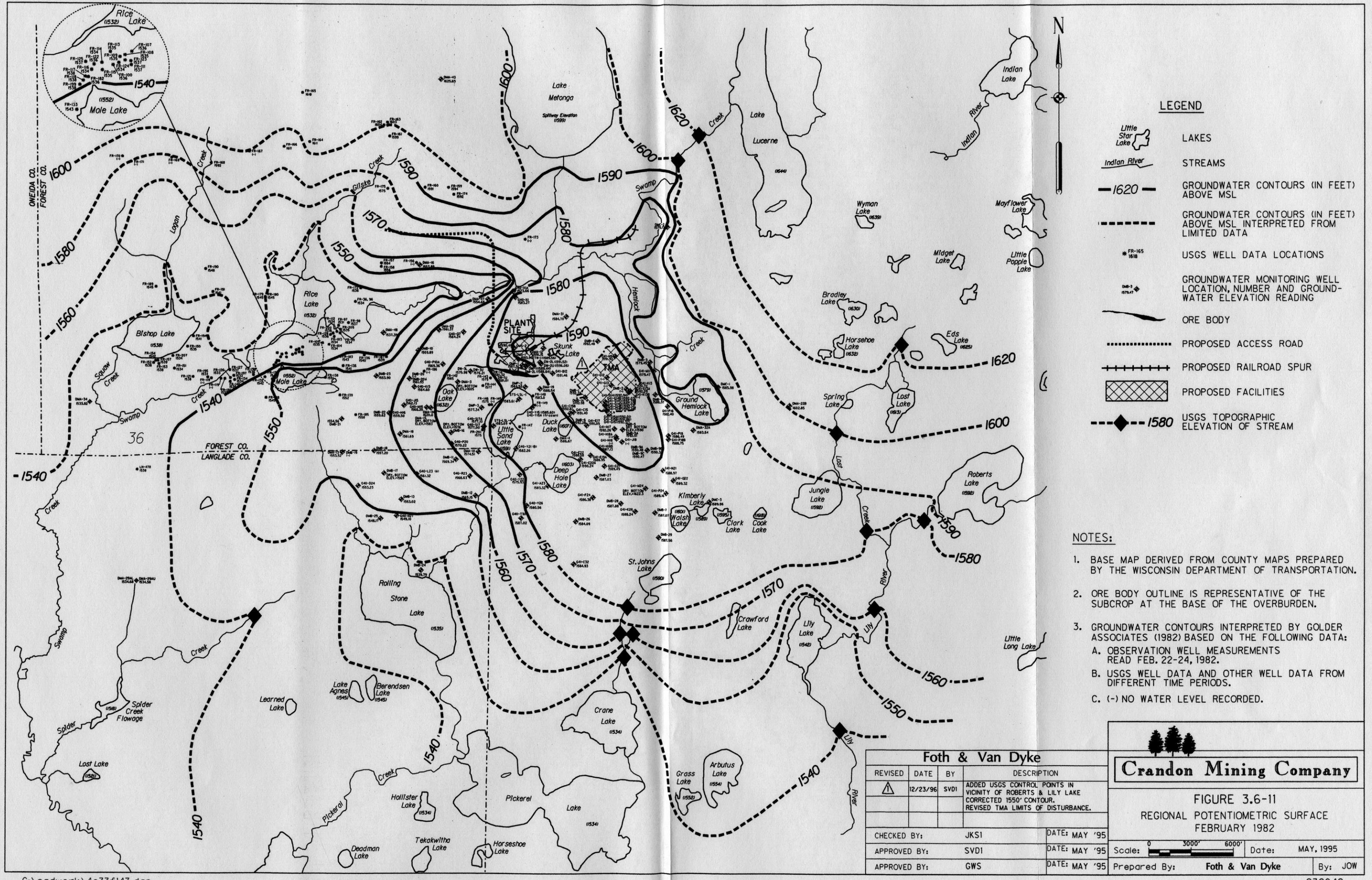

LEGEND

- LAKES (Little Star Lake)
- STREAMS (Indian River)
- GROUNDWATER CONTOURS (IN FEET) ABOVE MSL (1620)
- GROUNDWATER CONTOURS (IN FEET) ABOVE MSL INTERPRETED FROM LIMITED DATA
- USGS WELL DATA LOCATIONS (FR-165 1618)
- GROUNDWATER MONITORING WELL LOCATION, NUMBER AND GROUNDWATER ELEVATION READING (DNR-3 1579.47)
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- USGS TOPOGRAPHIC ELEVATION OF STREAM (1580)

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
3. GROUNDWATER CONTOURS INTERPRETED BY GOLDER ASSOCIATES (1982) BASED ON THE FOLLOWING DATA:
   A. OBSERVATION WELL MEASUREMENTS READ FEB. 22-24, 1982.
   B. USGS WELL DATA AND OTHER WELL DATA FROM DIFFERENT TIME PERIODS.
   C. (-) NO WATER LEVEL RECORDED.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVD1	ADDED USGS CONTROL POINTS IN VICINITY OF ROBERTS & LILY LAKE CORRECTED 1550' CONTOUR. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-11
REGIONAL POTENTIOMETRIC SURFACE
FEBRUARY 1982

Scale: 0 3000' 6000' | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: JOW

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N

2274000E 2274400E 2274800E 2275200E 2275600E 2276000E 2276400E 2276800E 2277200E 2277600E 2278000E 2278400E 2278800E 2279200E 2279600E 2280000E 2280400E 2280800E

119200 N
118800 N
118400 N
118000 N
117600 N
117200 N
116800 N
116400 N
116000 N
115600 N

"400N"
"200N"
"200S"

DUCK LAKE GABBRO DIKE

LEGEND

- CORE HOLE TRACE
- 2276269E — WEATHERING CROSS SECTIONS USED TO GENERATE LONGITUDINAL WEATHERING SECTIONS
- ORE BODY
- ---------- LOCATION OF LONGITUDINAL WEATHERING SECTIONS SHOWN ON FIGURES 3.6-13 TO 3.6-16
- -------- DUCK LAKE GABBRO DIKE

0 250 500 1000
BAR SCALE (FEET)

Foth & Van Dyke

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CHECKED BY:	JKSI	DATE: MAY '95
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APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-12
PLAN MAP SHOWING DRILL HOLE TRACE AND OUTLINE OF CRANDON FORMATION, LOCATION OF WEATHERING CROSS SECTIONS, LOCATION OF LONGITUDINAL WEATHERING SECTIONS AND LOCATION OF GABBRO "DIKE"

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JRB

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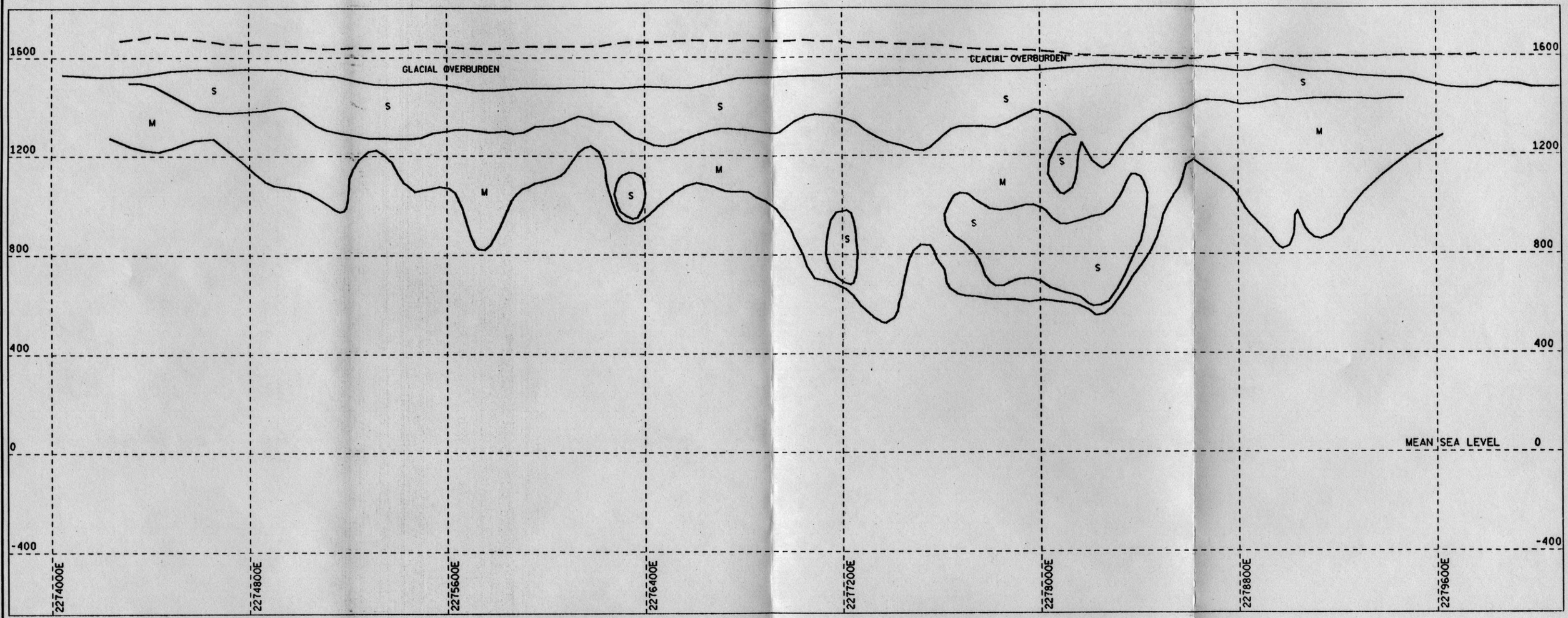

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
MODERATE: M	STRONG DEVELOPMENT OF ONE OF THE DESTRUCTIVE PROCCESSES (OR MODERATE DEVELOPMENT OF TWO) AND WEAK TO MODERATE DEVELOPMENT OF AT LEAST ONE MORE. ROCKS MAY OR MAY NOT BE STRONG ENOUGH TO HOLD A BACK, DEPENDING UPON WHICH DESTRUCTIVE PROCESSES HAVE BEEN ACTIVE. STRONG DEVELOPMENT OF ARGILLIZATION OR FRACTURING WOULD MAKE THE ROCK VERY WEAK OR UNSTABLE, WHEREAS STRONG DEVELOPMENT OF OXIDATION OR LEACHING MAY NOT SERIOUSLY AFFECT ITS ABILITY TO HOLD A BACK. SECONDARY PERMEABILITY FEATURES HAVE BEEN SLIGHTLY MODIFIED.
LOW:	MODERATE LEACHING WITH ONLY MINOR OTHER EFFECTS. THE COMPRESSSIVE STRENGTH OF THE ROCK IS NOT SERIOUSLY REDUCED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.
WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

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APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-13

LONGITUDINAL SECTION LOOKING NORTH WITHIN THE CRANDON FORMATION

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	AJE JR./JRB

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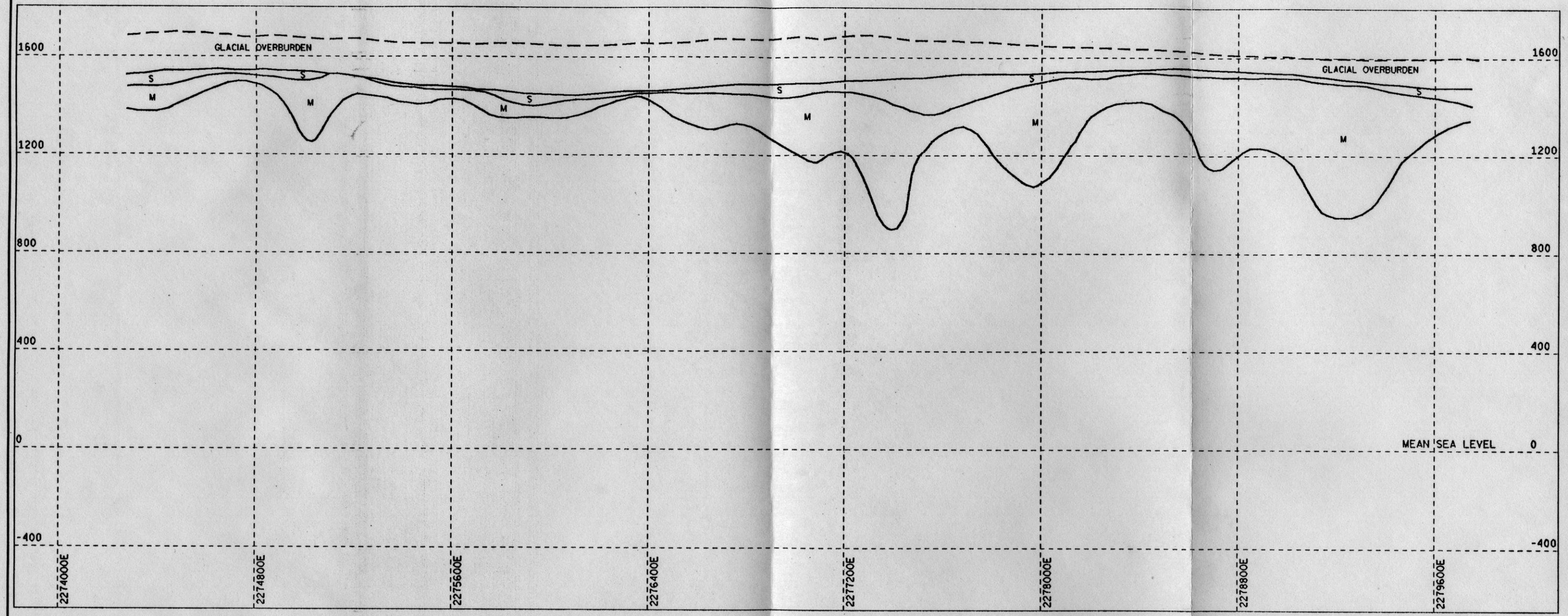

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
MODERATE: M	STRONG DEVELOPMENT OF ONE OF THE DESTRUCTIVE PROCCESSES (OR MODERATE DEVELOPMENT OF TWO) AND WEAK TO MODERATE DEVELOPMENT OF AT LEAST ONE MORE. ROCKS MAY OR MAY NOT BE STRONG ENOUGH TO HOLD A BACK, DEPENDING UPON WHICH DESTRUCTIVE PROCESSES HAVE BEEN ACTIVE. STRONG DEVELOPMENT OF ARGILLIZATION OR FRACTURING WOULD MAKE THE ROCK VERY WEAK OR UNSTABLE, WHEREAS STRONG DEVELOPMENT OF OXIDATION OR LEACHING MAY NOT SERIOUSLY AFFECT ITS ABILITY TO HOLD A BACK. SECONDARY PERMEABILITY FEATURES HAVE BEEN SLIGHTLY MODIFIED.
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WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

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FIGURE 3.6-14

E-W LONGITUDINAL SECTION
200' NORTH OF CRANDON FM HW CONTACT
AT SUBCROP - LOOKING DUE NORTH - MOLE LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	AJE JR./JRB

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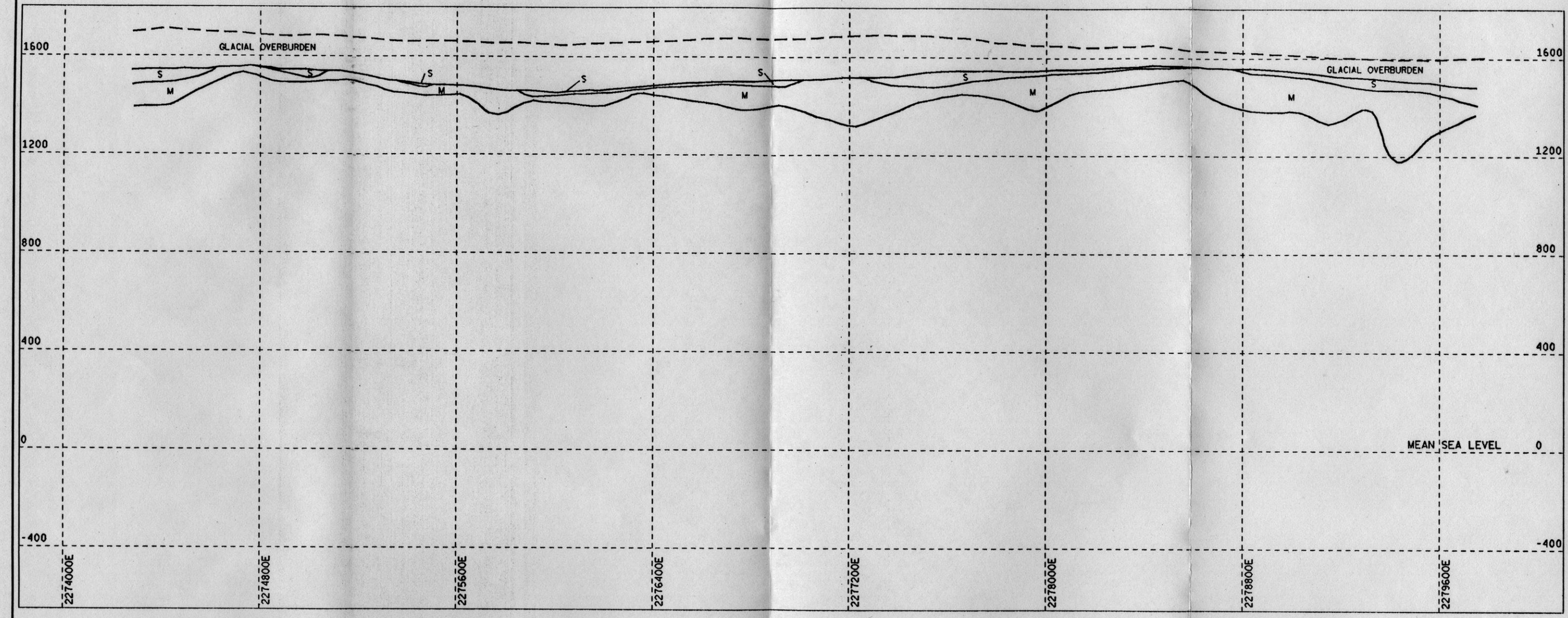

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
MODERATE: M	STRONG DEVELOPMENT OF ONE OF THE DESTRUCTIVE PROCCESSES (OR MODERATE DEVELOPMENT OF TWO) AND WEAK TO MODERATE DEVELOPMENT OF AT LEAST ONE MORE. ROCKS MAY OR MAY NOT BE STRONG ENOUGH TO HOLD A BACK, DEPENDING UPON WHICH DESTRUCTIVE PROCESSES HAVE BEEN ACTIVE. STRONG DEVELOPMENT OF ARGILLIZATION OR FRACTURING WOULD MAKE THE ROCK VERY WEAK OR UNSTABLE, WHEREAS STRONG DEVELOPMENT OF OXIDATION OR LEACHING MAY NOT SERIOUSLY AFFECT ITS ABILITY TO HOLD A BACK. SECONDARY PERMEABILITY FEATURES HAVE BEEN SLIGHTLY MODIFIED.
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WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

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APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-15

E-W LONGITUDINAL SECTION
400' NORTH OF CRANDON FM HW CONTACT
AT SUBCROP - LOOKING DUE NORTH - MOLE LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	AJE JR./JRB

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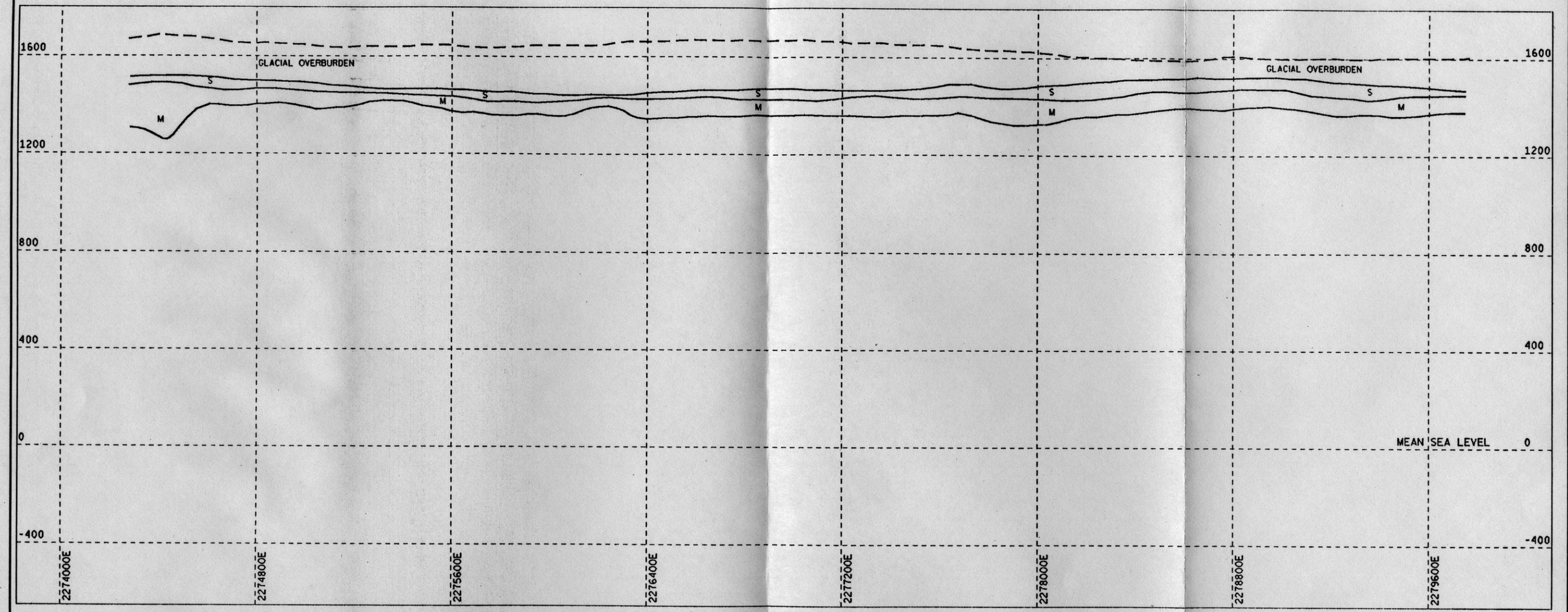

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
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APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-16

E-W LONGITUDINAL SECTION
200' SOUTH OF CRANDON FM FW CONTACT
AT SUBCROP - LOOKING DUE NORTH - SAND LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	AJE JR./JRB

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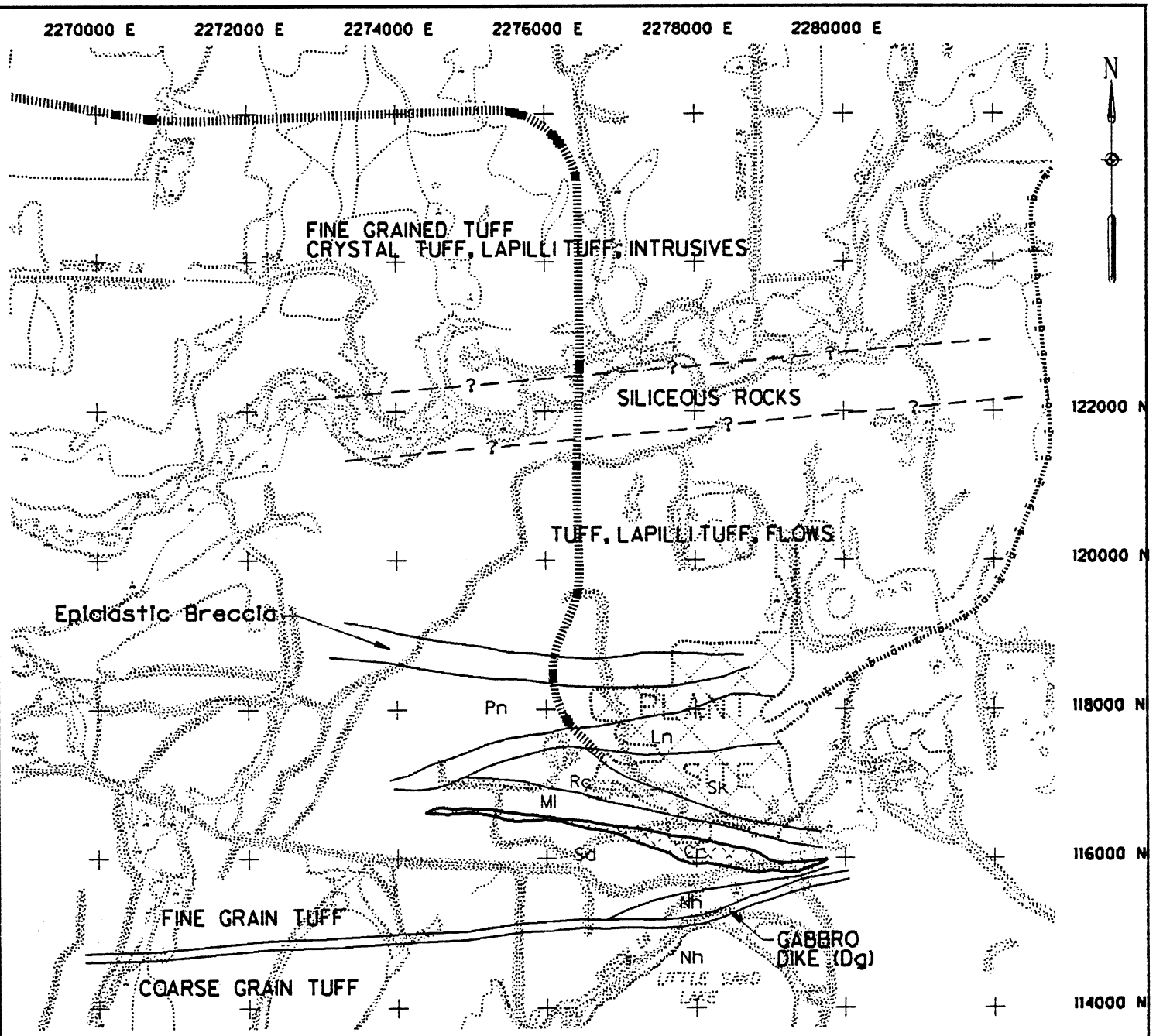

LEGEND

- RIVER/LAKE/WATERWAY
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- Nh — NASHVILLE FORMATION
- Dg — DUCK LAKE GABBRO DIKE
- Pn — PINE FORMATION
- Ln — LINCOLN FORMATION
- Cr — CRANDON FORMATION
- Sk — SKUNK LAKE FORMATION
- Sd — SAND LAKE FORMATION
- Ml — MOLE LAKE FORMATION
- Rc — RICE LAKE FORMATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

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REVISED	DATE	BY	DESCRIPTION

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APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-17

BEDROCK GEOLOGY OF THE STUDY AREA AND APPROXIMATE LOCATION OF GABBRO DIKE

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

- LAKES
- 1600 — EXISTING CONTOUR
- x1677.0 — SPOT ELEVATION
- ORE BODY
- ROADWAY
- TRAIL
- MARSH
- 77 — EXPLORATION HOLE / BEDROCK PIEZOMETER USED FOR BEDROCK PERMEABILITY TEST, SYMBOL DENOTES COLLAR LOCATION AT SURFACE

N

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-18

LOCATION OF BEDROCK PACKER AND SLUG TESTS

Scale: 0 315' 750' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: GAM

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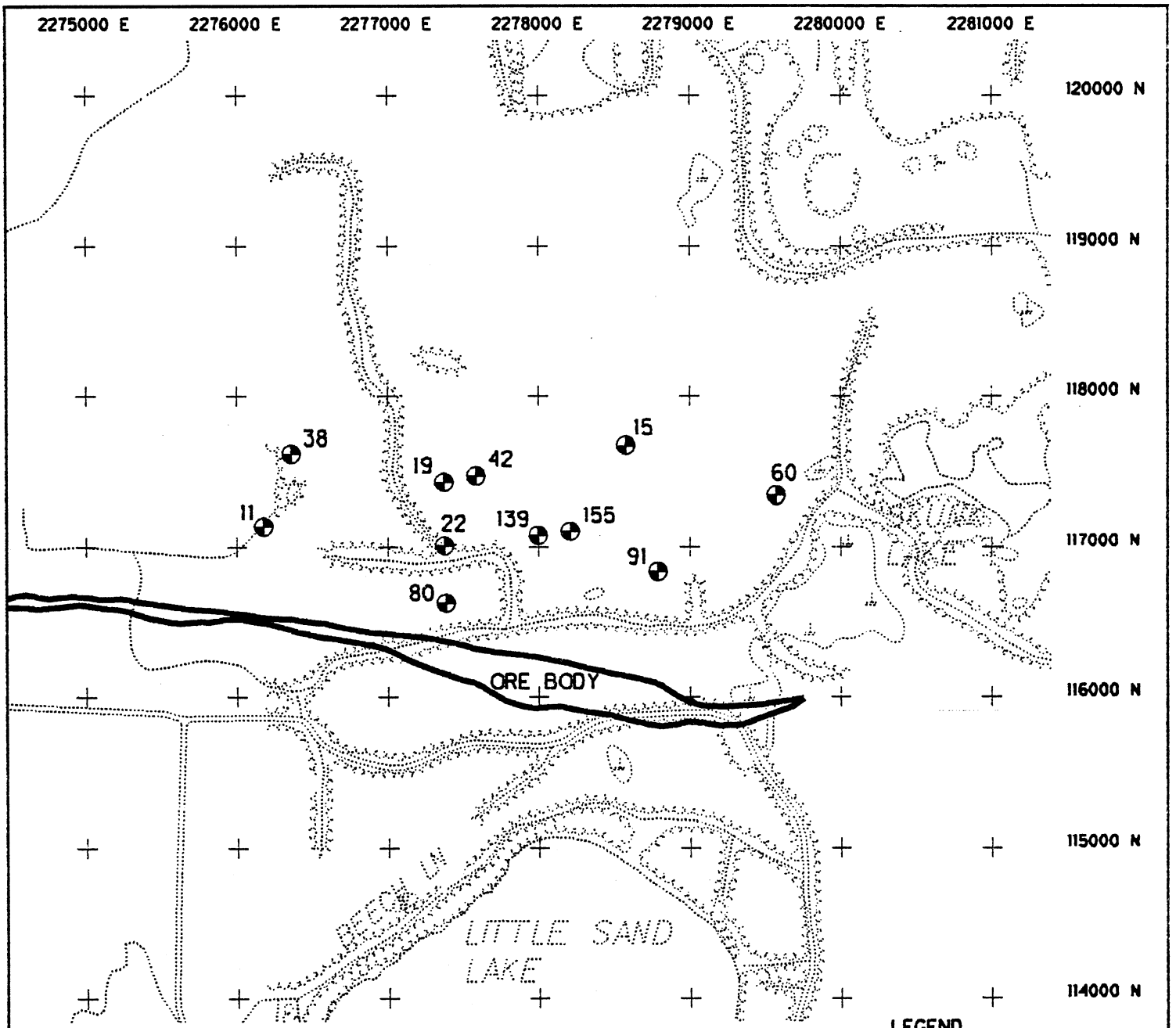

LEGEND

- RIVER/LAKE/WATERWAY
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- 42 — CORE HOLE NUMBER AND COLLAR LOCATION AT SURFACE

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE. MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

N

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-19

CORE HOLES USED ON DOWN HOLE TEMPERATURE SURVEYS

Scale:	1" = 1000'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	GAM

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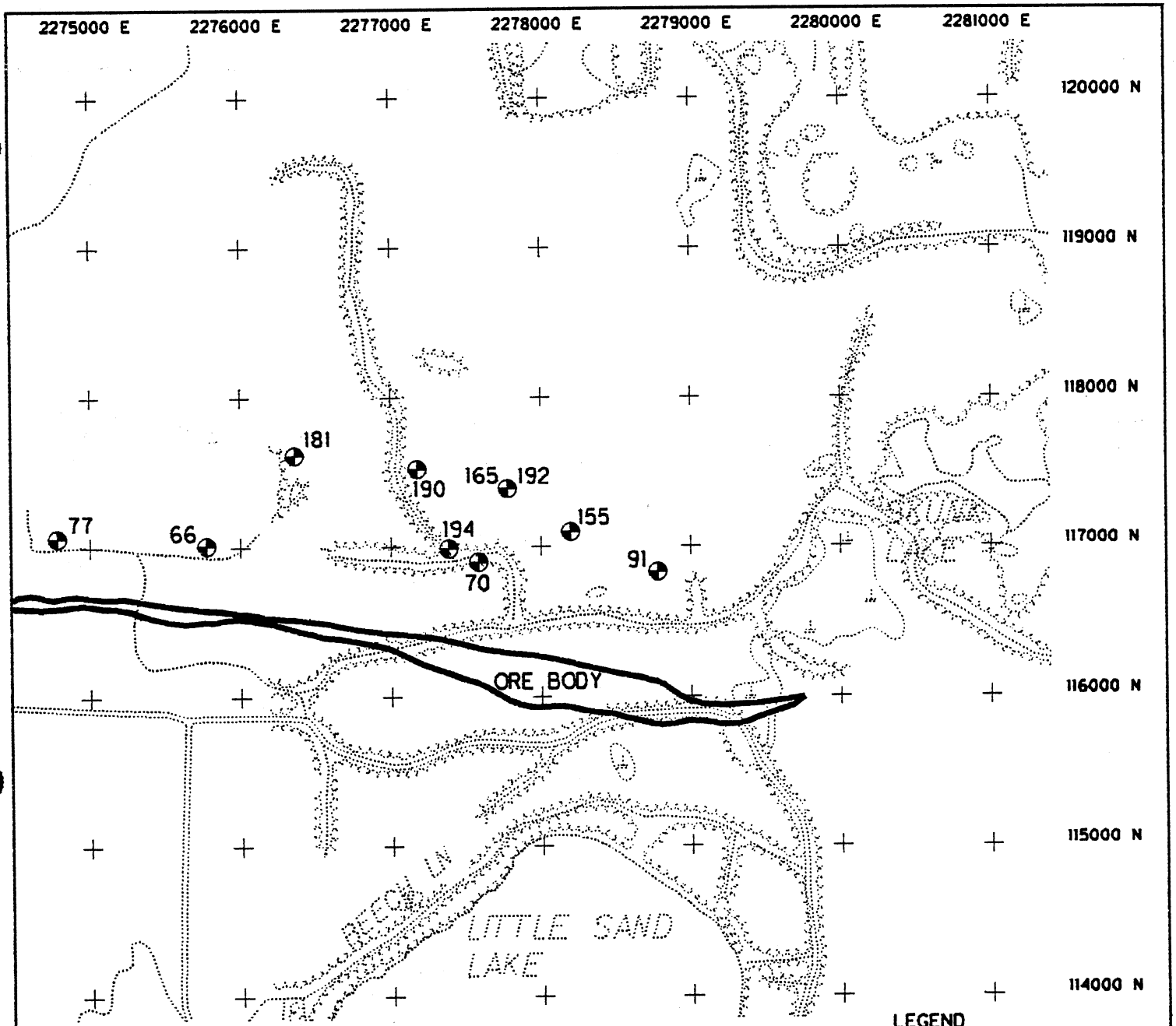

LEGEND

- RIVER/LAKE/WATERWAY
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- 66 — CORE HOLE NUMBER AND COLLAR LOCATION AT SURFACE

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-20
CORE HOLES USED FOR WATER CHEMISTRY ANALYSIS

Scale:	1" = 1000'	Date:	MAY. 1995
Prepared By:	Foth & Van Dyke	By:	GAM

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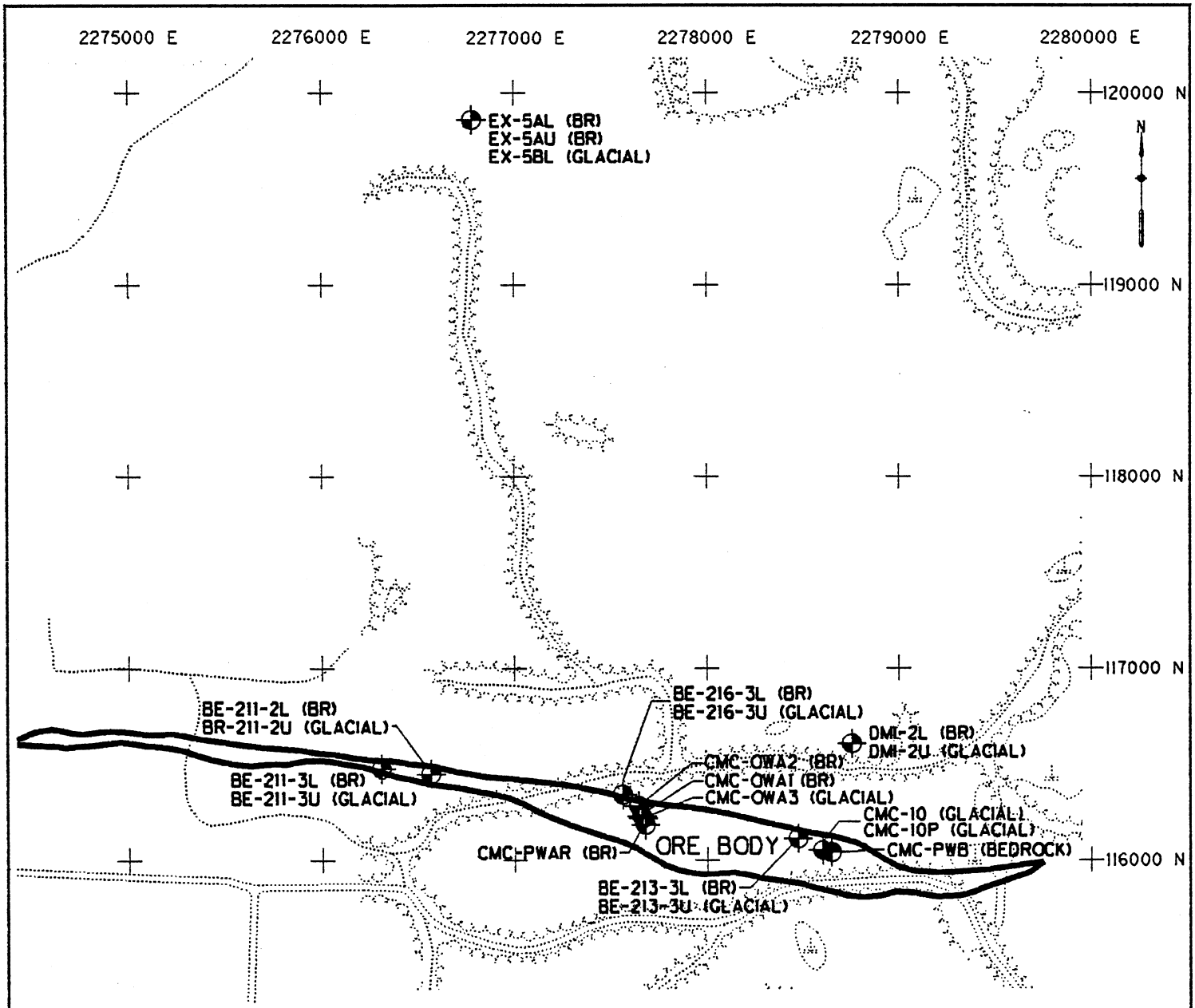

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

- RIVER/LAKE/WATERWAY
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- BE-213-3L (BR) / BE-213-3U (GLACIAL) — MONITORING WELL NUMBER, LOCATION AND COMPARISON

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95	
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APPROVED BY:	GWS	DATE: MAY '95	

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FIGURE 3.6-21

MONITORING WELL LOCATION FOR THE COMPARISON OF BEDROCK VS. GLACIAL HYDROGRAPHS

Scale:	1" = 800'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	GAM

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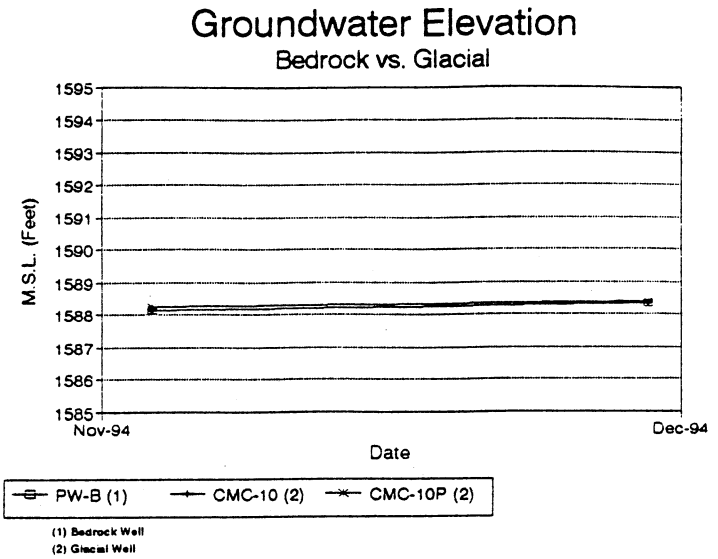

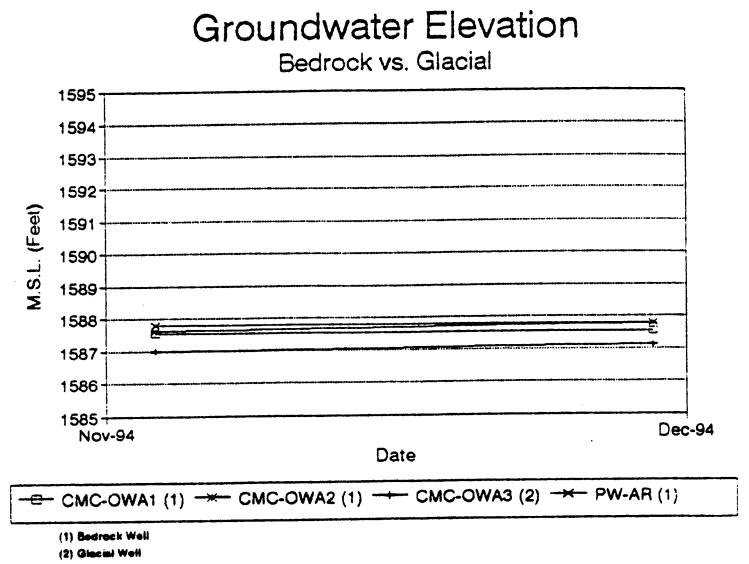

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REVISED	DATE	BY	DESCRIPTION		
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APPROVED BY:		SVDI		DATE:	MAY'95
APPROVED BY:		JWS		DATE:	MAY'95

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FIGURE 3.6-22

BEDROCK VS. GLACIAL HYDROGRAPHS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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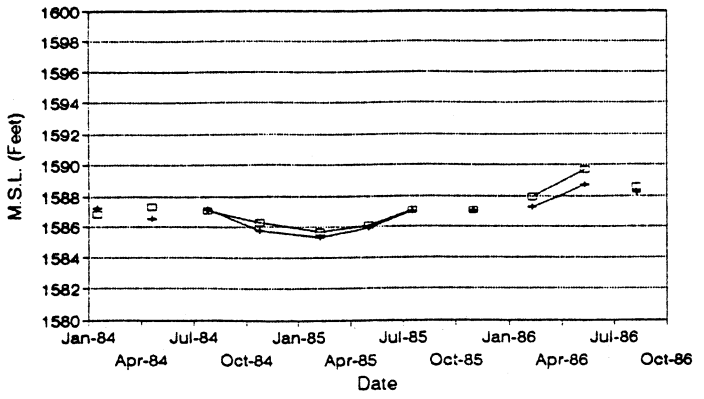
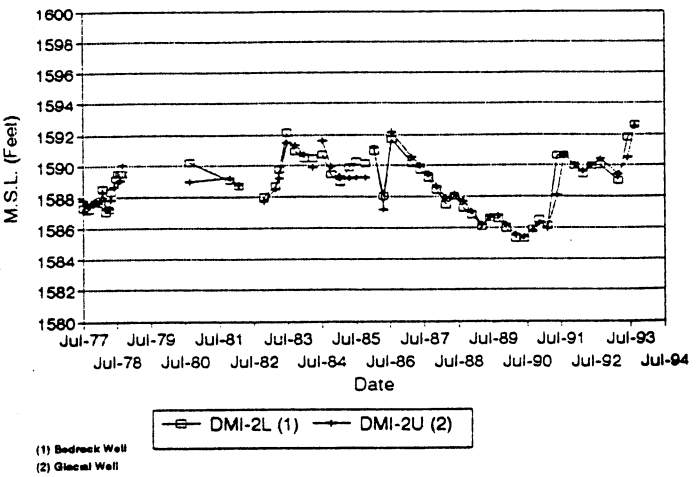
Groundwater Elevation
Bedrock vs. Glacial



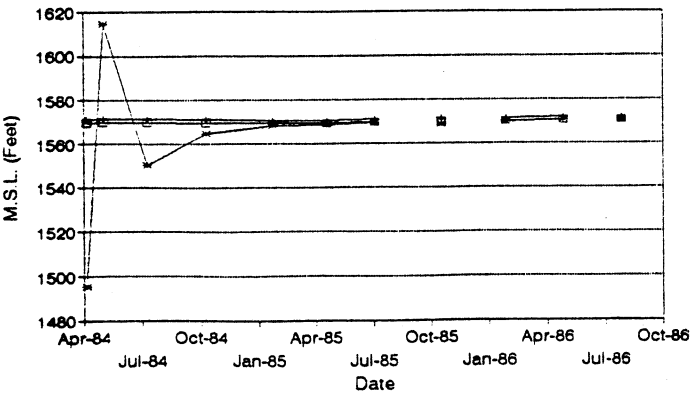
(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

Crandon Mining Company

FIGURE 3.6-23

BEDROCK VS. GLACIAL HYDROGRAPHS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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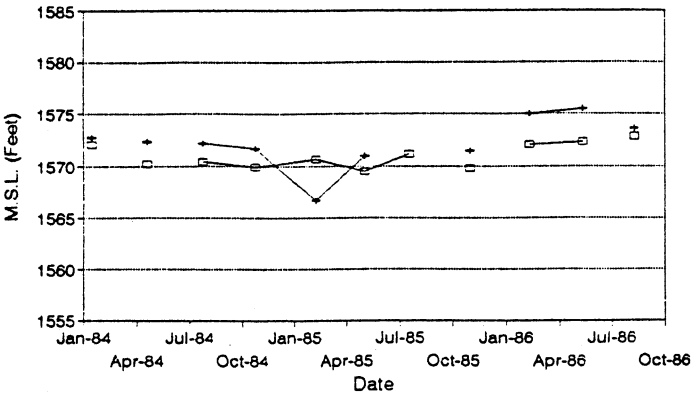
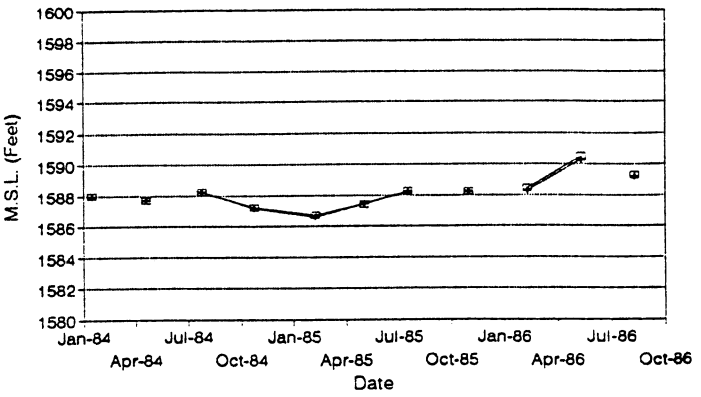
93C049

Groundwater Elevation
Bedrock vs. Glacial



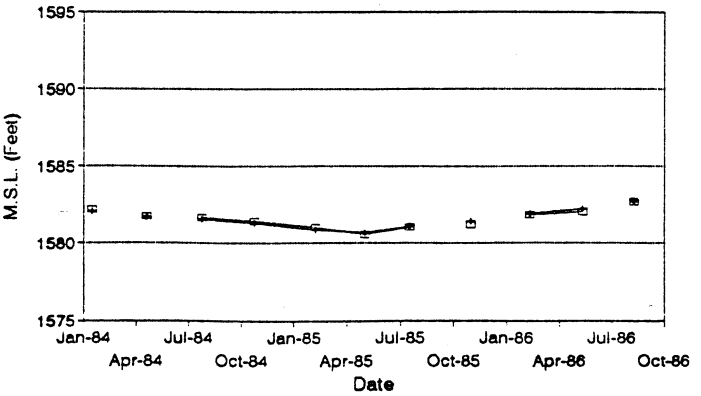
(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	FEB.'95

Crandon Mining Company

FIGURE 3.6-24

BEDROCK VS. GLACIAL HYDROGRAPHS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

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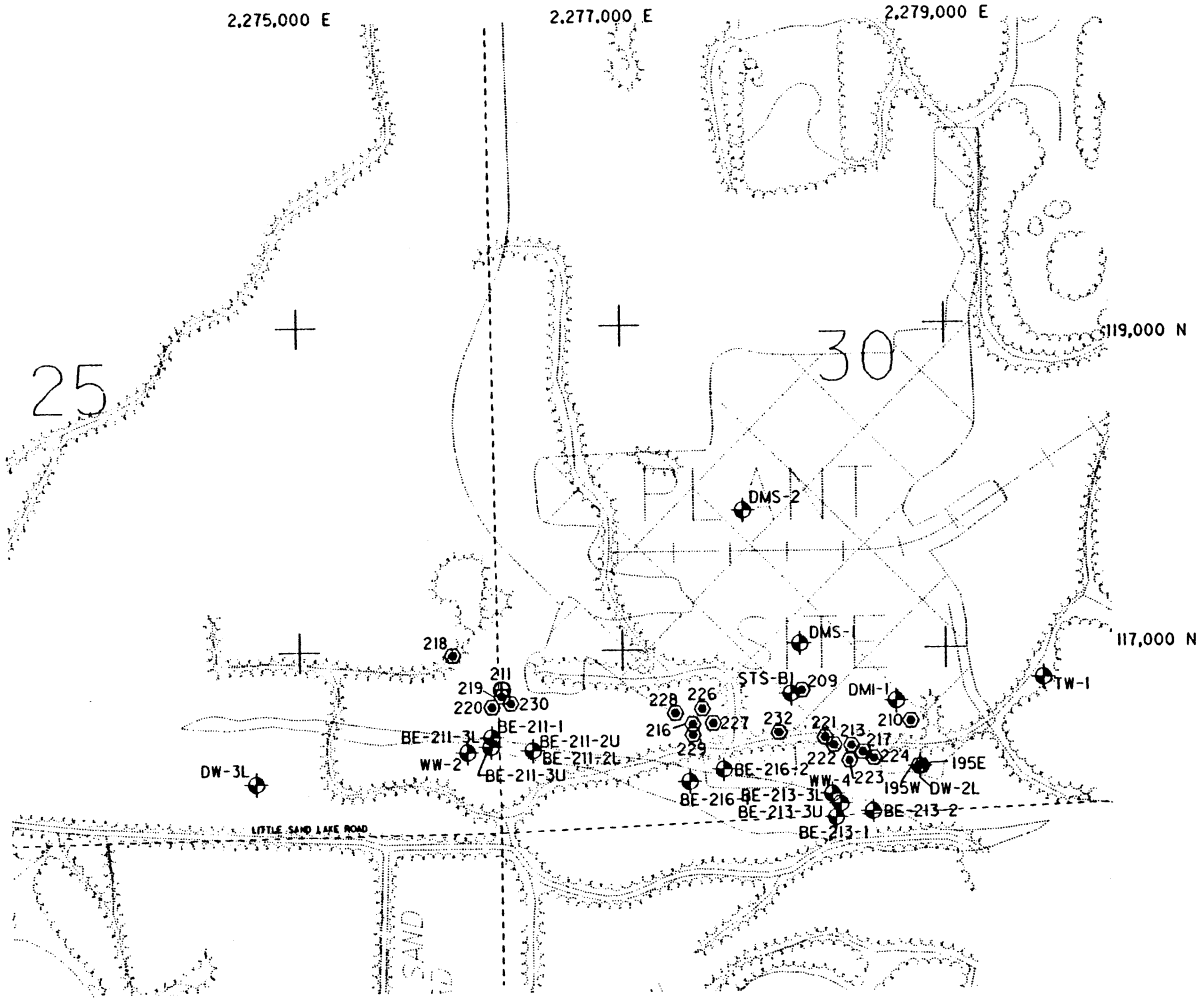
93C049



LEGEND

- LAKES
- STREAMS
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED HAUL ROAD AND PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- DMI-1 OBSERVATION WELL
- 209 ANGLED CORE HOLE OBSERVATION POINT COLLAR LOCATION
- 211 ANGLED CORE HOLE USED FOR PUMPED WELL COLLAR LOCATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

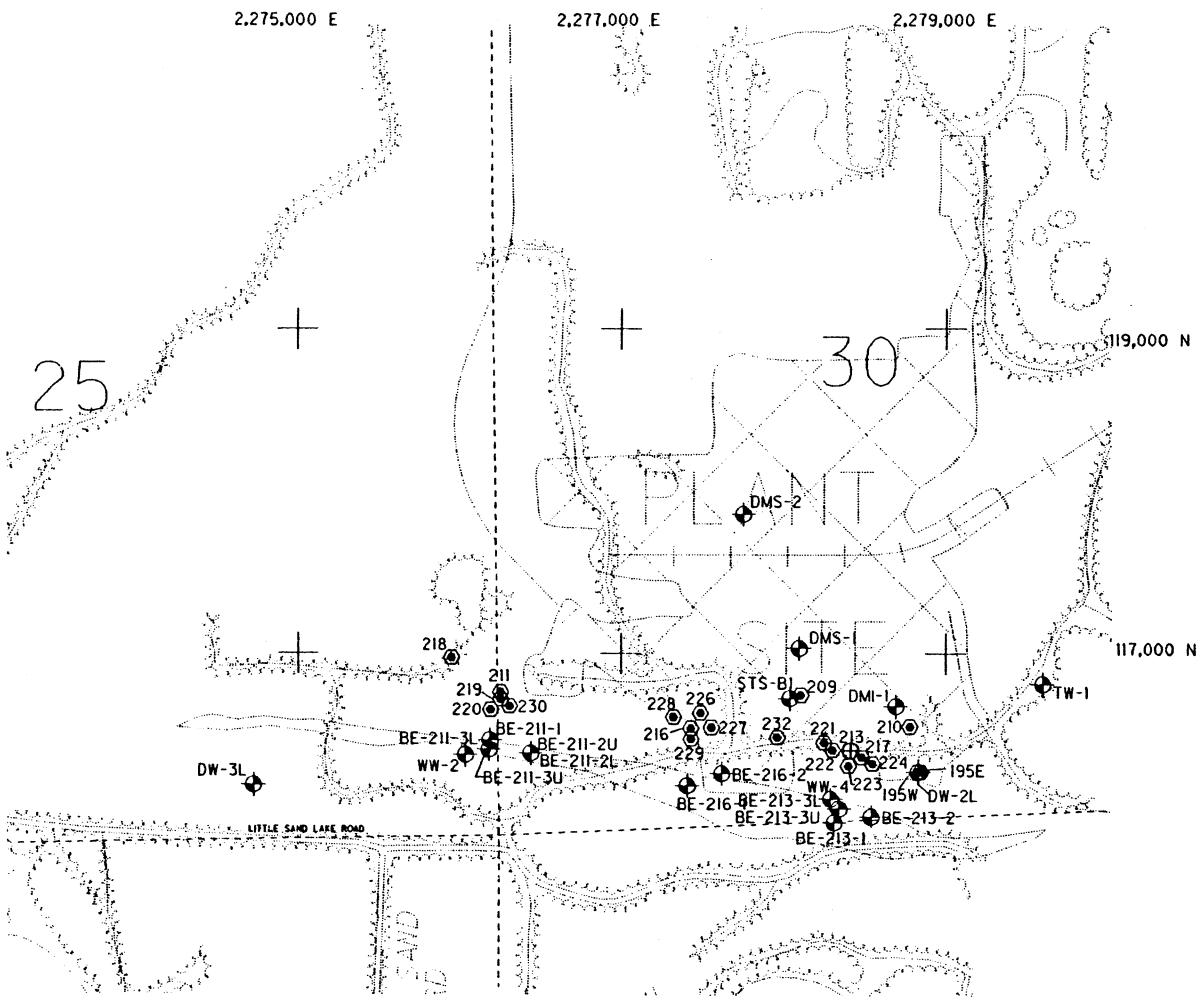
FIGURE 3.6-25

211 PUMP TEST SETUP

Scale: 0 600' 1200' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: KMP

93C049



LEGEND

- LAKES
- STREAMS
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED HAUL ROAD AND PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- DMI-1 OBSERVATION WELL
- 209 ANGLED CORE HOLE OBSERVATION POINT COLLAR LOCATION
- 213 ANGLED CORE HOLE USED FOR PUMPED WELL COLLAR LOCATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

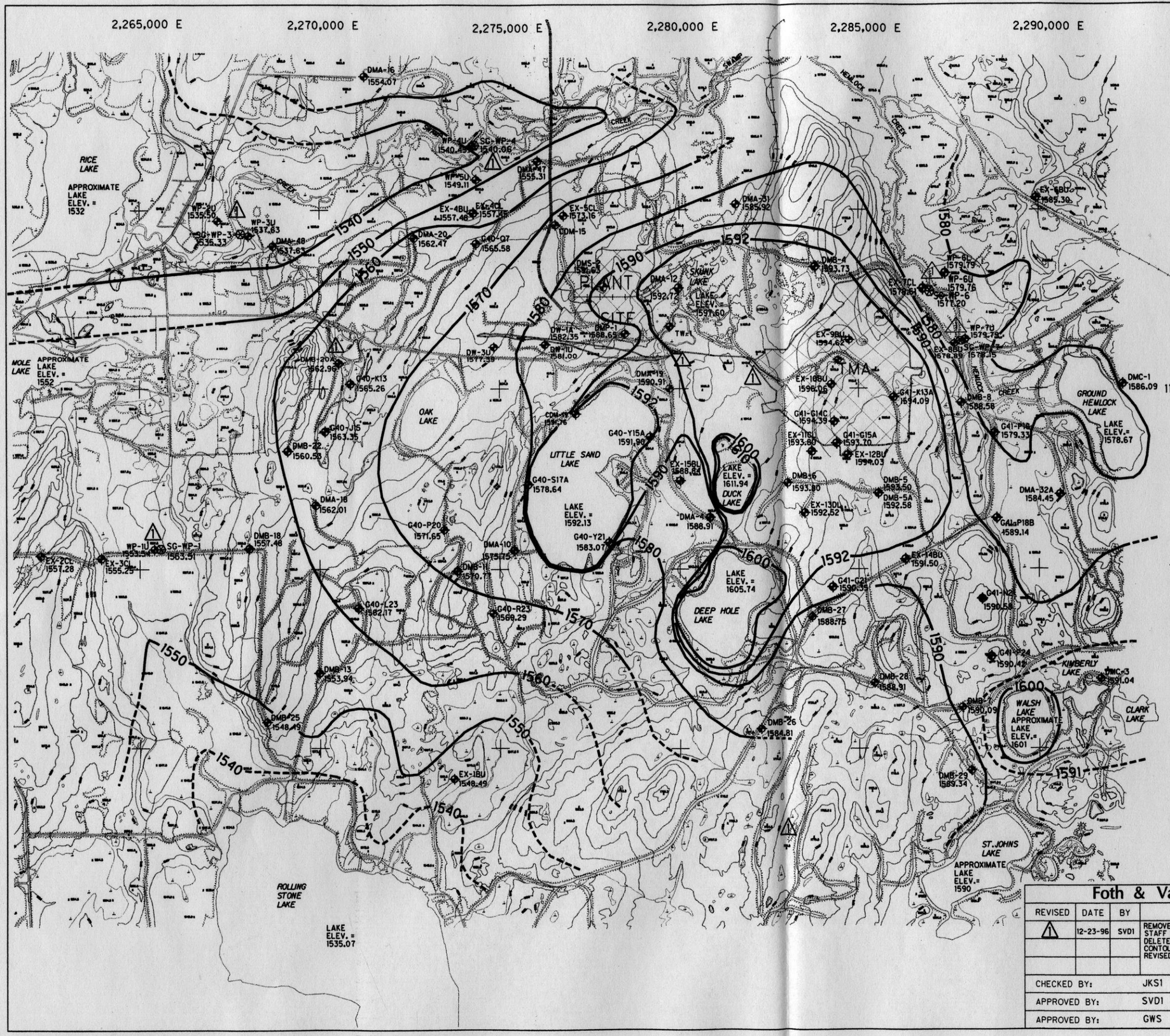
FIGURE 3.6-26

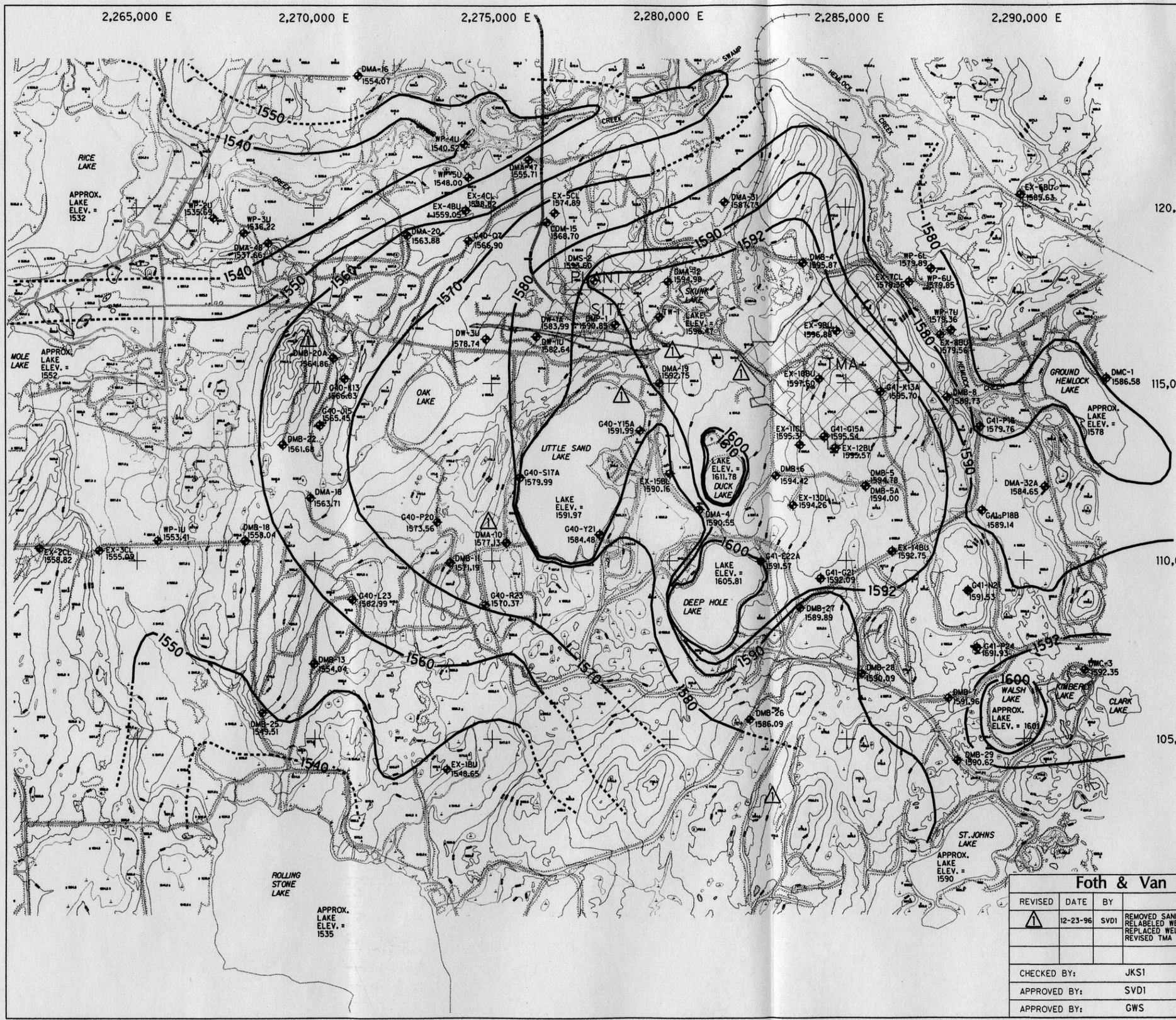
213 PUMP TEST SETUP

Scale: 0 600' 1200' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: KMP

/d3/dl/users/iow/4c33f99.dgn


2,265,000 E
2,270,000 E
2,275,000 E
2,280,000 E
2,285,000 E
2,290,000 E
120,000 N
115,000 N
110,000 N
105,000 N
RICE LAKE
APPROXIMATE LAKE ELEV. = 1532
MOLE LAKE
APPROXIMATE LAKE ELEV. = 1552
OAK LAKE
LITTLE SAND LAKE
LAKE ELEV. = 1592.13
DUCK LAKE
LAKE ELEV. = 1611.94
DEEP HOLE LAKE
LAKE ELEV. = 1605.74
SKUNK LAKE
LAKE ELEV. = 1597.60
PLANT SITE
TMA
HEMLOCK CREEK
GROUND HEMLOCK LAKE
LAKE ELEV. = 1578.67
KIMBERLY LAKE
WALSH LAKE APPROXIMATE LAKE ELEV. = 1601
CLARK LAKE
ST. JOHNS LAKE
APPROXIMATE LAKE ELEV. = 1590
ROLLING STONE LAKE
LAKE ELEV. = 1535.07
1540
1550
1560
1570
1580
1590
1592
1600
1591
DMA-16 1554.07
WP-4U 1540.49
SG-WP-4 1540.08
DMA-17 1555.31
WP-5U 1549.11
EX-4BU 1557.48
EX-4CL 1557.48
WP-2U 1535.56
WP-3U 1537.63
SG-WP-3 1535.33
DMA-48 1537.63
DMA-20 1562.47
G40-Q7 1565.58
EX-5CL 1573.16
DDM-15
DMA-31 1585.92
DMS-2 1574.63
DMA-12 1592.72
DMP-1 1588.69
DW-1A 1582.35
DW-1U 1581.00
DW-3U 1577.39
DMB-20A 1562.96
G40-K13 1565.26
G40-J15 1563.35
DMB-22 1560.58
DMA-18 1562.01
G40-P20 1571.65
DMA-10 1575.75
DMB-11 1570.77
G40-R23 1569.29
G40-L23 1562.17
DMB-13 1553.94
DMB-25 1548.49
EX-1BU 1548.49
G40-Y15A 1591.90
EX-15BL 1588.84
G40-S17A 1578.64
G40-Y21 1583.07
DMA-4 1588.91
DMR-19 1590.91
DDM-19 1591.16
DW-2U 1591.90
EX-2CL 1557.28
EX-3CL 1555.25
WP-1U 1563.54
SG-WP-1 1563.51
DMB-18 1557.48
EX-16BU 1596.06
G41-K13A 1594.09
G41-G14C 1594.39
EX-11BL 1593.80
G41-G15A 1593.70
EX-12BU 1594.03
DMB-16 1593.80
DMB-5 1593.50
DMB-5A 1592.58
EX-13DL 1592.52
G41aP18B 1589.14
EX-14BU 1591.50
G41-N23 1590.58
G41-P24 1590.48
DMB-27 1588.75
DMB-28 1589.91
DMB-7 1590.09
DMB-29 1589.34
DMB-26 1584.81
EX-9BU 1594.62
EX-8BU 1576.28
WP-7U 1579.75
WP-6U 1579.76
WP-6 1577.20
EX-7CL 1579.84
EX-6BU 1585.30
DMB-8 1588.58
G41-P18 1579.33
DMA-32A 1584.45
DMC-1 1586.09
DMC-3 1591.04
SG-WP-1 1553.54
EX-2CL 1557.28
EX-3CL 1555.25
DMB-18 1557.48
DMB-13 1553.94
DMB-25 1548.49
EX-1BU 1548.49
DMB-22 1560.58
DMA-18 1562.01
G40-P20 1571.65
G40-L23 1562.17
G40-J15 1563.35
G40-K13 1565.26
DMB-20A 1562.96
DW-3U 1577.39
DW-1U 1581.00
DW-1A 1582.35
DMP-1 1588.69
DMA-12 1592.72
DMS-2 1574.63
DDM-15
EX-5CL 1573.16
DMA-31 1585.92
DMB-4 1593.73
EX-7CL 1579.84
WP-6U 1579.76
WP-6 1577.20
WP-7U 1579.75
EX-8BU 1576.28
EX-9BU 1594.62
DMC-1 1586.09
DMB-8 1588.58
G41-P18 1579.33
DMA-32A 1584.45
G41aP18B 1589.14
EX-14BU 1591.50
G41-N23 1590.58
G41-P24 1590.48
DMC-3 1591.04
DMB-7 1590.09
DMB-29 1589.34
DMB-26 1584.81
DMB-27 1588.75
DMB-28 1589.91
DMB-5A 1592.58
DMB-5 1593.50
DMB-16 1593.80
EX-13DL 1592.52
EX-11BL 1593.80
EX-16BU 1596.06
G41-K13A 1594.09
G41-G14C 1594.39
G41-G15A 1593.70
EX-12BU 1594.03
EX-15BL 1588.84
G40-S17A 1578.64
G40-Y15A 1591.90
G40-Y21 1583.07
DMA-4 1588.91
DMA-10 1575.75
DMB-11 1570.77
G40-R23 1569.29
G40-L23 1562.17
DMB-13 1553.94
DMB-25 1548.49
EX-1BU 1548.49
DMB-22 1560.58
DMA-18 1562.01
G40-P20 1571.65



LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7CL 1578.35 — MONITORING WELL LOCATION, NUMBER AND WATER TABLE ELEVATION
- —1580— GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)
- ----1580---- INFERRED GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12-23-96	SVD1	REMOVED SAND POINT DATA. RELABELED WELL DMB-10 TO DMA-10. REPLACED WELL DMB-20 WITH DMB-20A. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-28
HIGH WATER TABLE CONTOUR MAP
AUGUST, 1986

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JRB2

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93C049

2,265,000 E 2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E 2,290,000 E

120,000 N

115,000 N

110,000 N

105,000 N

RICE LAKE
APPROX. LAKE ELEV. = 1532
MOLE LAKE
APPROX. LAKE ELEV. = 1552
OAK LAKE
LITTLE SAND LAKE
LAKE ELEV. = 1593.00
DUCK LAKE
LAKE ELEV. = 1612.68
DEEP HOLE LAKE
LAKE ELEV. = 1605.74
PLANT SITE
TMA
SKUNK LAKE
LAKE ELEV. = 1591.29
SWAMP
CREEK
HEMLOCK CREEK
GROUND HEMLOCK LAKE
APPROX. LAKE ELEV. = 1578
WALSH LAKE
APPROX. LAKE ELEV. = 1601
KIMBERLY LAKE
CLARK LAKE
ST. JOHNS LAKE
APPROX. LAKE ELEV. = 1590
ROLLING STONE LAKE
APPROX. LAKE ELEV. = 1535

1540 1550 1560 1570 1580 1590 1592 1600

N

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-10AL 1589.94 — MONITORING WELL LOCATION, NUMBER AND GROUND WATER ELEVATION
- —1590— GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET
- ····1550···· INFERRED GROUNDWATER CONTOUR
- CMC-02R — WELL USED FOR WATER TABLE CONTOUR

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
6. GROUNDWATER ELEVATIONS MEASURED JUNE 12, 1995.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS	DATE:	DEC. '96
APPROVED BY:	SVD1	DATE:	DEC. '96
APPROVED BY:	GWS	DATE:	DEC. '96

Crandon Mining Company

FIGURE 3.6-28A
WATER TABLE CONTOUR MAP
JUNE, 1995

Scale:	AS SHOWN	Date:	DECEMBER, 1996
Prepared By:	Foth & Van Dyke	By:	JRB2

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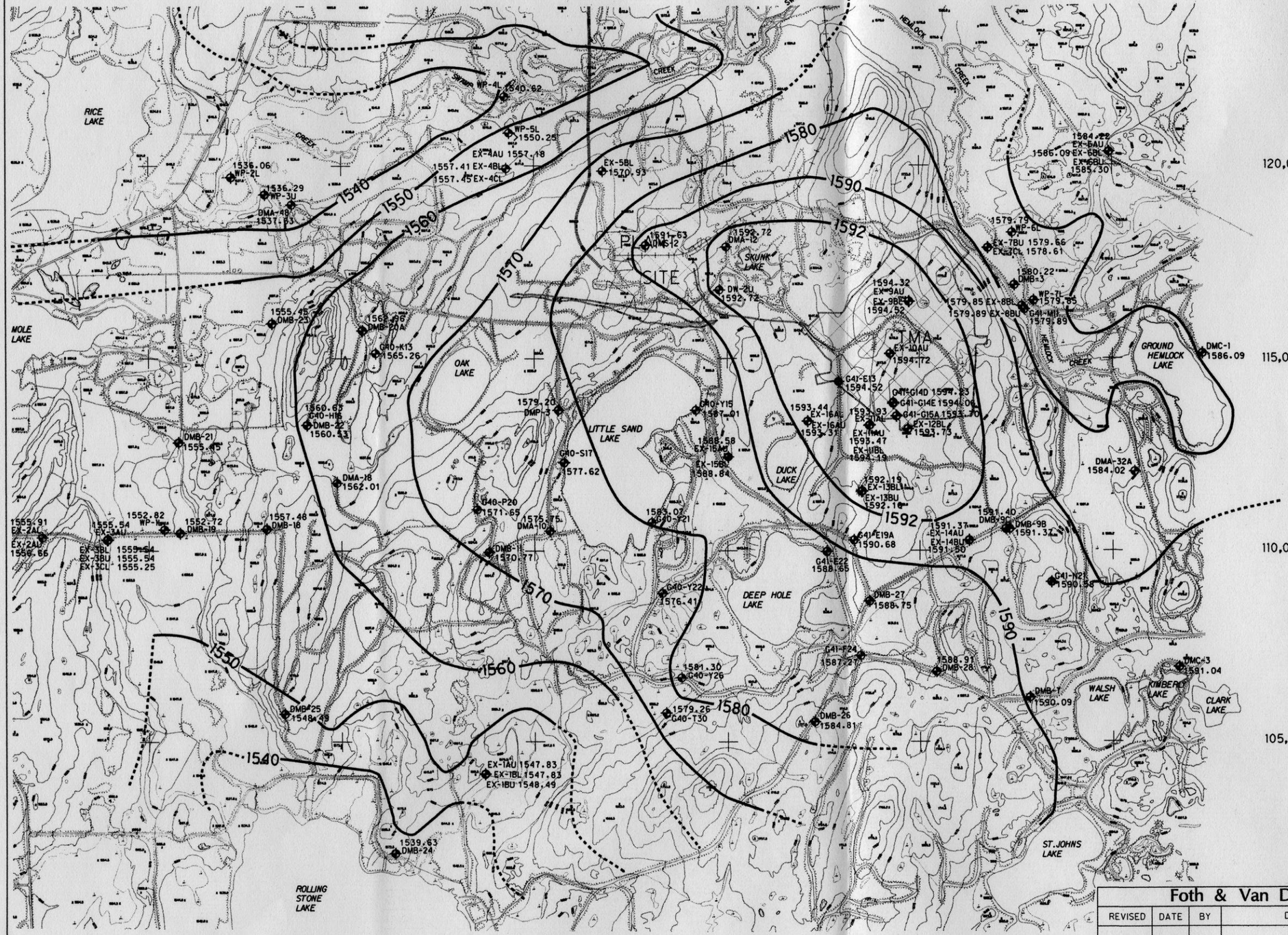
93C049



LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7CL 1578.61 — MONITORING WELL LOCATION, NUMBER AND PIEZOMETRIC HEAD
- —1590— GROUNDWATER EQUIPOTENTIAL LINE (CONTOUR INTERVAL = 10 FEET)
- ·····1550···· INFERRED GROUNDWATER EQUIPOTENTIAL LINE

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: DEC. '96
APPROVED BY:	SVD1	DATE: DEC. '96
APPROVED BY:	GWS	DATE: DEC. '96

Crandon Mining Company

FIGURE 3.6-28B
POTENTIOMETRIC SURFACE OF GLACIAL OUTWASH, OCTOBER 31, 1984

Scale:	AS SHOWN	Date:	DECEMBER, 1996
Prepared By:	Foth & Van Dyke	By:	JRB2

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93C049

2,265,000 E | 2,270,000 E | 2,275,000 E | 2,280,000 E | 2,285,000 E | 2,290,000 E

120,000 N | 115,000 N | 110,000 N | 105,000 N

RICE LAKE | MOLE LAKE | OAK LAKE | LITTLE SAND LAKE | DUCK LAKE | DEEP HOLE LAKE | ROLLING STONE LAKE | SKUNK LAKE | HEMLOCK CREEK | GROUND HEMLOCK LAKE | WALSH LAKE | KIMBERLY LAKE | CLARK LAKE | ST. JOHNS LAKE

PLANT SITE | TMA

1540 | 1550 | 1560 | 1570 | 1580 | 1590 | 1592

EX-4AL #657.68 | EX-6AL 1584.22 | EX-7AL 1582.32 | EX-7BL 1581.27 | EX-8AL 1584.68 | EX-8AU 1582.97 | DMS-1 1574.78 | TW-1 1582.29 | 1577.49 | DW-3L | DW-3U 1577.39 | DW-1L 1582.32 | DW-1U 1581.00 | BE-2U-3U 1583.37 | BE-2L-3U 1581.30 | BE-2L-3U 1585.7 | DW-2U 1589.93 | G40-M15 1569.95 | G41-K13 1593.37 | G41-G14B 1593.90 | G41-G14F 1593.73 | G41-G15 1593.90 | EX-12AU 1593.73 | G41-C15 1593.16 | EX-15AL 1587.80 | G41-B17 1592.78 | EX-13AL 1592.16 | EX-3AL 1553.64 | G40-D24 1553.58 | G40-H27 1549.47 | EX-1AL 1548.13

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7AL 1582.32 — MONITORING WELL LOCATION, NUMBER AND WATER TABLE ELEVATION
- —1590— GROUNDWATER EQUIPOTENTIAL LINE (CONTOUR INTERVAL = 10 FEET)
- ····1550···· INFERRED GROUNDWATER EQUIPOTENTIAL LINE

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKS1	DATE: DEC. '96
APPROVED BY:	SVD1	DATE: DEC. '96
APPROVED BY:	GWS	DATE: DEC. '96

Crandon Mining Company

FIGURE 3.6-28C

POTENTIOMETRIC SURFACE OF PRE- TO EARLY WISCONSINAN TILL OCTOBER 31, 1984

Scale:	AS SHOWN	Date:	DECEMBER, 1996
Prepared By:	Foth & Van Dyke	By:	JRB2

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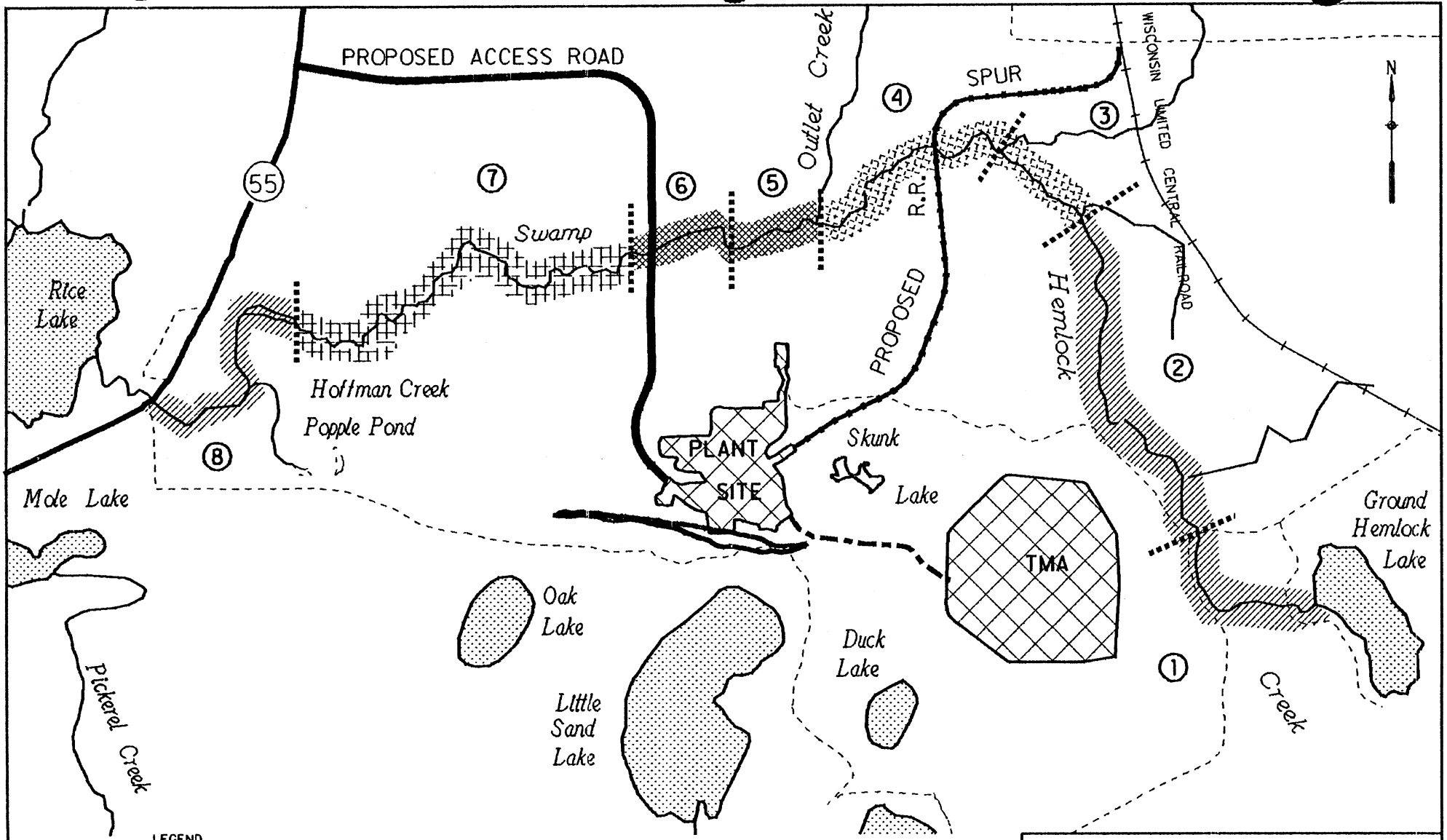
93C049



Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	RFS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-29

OBSERVED BOTTOM CHARACTERISTICS OF HEMLOCK AND SWAMP CREEKS

Scale:	1" = 3000'	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JOW

/d3/dl/users/jpr/14c57f47.dgn

93C0049

2,265,000 E 2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E 2,290,000 E

120,000 N

115,000 N

110,000 N

105,000 N

RICE LAKE
SWAMP
CREEK
SWAMP
CREEK
HEMLOCK
CREEK
PLANT SITE
SKUNK LAKE
CMC-BO-101A 1628.69 (1/95)
G41-G12 1661.29 (10/84)
TMA
MOLE LAKE
DMB-2D 1580.83 (10/84)
OAK LAKE
DMA-1N 1620.37 (10/83)
CMC-DL-103A 1607.54 (1/95)
G41-C15C 1607.87 (10/84)
LITTLE SAND LAKE
DUCK LAKE
G41-H18A 1679.20 (1/84)
HEMLOCK CREEK
GROUND HEMLOCK LAKE
DEEP HOLE LAKE
G41-M24 1622.44 (9/80)
WALSH LAKE
KIMBERLY LAKE
CLARK LAKE
ST. JOHNS LAKE
ROLLING STONE LAKE

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- G41-G12 1661.29 (10/84) — PERCHED MONITORING WELL LOCATION GROUNDWATER ELEVATION, (MONTH/YEAR OF MEASUREMENT)

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	01/97	GWS	REVISED TMA LIMITS OF DISTURBANCE

CHECKED BY:	JKS1	DATE: AUG. '95
APPROVED BY:	SVD1	DATE: AUG. '95
APPROVED BY:	GWS	DATE: AUG. '95

Crandon Mining Company

FIGURE 3.6-29A

LOCATION OF PERCHED GROUNDWATER

Scale: AS SHOWN | Date: AUGUST, 1995

Prepared By: Foth & Van Dyke | By: JRB2

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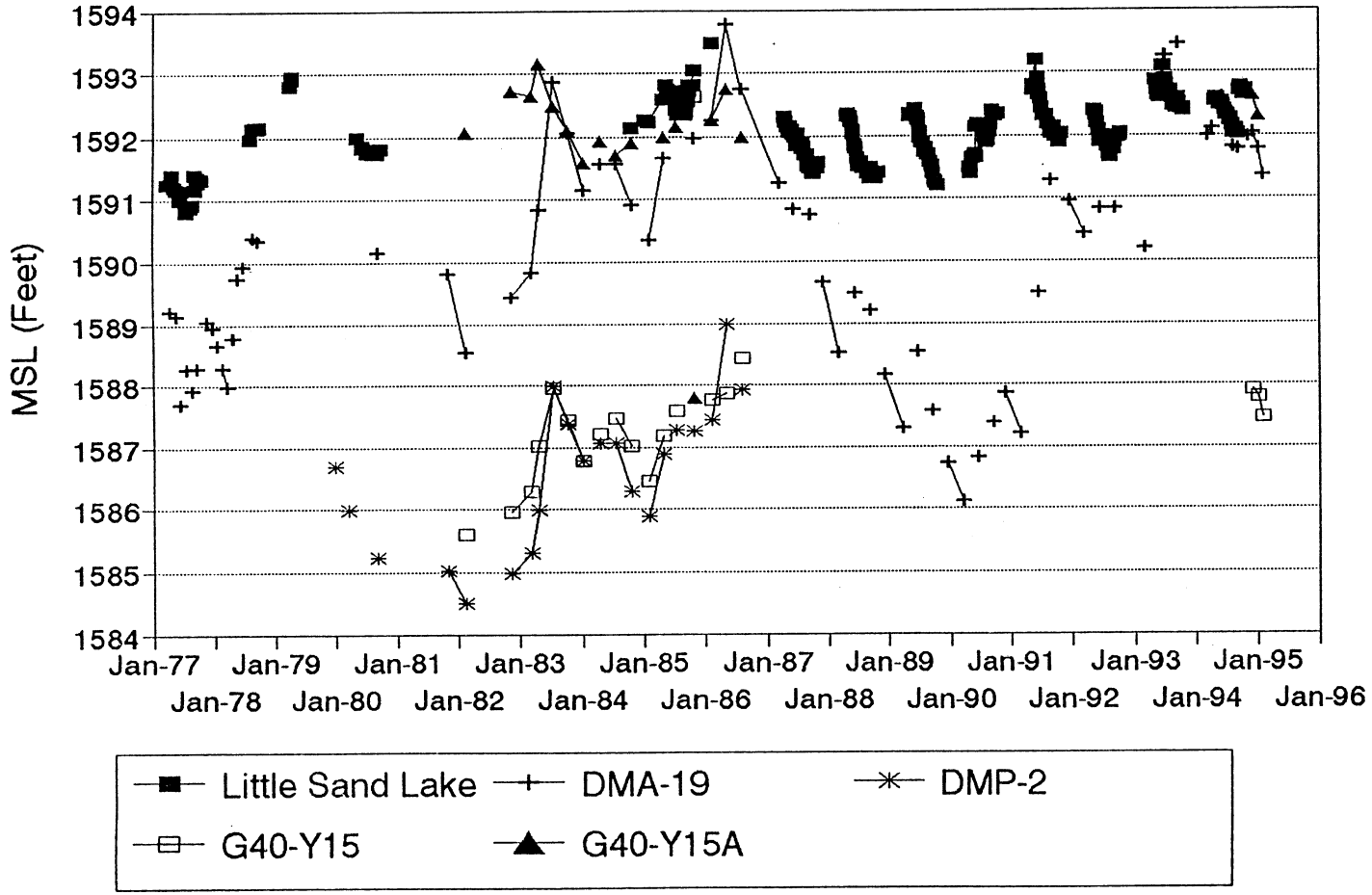
Crandon Project

Surface Water and Groundwater Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

Crandon Mining Company

FIGURE 3.6-30

LAKE STAGE OF LITTLE SAND LAKE
VS. UPGRADIENT WELLS

Scale:	N.T.S.	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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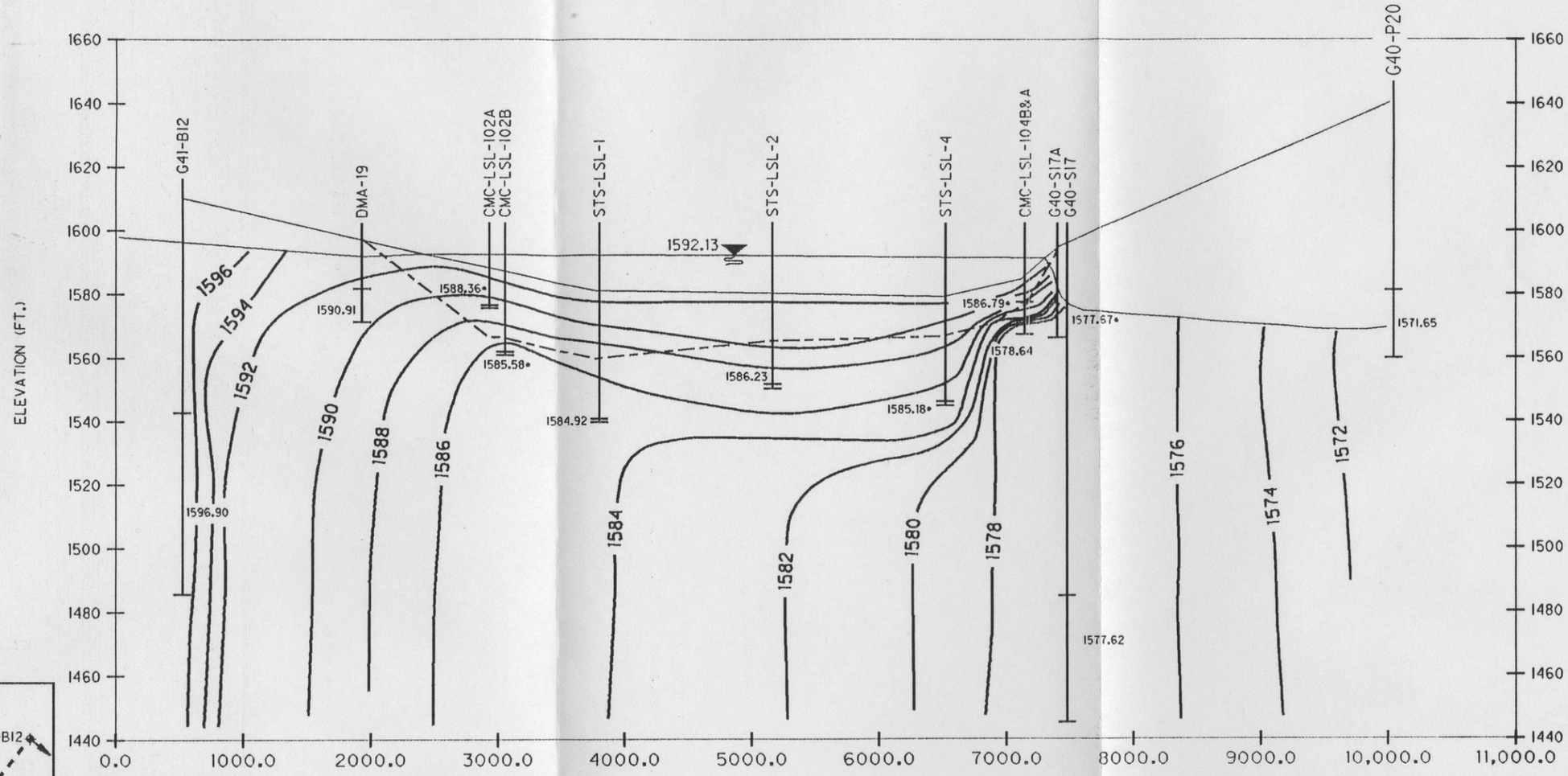
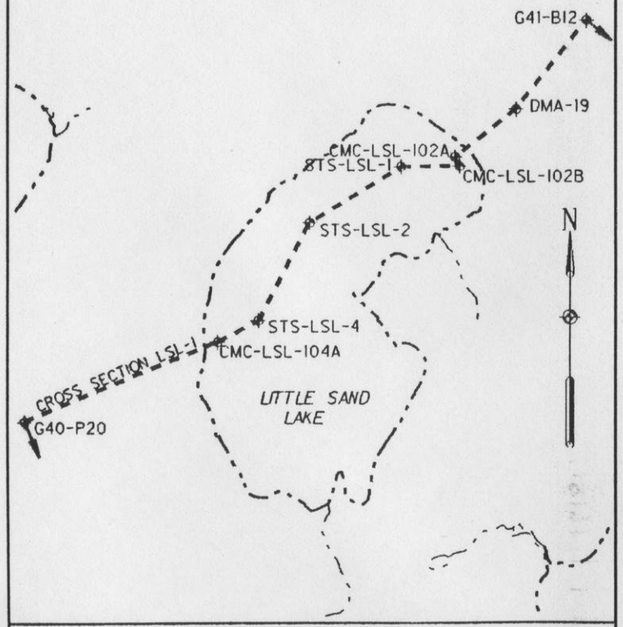
93C049



NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-31
SECTION LSL-1
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED 10/30/84

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

93C049

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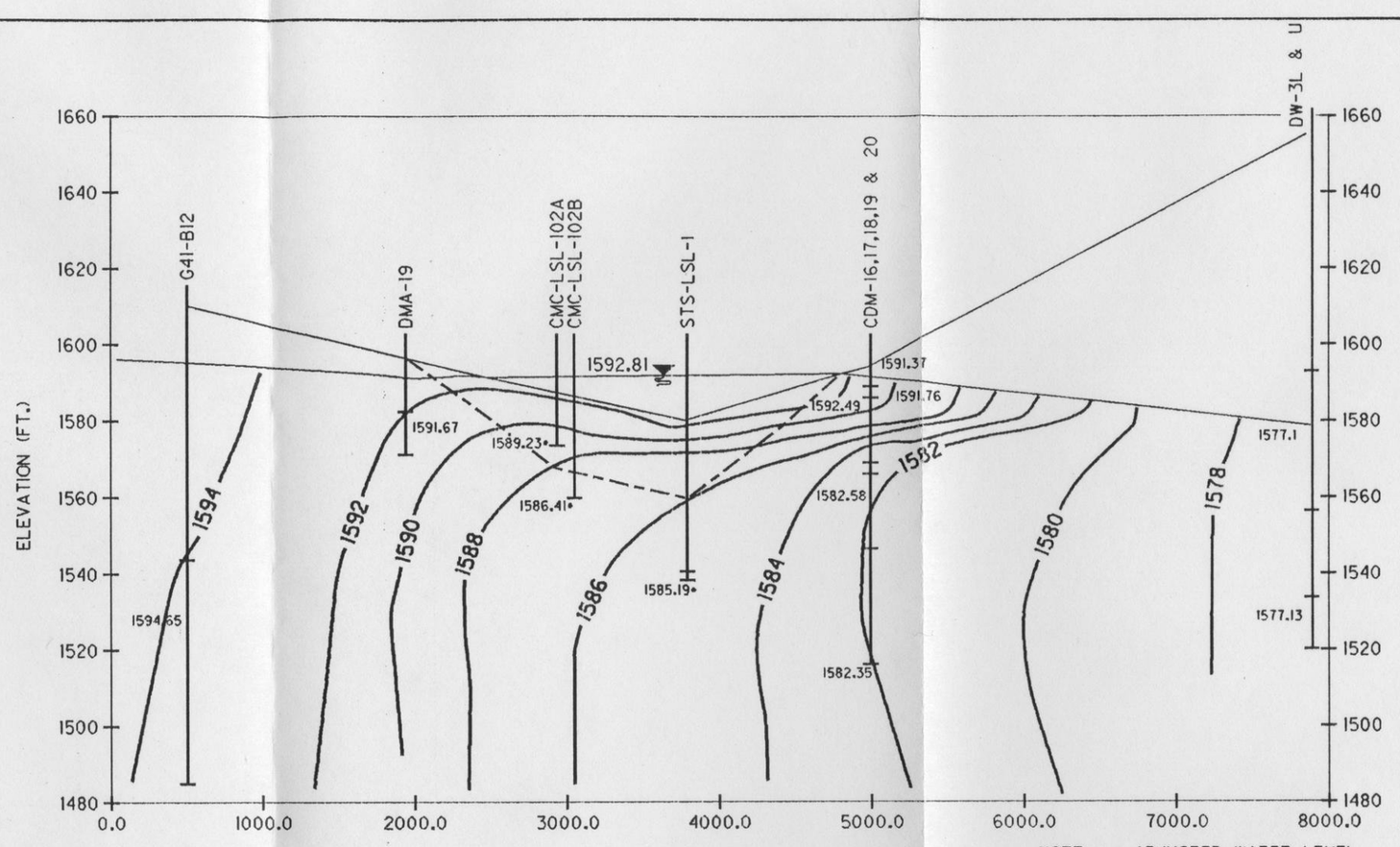
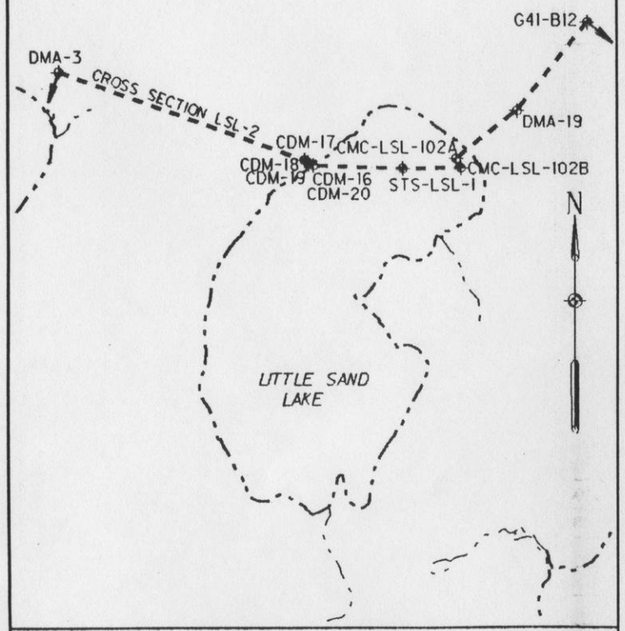


NOTE: • = ADJUSTED WATER LEVEL
(SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL- 2

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:		JKSI		DATE: MAY '95
APPROVED BY:		SVDI		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-32
SECTION LSL-2
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED 5/9/85

Scale:	AS SHOWN	Date:	MAY, 1994
Prepared By:	Foth & Van Dyke	By:	KMP

93C049

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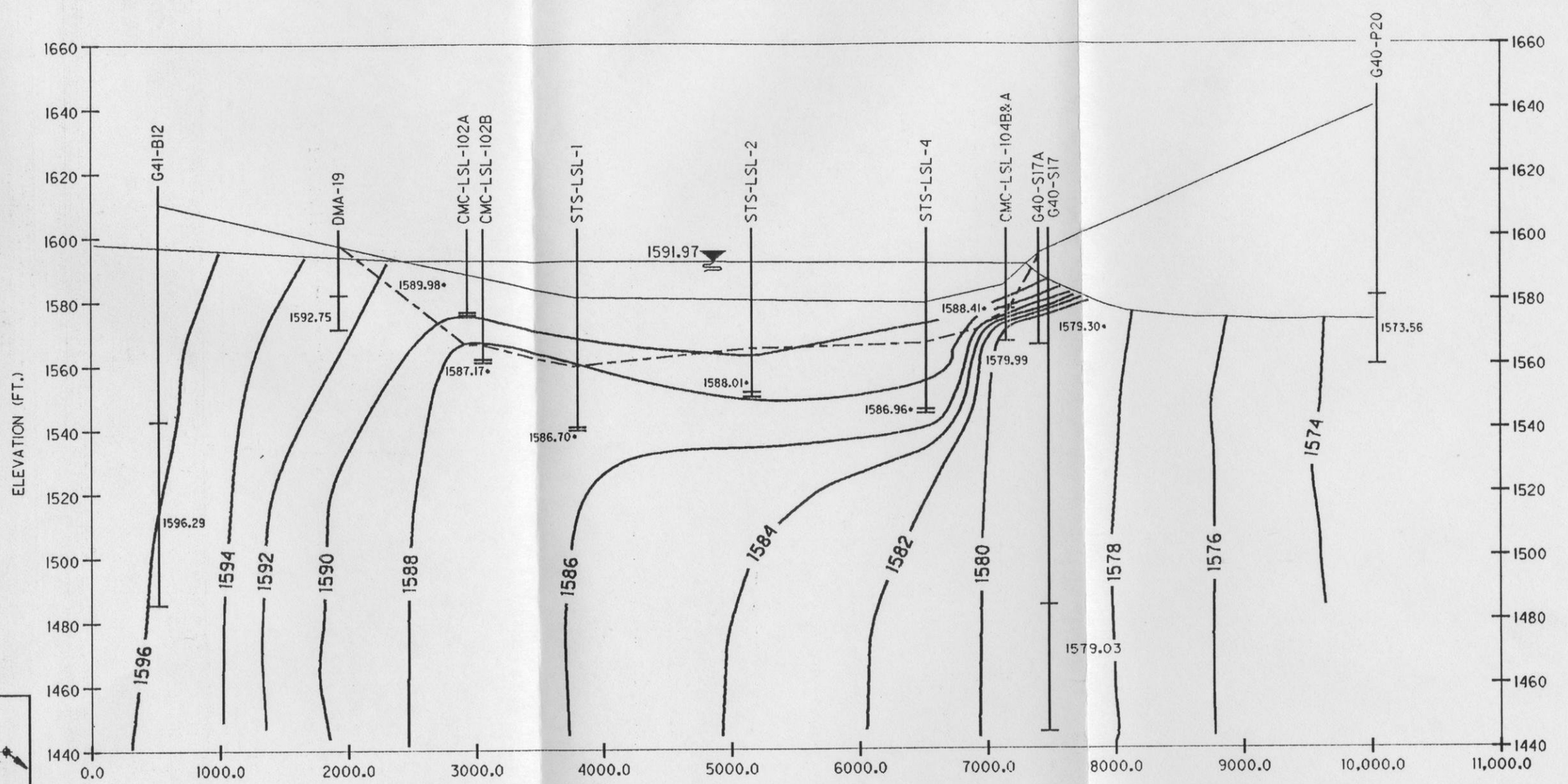
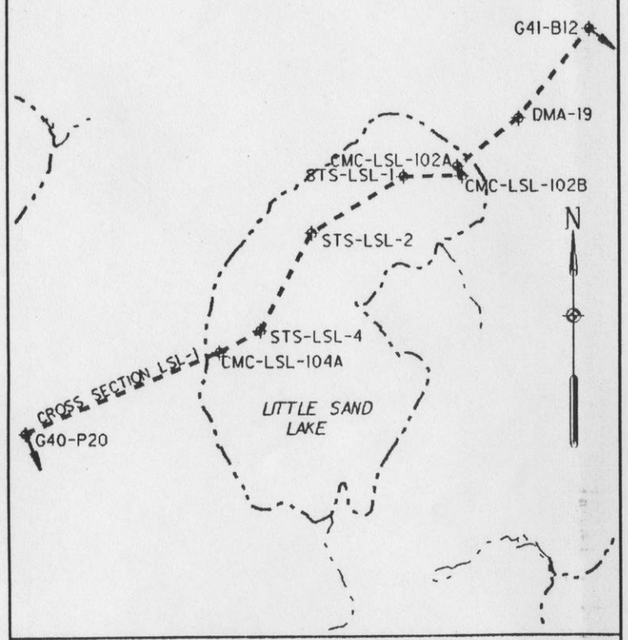


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:		JKSI		DATE: MAY '95
APPROVED BY:		SVDI		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-33
SECTION LSL-1
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
HIGH GW LEVELS - 8/11/86

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

93C049

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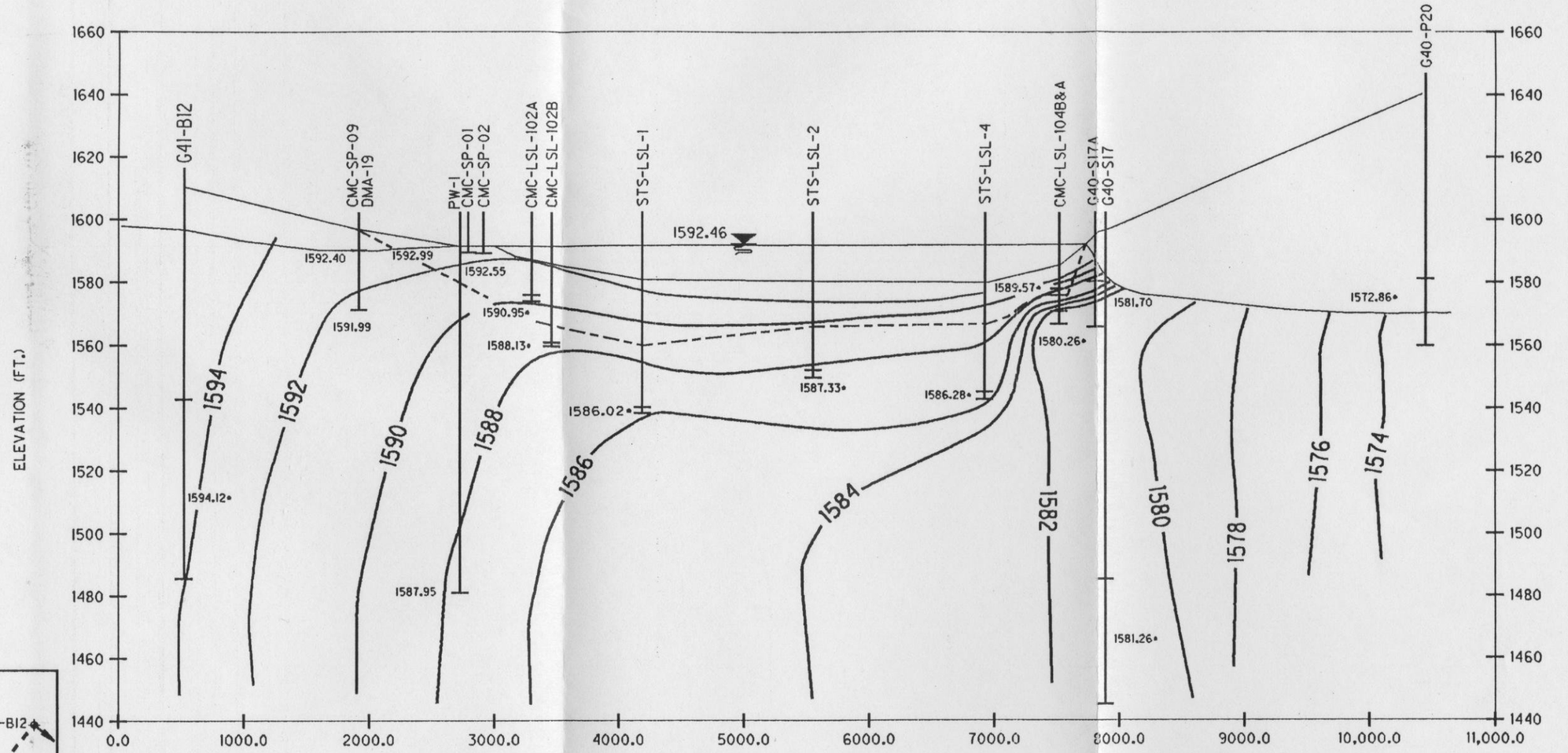
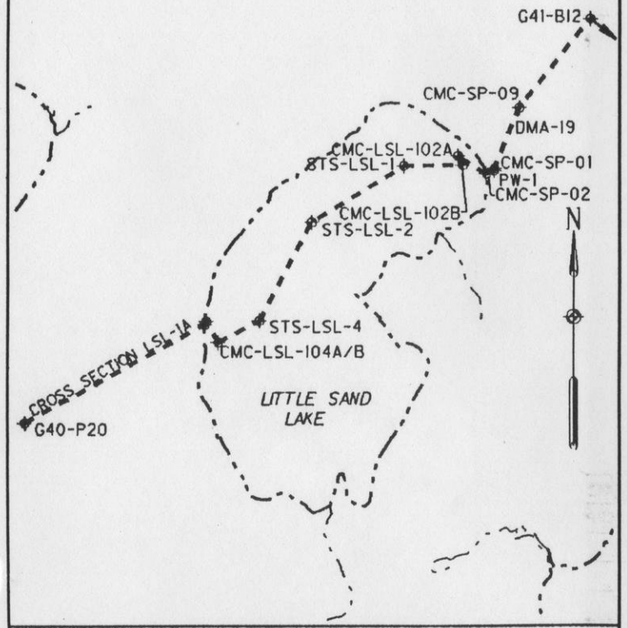


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1A

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:		JKSI		DATE: MAY '95
APPROVED BY:		SVDI		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-34
SECTION LSL-1A
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED DECEMBER, 1994

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

93C049

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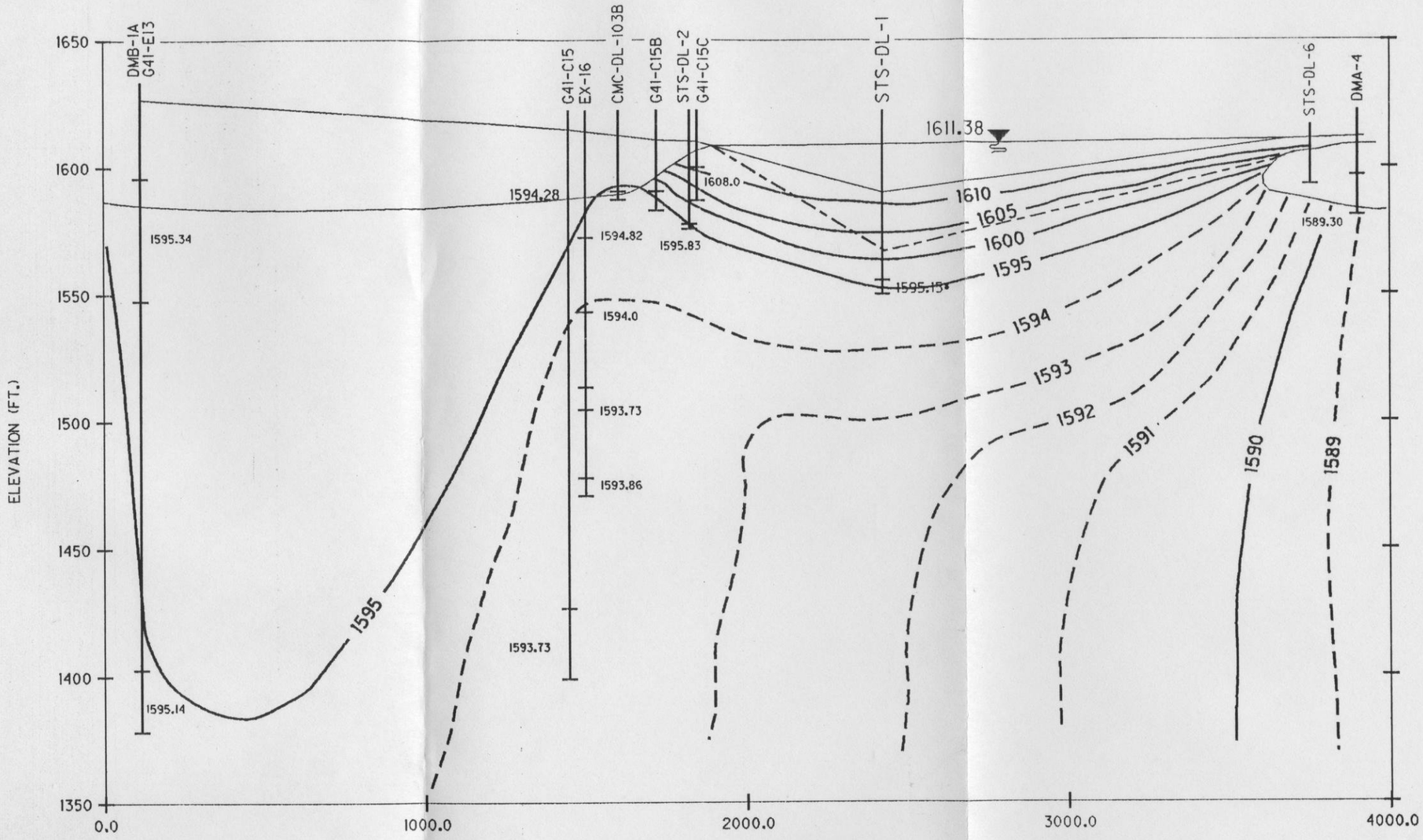
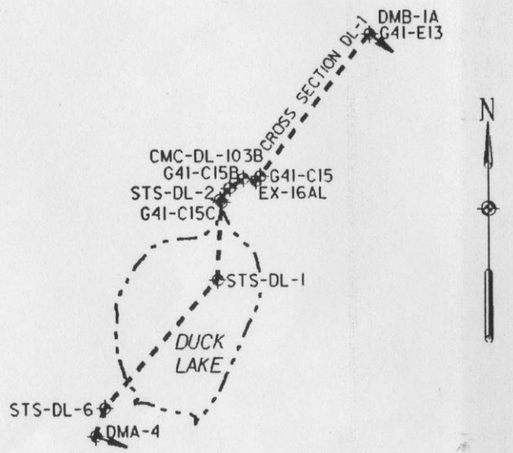


CROSS SECTION DL-1

SCALE: HORIZ. 1"=500'
VERT. 1"=50'

NOTE: * = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)



CROSS SECTION LOCATION MAP

SCALE: 1"=1200'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-35
SECTION DL-1
DUCK LAKE HYDRAULIC CROSS SECTION
MEASURED 2/15/86

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KM

93C049

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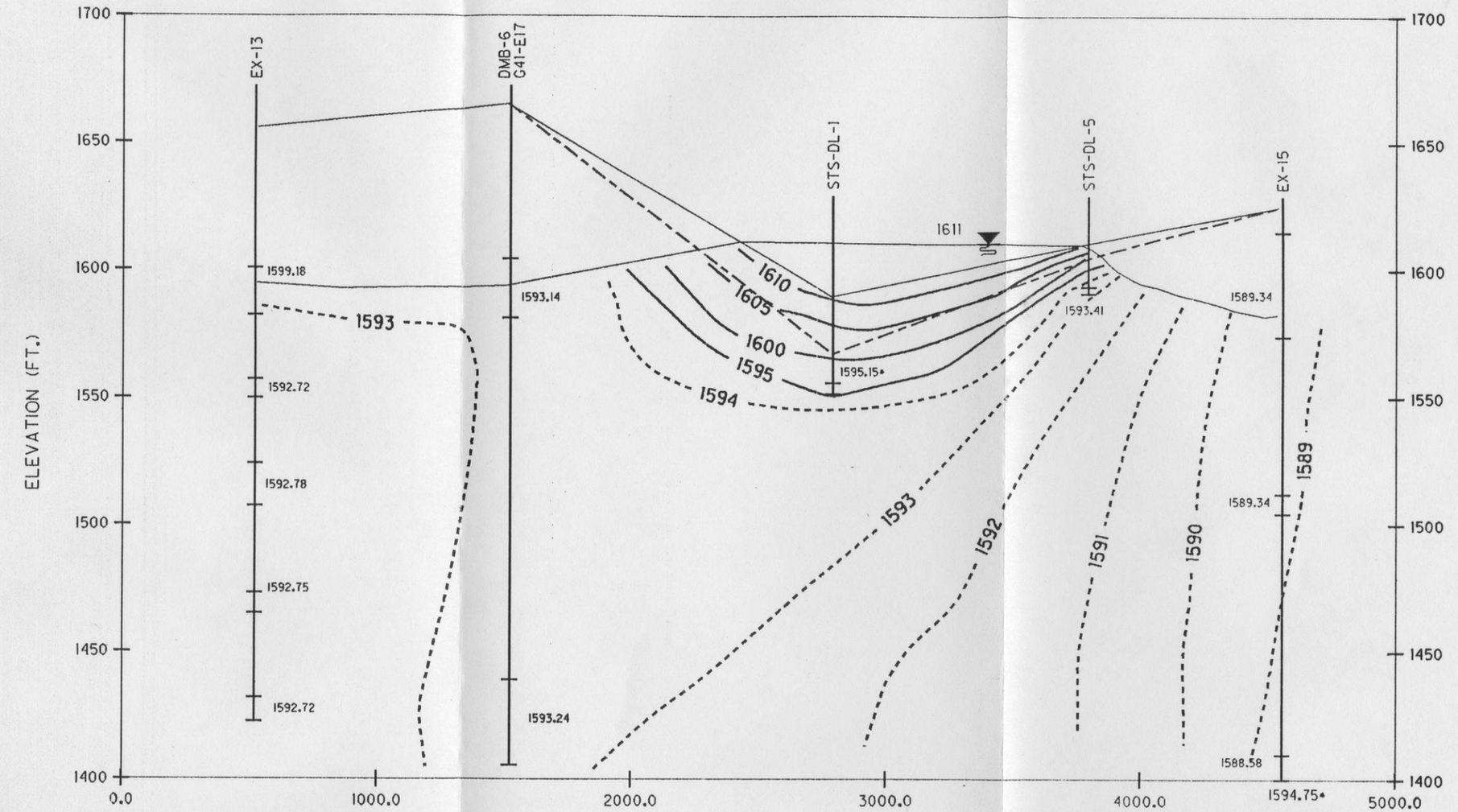
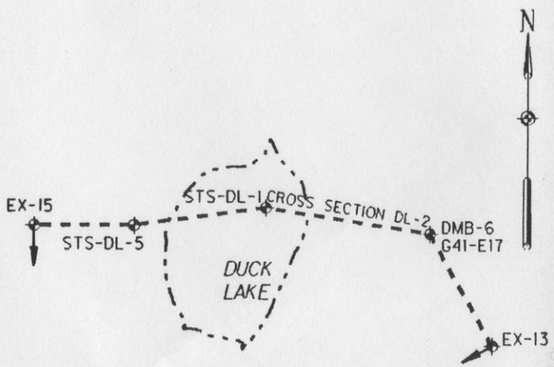


NOTE: * = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION DL-2

SCALE: HORIZ. 1"=500'
VERT. 1"=50'



CROSS SECTION LOCATION MAP

SCALE: 1"=1200'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:		JKSI		DATE: MAY '95
APPROVED BY:		SVDI		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-36
SECTION DL-2
DUCK LAKE LAKE HYDRAULIC CROSS SECTION
MEASURED 2/15/86

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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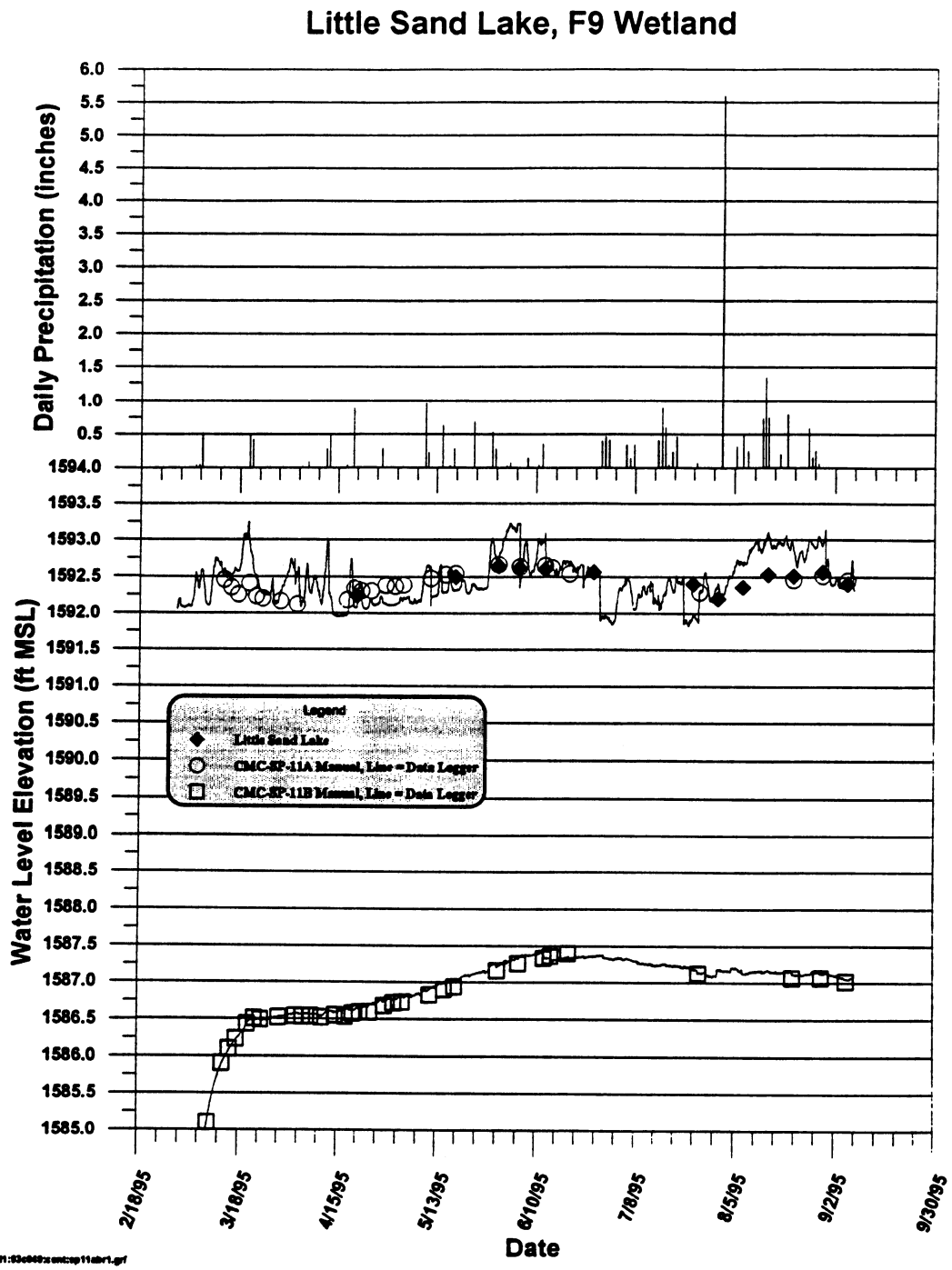

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAR. '96
APPROVED BY:	SVDI	DATE: MAR. '96
APPROVED BY:	JWS	DATE: MAR. '96

Crandon Mining Company

FIGURE 3.6-36A
COMPARISON OF TRANSIENT GROUNDWATER LEVELS IN THE F9 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MARCH, 1996
Prepared By:	Foth & Van Dyke	By:	JRB

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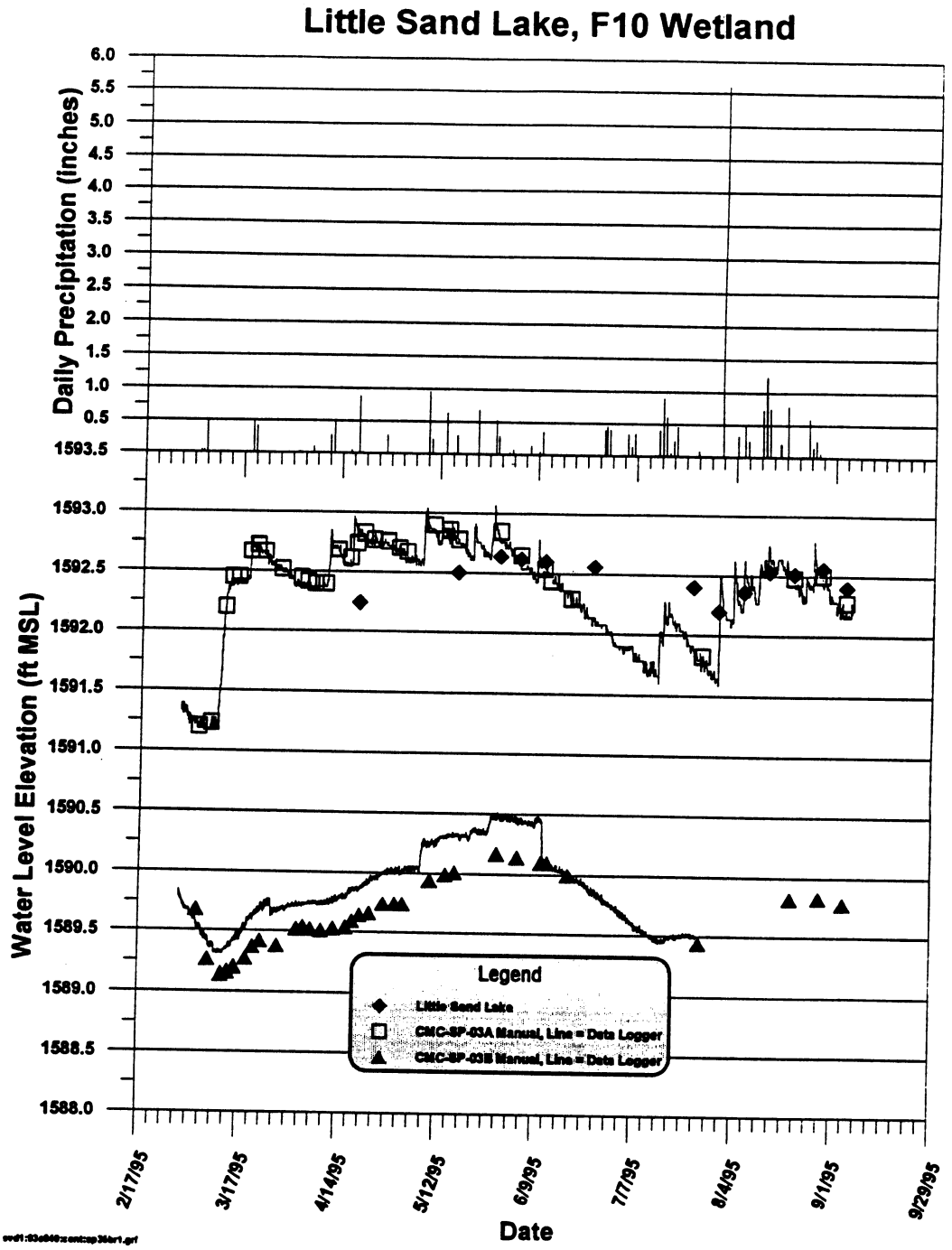
93C049



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAR. '96
APPROVED BY:	SVDI	DATE: MAR. '96
APPROVED BY:	JWS	DATE: MAR. '96

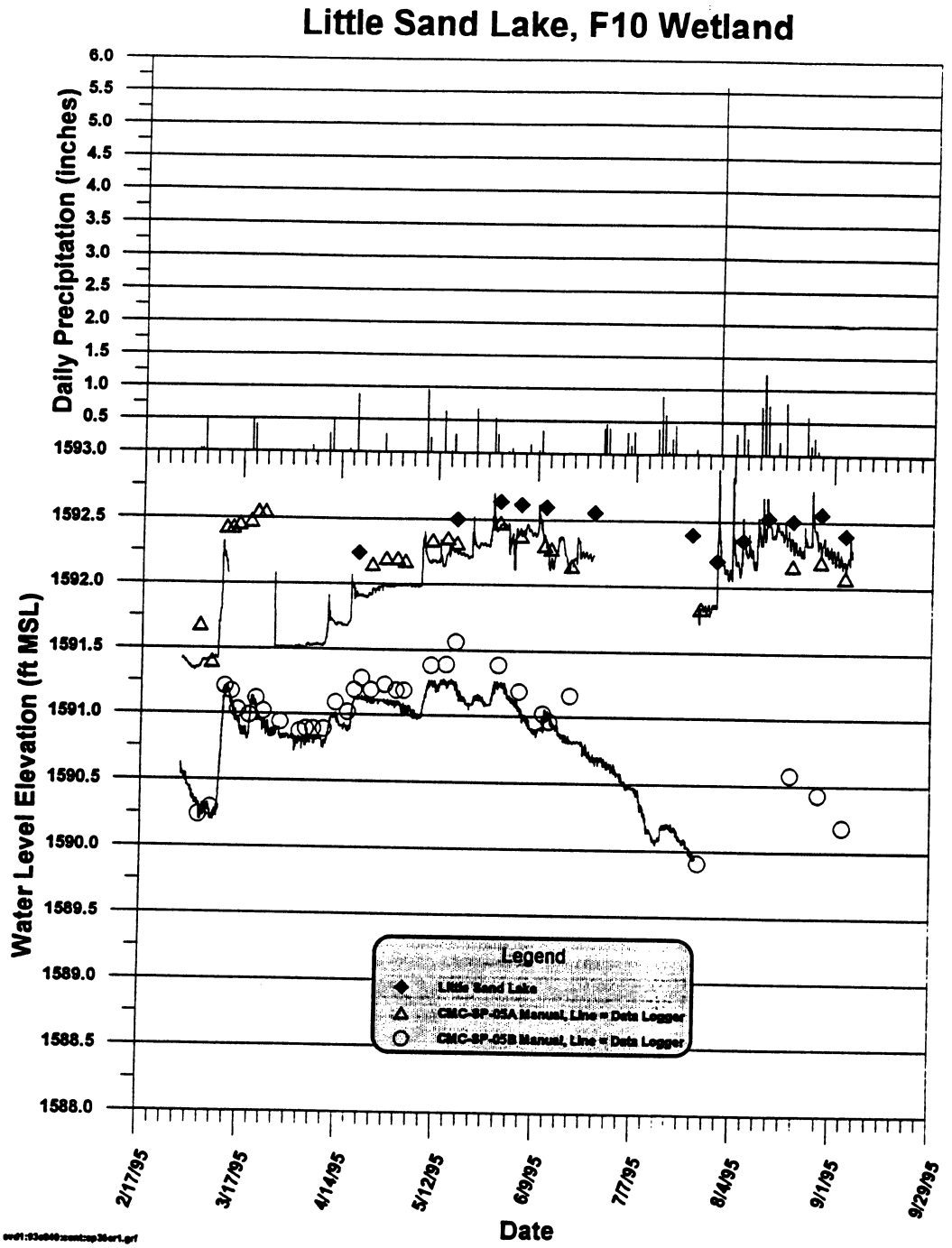
Crandon Mining Company

FIGURE 3.6-36B
COMPARISON OF TRANSIENT GROUNDWATER LEVELS IN THE F10 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MARCH, 1996
Prepared By:	Foth & Van Dyke	By:	JRB

c:\cadwork\4c33f164.dgn

93C049



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY: JKSI			DATE: MAR. '96
APPROVED BY: SVDI			DATE: MAR. '96
APPROVED BY: JWS			DATE: MAR. '96

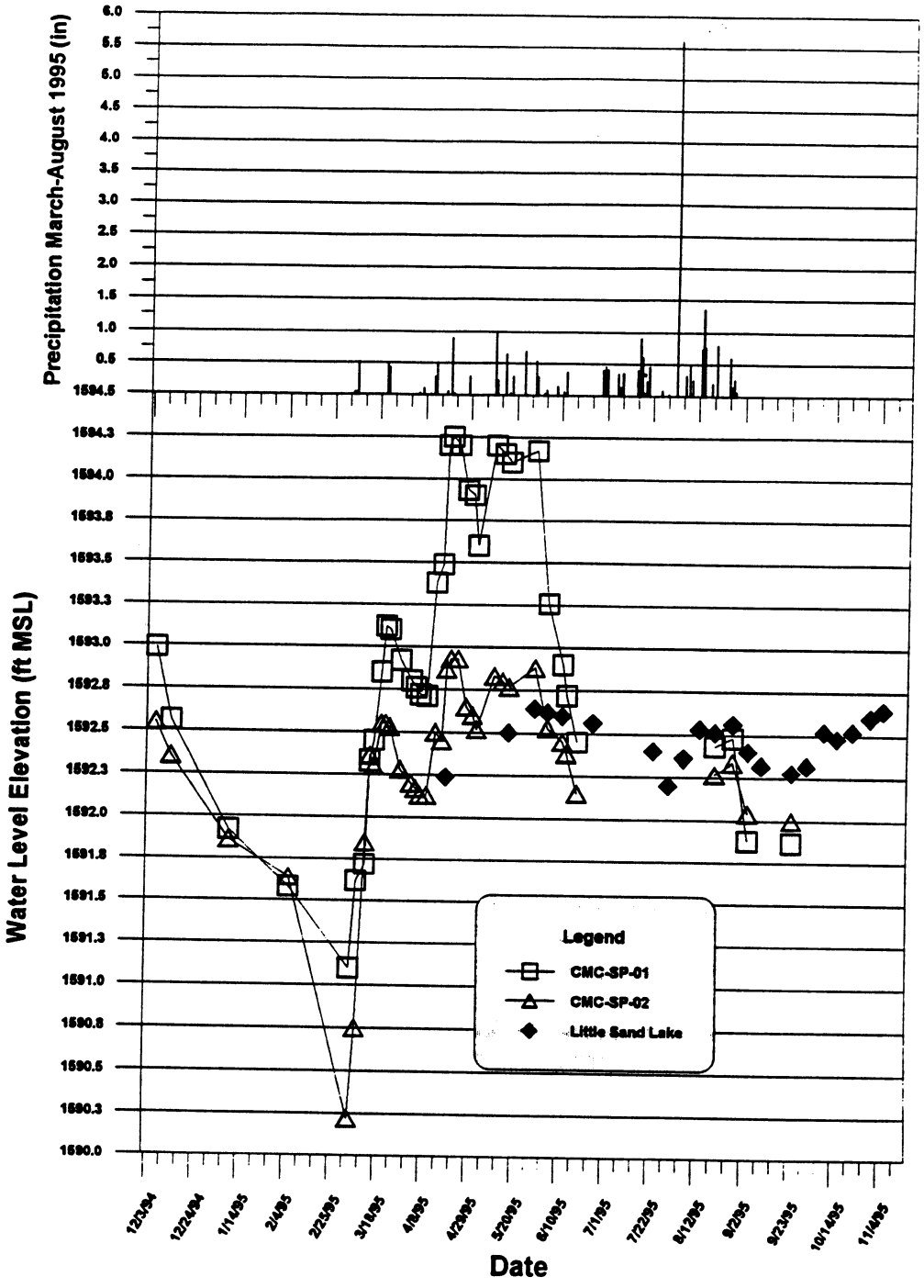
Crandon Mining Company

FIGURE 3.6-36C
COMPARISON OF TRANSIENT GROUNDWATER LEVELS NEAR THE F10 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN		Date: MARCH, 1996	
Prepared By: Foth & Van Dyke			By: JRB

c:\cadwork\4c33f164.dgn

93C049



svd1:93c049:conc:misc:sp01.grf

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE: MAR. '96	
APPROVED BY:	SVDI		DATE: MAR. '96	
APPROVED BY:	JWS		DATE: MAR. '96	

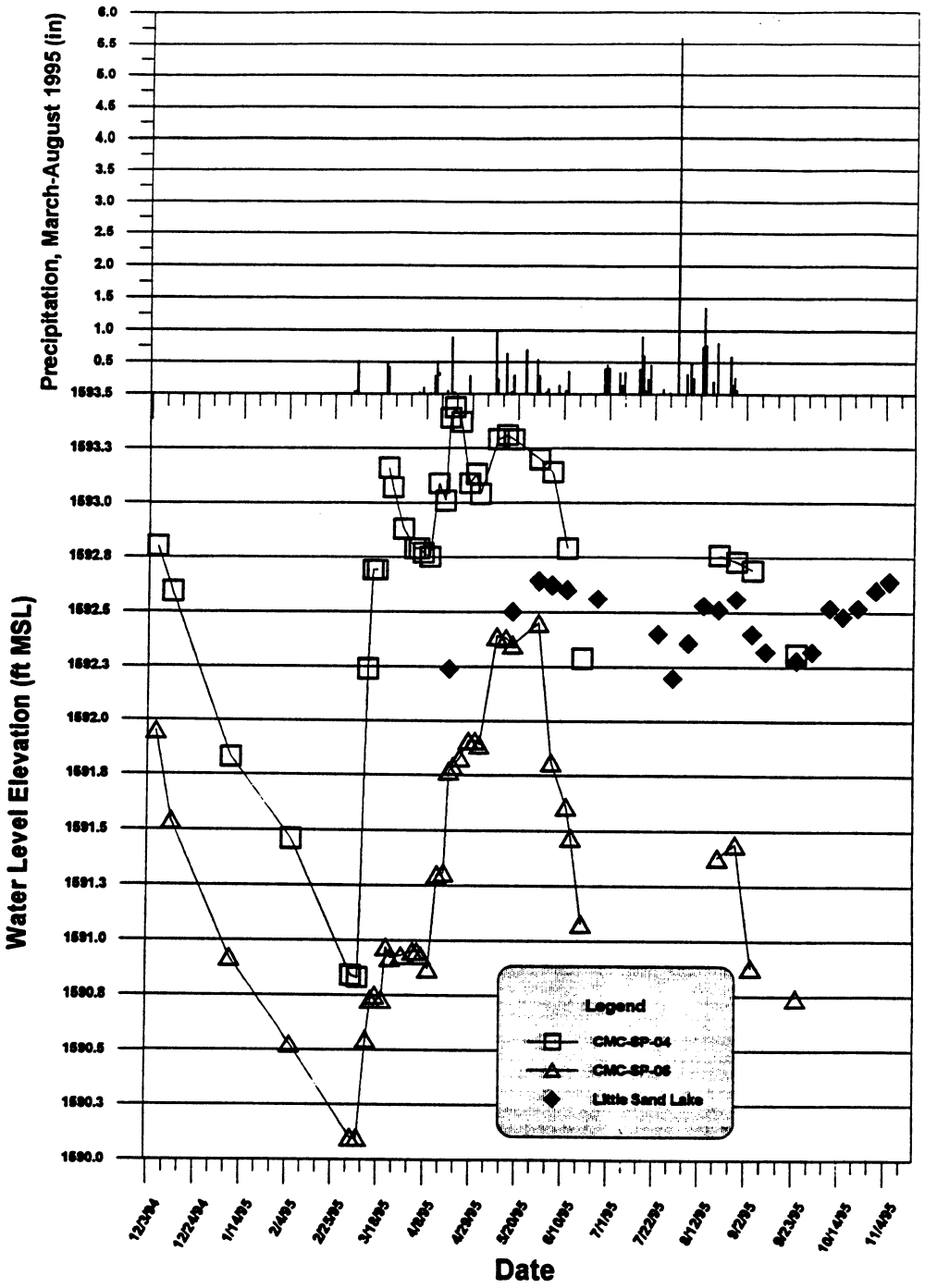
Crandon Mining Company

FIGURE 3.6-36D
COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-01 & CMC-SP-02 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996
Prepared By: Foth & Van Dyke	By: JRB

c:\cadwork\4c33f164.dgn

93C049



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Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE: MAR. '96	
APPROVED BY:	SVDI		DATE: MAR. '96	
APPROVED BY:	JWS		DATE: MAR. '96	

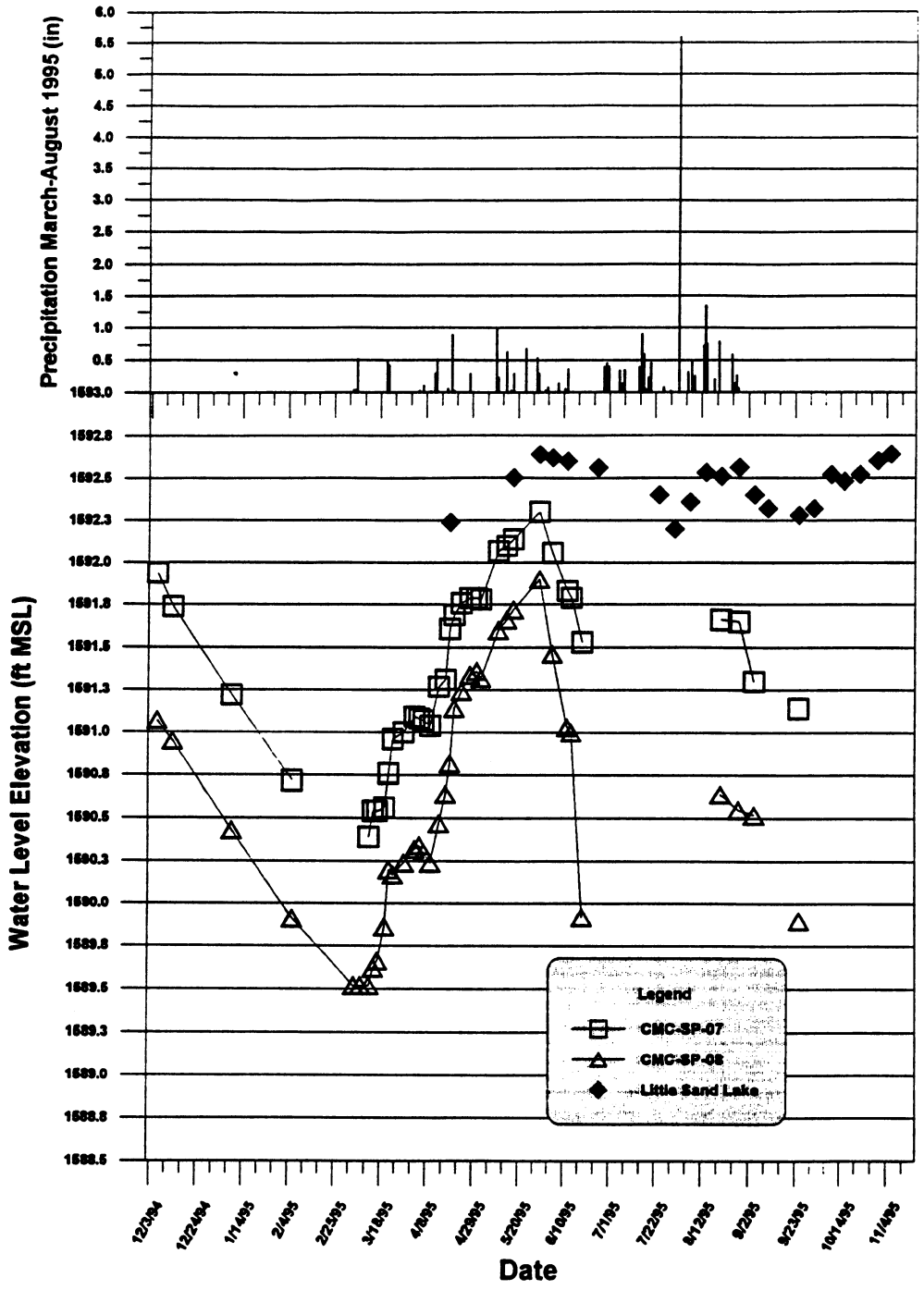
Crandon Mining Company

FIGURE 3.6-36E
COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-04 & CMC-SP-06 TO LAKE STAGE OF LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MARCH, 1996
Prepared By:	Foth & Van Dyke	By:	JRB

c:\cadwork\4c33f164.dgn

93C049



svd1:93c049:conc:misc:sp07.grf

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY:	JKSI	DATE: MAR. '96	
APPROVED BY:	SVDI	DATE: MAR. '96	
APPROVED BY:	JWS	DATE: MAR. '96	

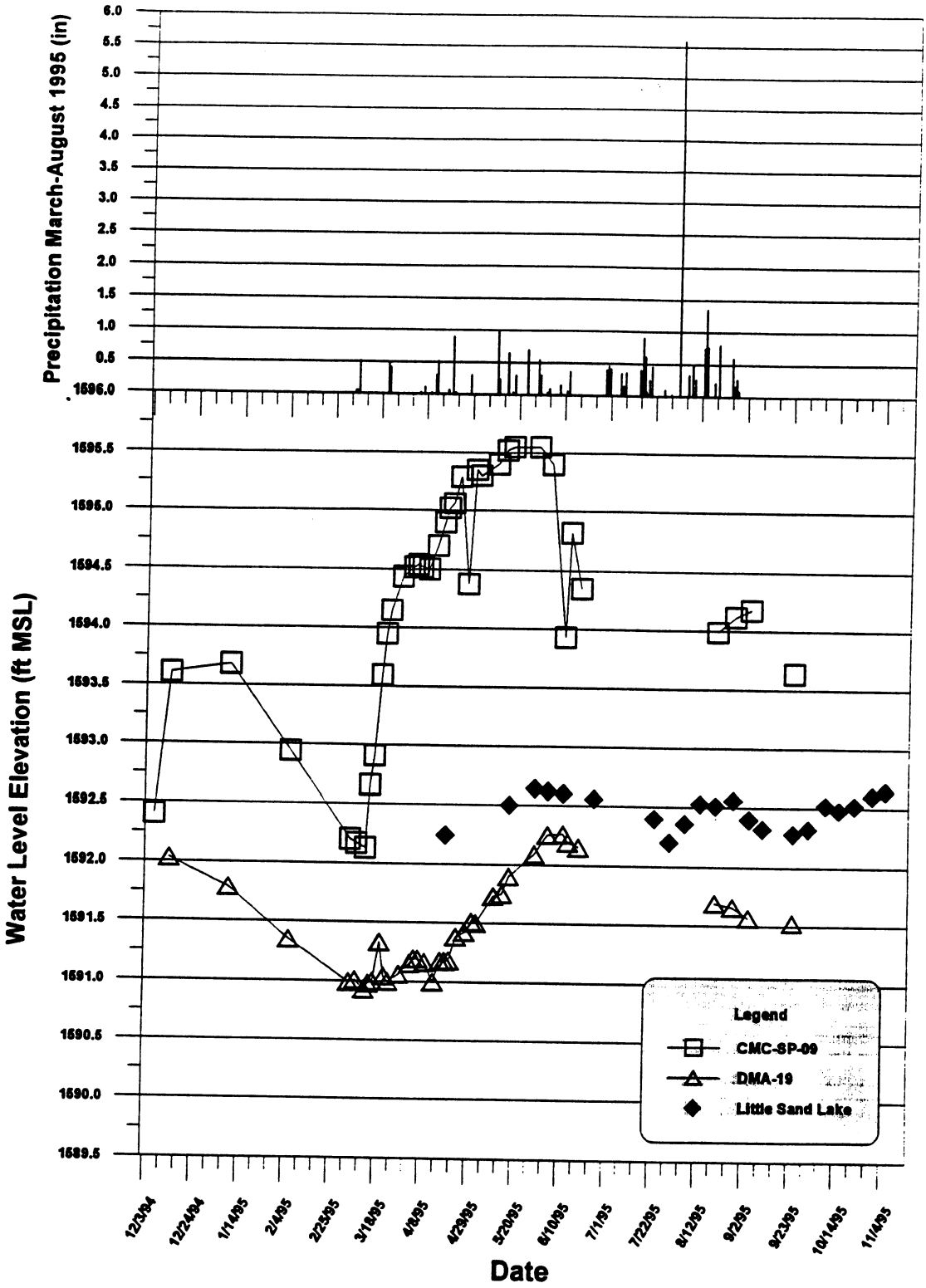
Crandon Mining Company

FIGURE 3.6-36F
COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-07 & CMC-SP-08 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996
Prepared By: Foth & Van Dyke	By: JRB

c:\cadwork\4c33f164.dgn

93C049



svd1:93c049:cont:miscap09.grf

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI			DATE: MAR. '96
APPROVED BY:	SVDI			DATE: MAR. '96
APPROVED BY:	JWS			DATE: MAR. '96

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FIGURE 3.6-36G

COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-09 & DMA-19 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996
Prepared By: Foth & Van Dyke	By: JRB

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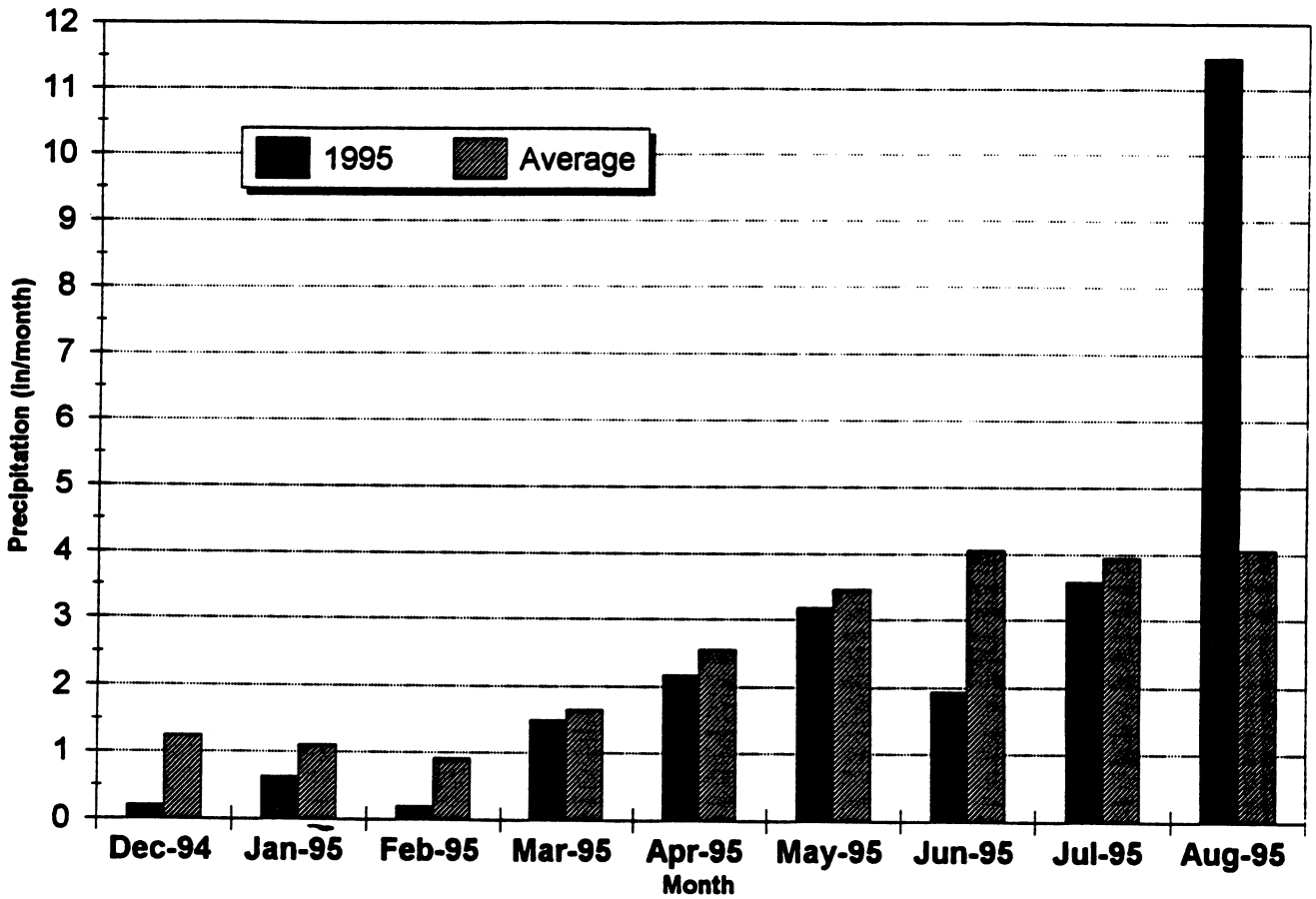
93C049

Monthly Precipitation Record
South Pelican Lake



Source: National Oceanic and Atmospheric Administration

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY: JKSI			DATE: MAR. '96
APPROVED BY: SVDI			DATE: MAR. '96
APPROVED BY: JWS			DATE: MAR. '96

Crandon Mining Company

FIGURE 3.6-36H

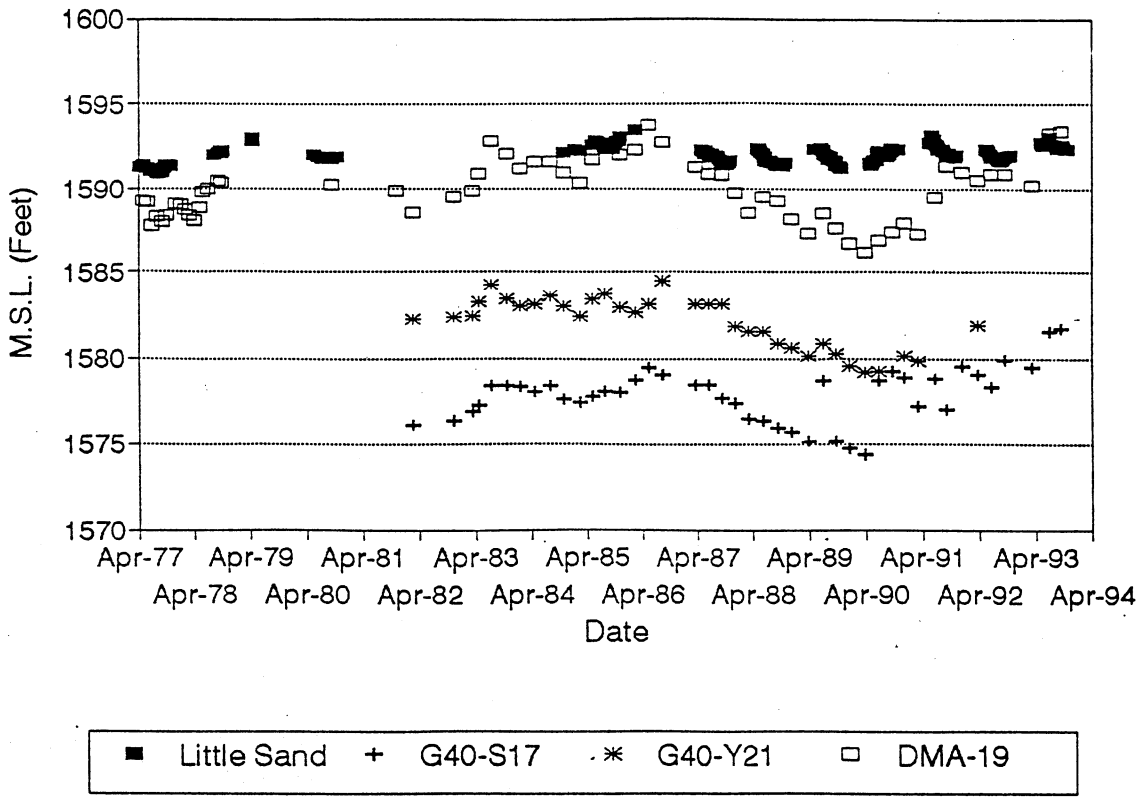
COMPARISON OF 1995 MONTHLY PRECIPITATION TO LONG TERM AVERAGE

Scale: AS SHOWN	Date: MARCH 1996
Prepared By: Foth & Van Dyke	By: JRB

c:\cadwork\4c33f164.dgn

93C049

Groundwater and Surface Water Elevation



Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE:	MAY'95
APPROVED BY:	SVDI		DATE:	MAY'95
APPROVED BY:	JWS		DATE:	MAY'95

Crandon Mining Company

FIGURE 3.6-37

HYDROGRAPHS OF LITTLE SAND LAKE AND SURROUNDING WELLS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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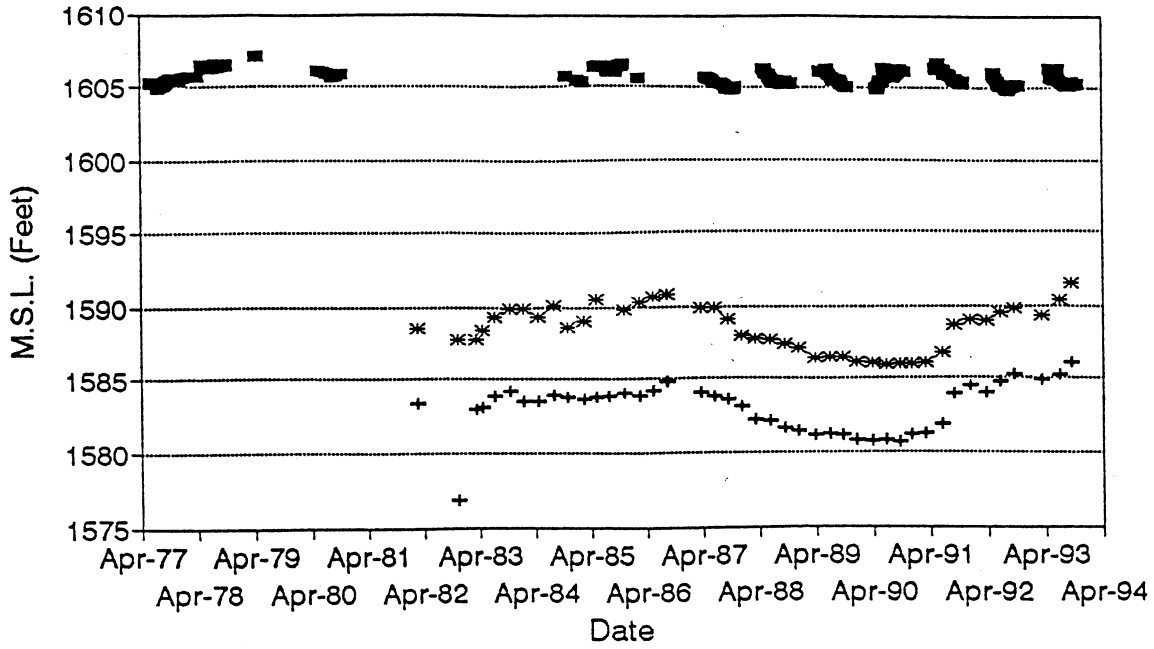
93C049

Groundwater and Surface Water Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY: JKSI			DATE: MAY'95
APPROVED BY: SVDI			DATE: MAY'95
APPROVED BY: JWS			DATE: MAY'95

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FIGURE 3.6-38

HYDROGRAPHS OF DEEP HOLE LAKE AND SURROUNDING WELLS

Scale: AS SHOWN	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP

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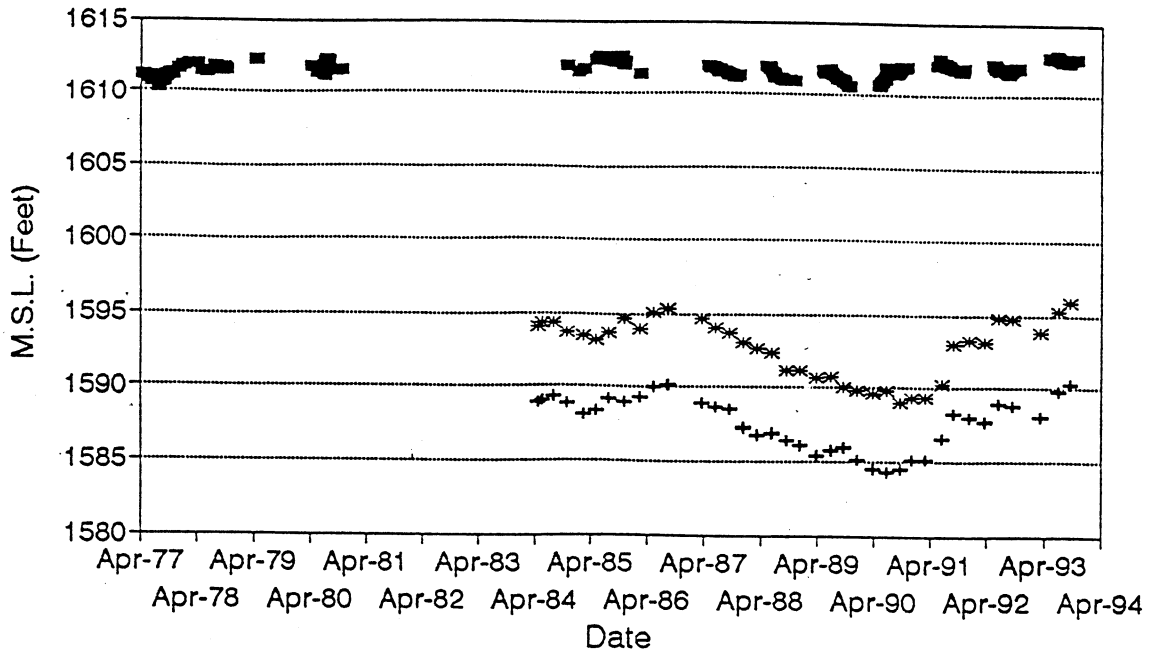
93C049

Groundwater and Surface Water Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY: JKSI			DATE: MAY'95
APPROVED BY: SVDI			DATE: MAY'95
APPROVED BY: JWS			DATE: MAY'95

Crandon Mining Company

FIGURE 3.6-39

HYDROGRAPHS OF DUCK LAKE AND SURROUNDING WELLS

Scale: AS SHOWN	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP

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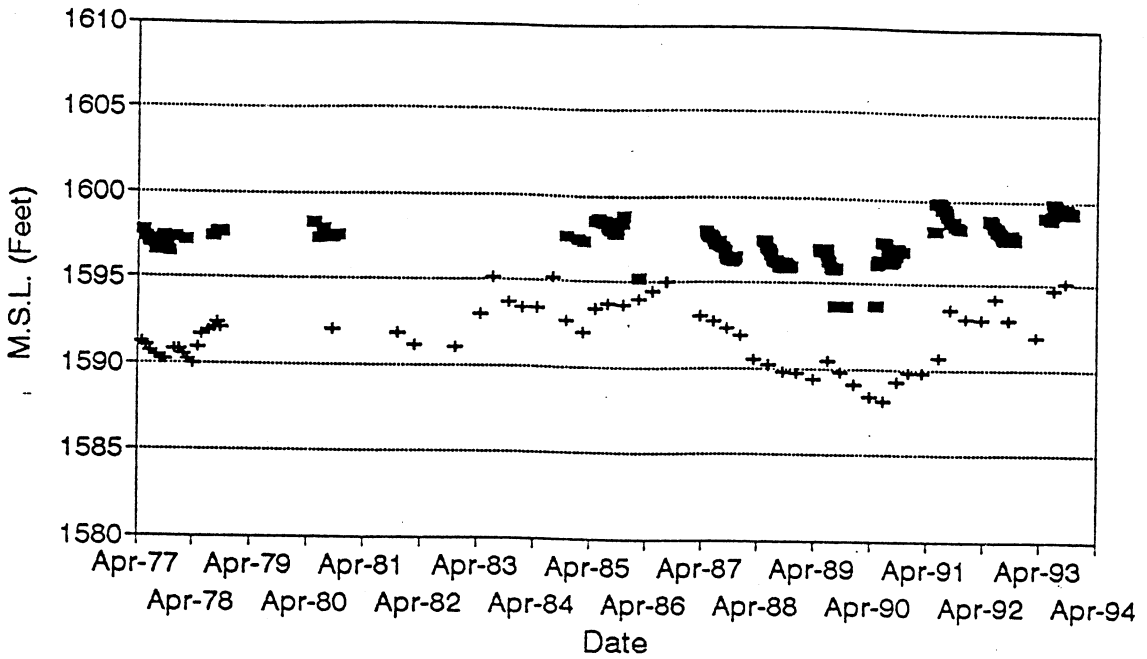
Groundwater and Surface Water Elevation



Foth & Van Dyke					
REVISED	DATE	BY	DESCRIPTION		
CHECKED BY:		JKSI		DATE:	MAY'95
APPROVED BY:		SVDI		DATE:	MAY'95
APPROVED BY:		JWS		DATE:	MAY'95

Crandon Mining Company

FIGURE 3.6-40

HYDROGRAPHS OF SKUNK LAKE AND SURROUNDING WELLS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	KMP

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93C049

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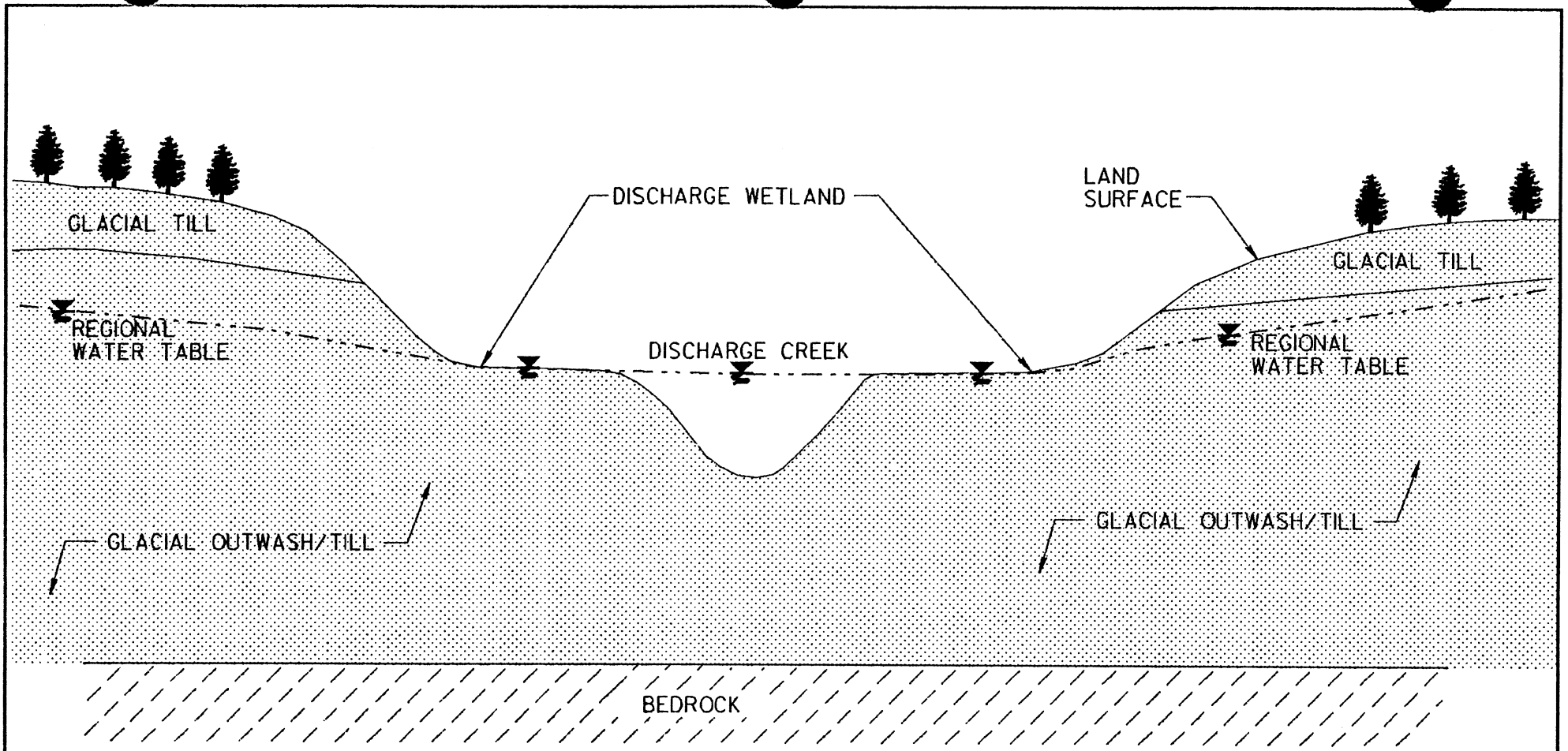


Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

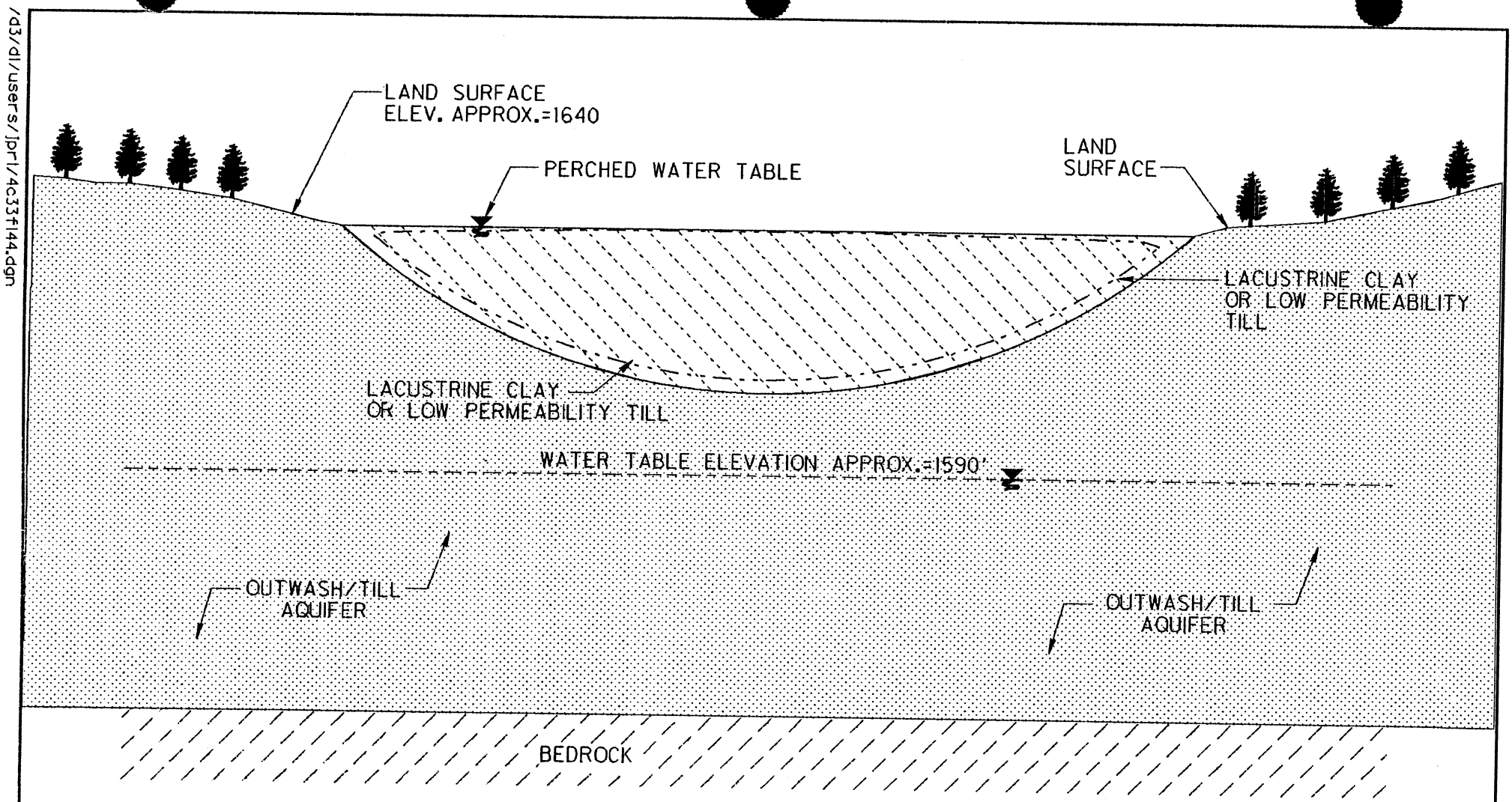
Crandon Mining Company

FIGURE 3.6-41

SCHEMATIC OF DISCHARGE TYPE WETLAND

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049



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93C049

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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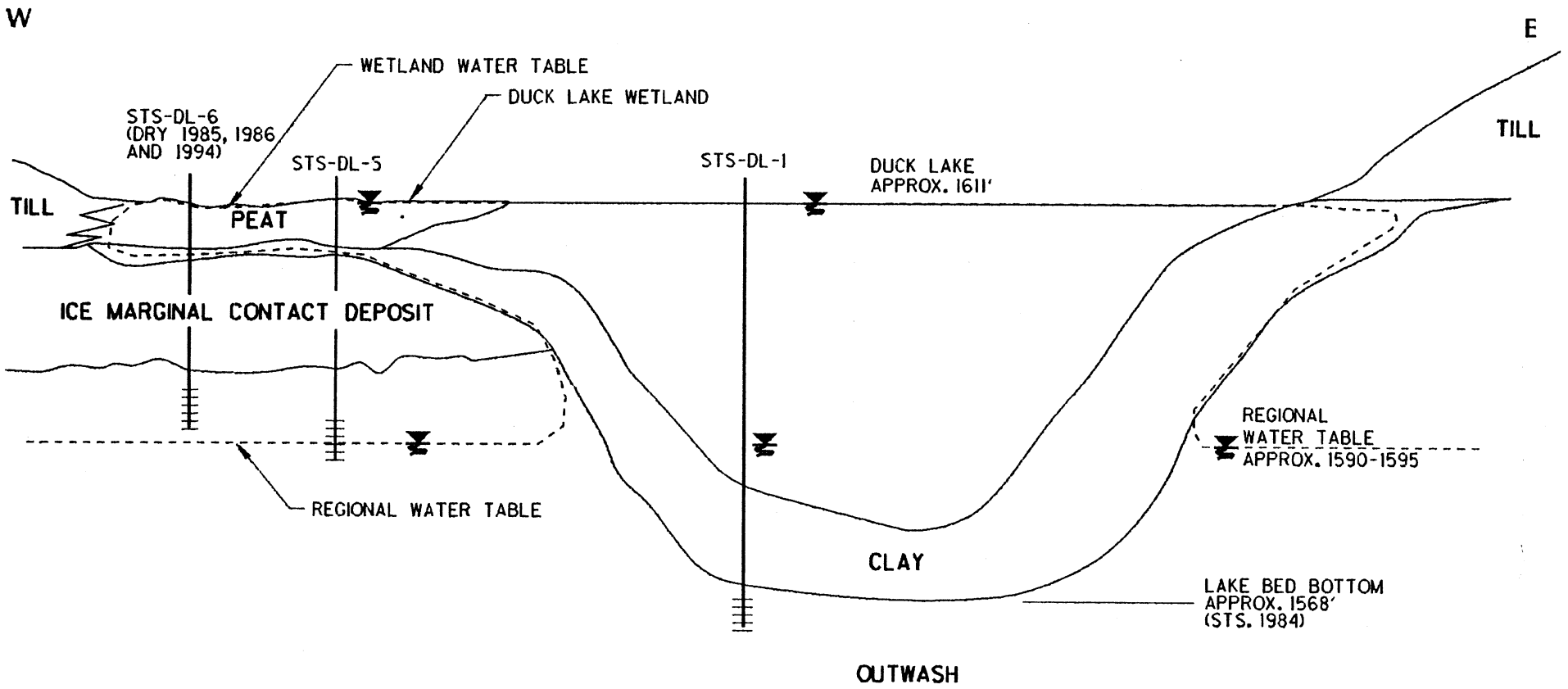
FIGURE 3.6-42

SCHEMATIC OF RECHARGE WETLAND
TYPE 1

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

/d3/dl/users/jpr1/4c33f146.dgn



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

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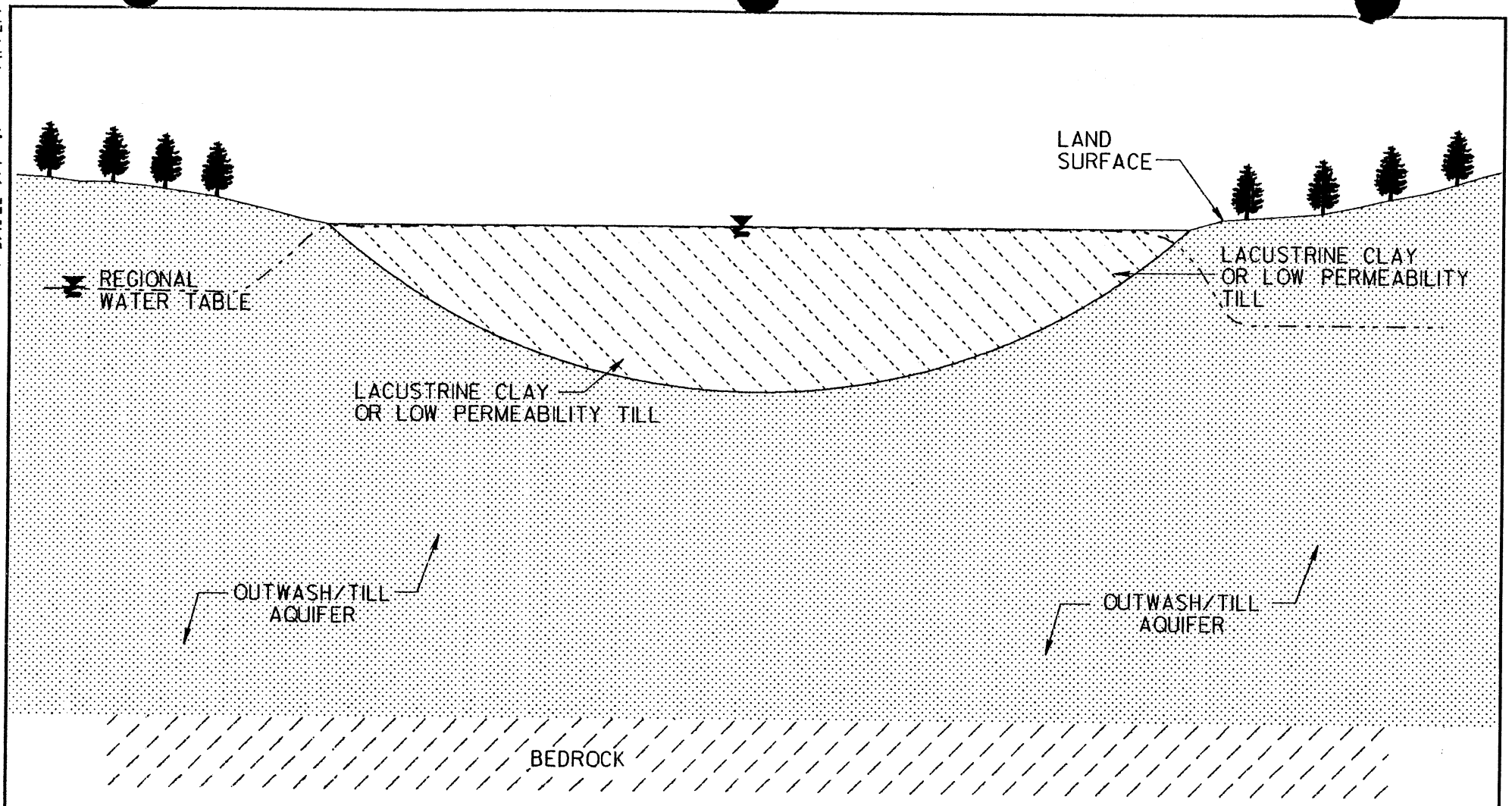
FIGURE 3.6-43

SCHEMATIC OF RECHARGE WETLAND
TYPE 2

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049

/d3/dl/users/jprl/4c33fl45.dgn



Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-44

SCHEMATIC DIAGRAM OF RECHARGE WETLAND TYPE 3

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	BSH

93C049

2,260,000 E | 2,265,000 E | 2,270,000 E | 2,275,000 E | 2,280,000 E | 2,285,000 E | 2,290,000 E

N

130,000 N | 125,000 N | 120,000 N | 115,000 N | 110,000 N | 105,000 N | 100,000 N

LAKE METONGA
RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
SKUNK LAKE
PLANT SITE
ORE BODY
TMA
GROUND HEMLOCK LAKE
KIMBERLY LAKE
CLARK LAKE
WALSH LAKE
ST JOHNS LAKE
ROLLING STONE LAKE

OC-1, RL-1, ML-1, PC-1, MS-1, CR129-1, HC-1, SC-1, SC-2, UN-1

Z1 Z2 Z3 Z4 Z5 Z6 Z7 Z8 Z9 Z10 Z11 Z12 Z13 Z14 Z15 Z16 Z17 Z18 Z19 Z20 Z21 Z22 Z23 Z24 Z25 Z26

T1 T2 T3 T4 T5

W1 W2

P1 P2

R1 R1A R3 R4 R5 R7 R7A R8

A1 A2 A3 B1 B2 B3 B4 B5 B8 D1 D2 D3 D4 D4A D5 D8 D18

F1 F2 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F30 F31 F32 F33 F34 F35 F36 F37 F38 F39 F40 F42 F43 F45 F46 F48 F50 F51 F52 F53 F54 F55 F56 F57 F58 F60 F61 F62 F63 F64 F65 F66 F69 F70 F72 F86 F87 F90 F119 F121 F122 F122A F125 F126 F127

G1

I1 I2 I3 I4 I5 I6 I7 I8 I9 I10 I11

J1

K1 K2 K3 K4 K5

L1

M1 M2 M3 M4 M5 M6

N1

O1

X1 X2 X3 X4

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- x 1542.0 EXISTING SPOT ELEVATION
- 1600 EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- PROPOSED ACCESS ROAD
- WETLAND DIVIDER

- DISCHARGE WETLAND.
- RECHARGE WETLAND TYPE 1. UNSATURATED ZONE EXISTS UNDER WETLAND.
- RECHARGE WETLAND TYPE 2. UNSATURATED ZONE EXISTS UNDER WETLAND. WETLAND IS CONNECTED LATERALLY TO A HEAD DEPENDENT SEEPAGE LAKE WATER BODY.
- RECHARGE WETLAND TYPE 3. HEAD DEPENDENT SEEPAGE WETLAND CONTINUOUSLY SATURATED SOILS FROM WETLAND SURFACE TO REGIONAL GROUNDWATER SYSTEM.

- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1000' 2000'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVD1	CHANGE WETLAND FROM DISCHARGE TO TYPE 1. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-45
HYROGEOLOGIC CLASSIFICATION OF DELINEATED AND MAJOR WETLAND AREAS IN STUDY AREA

Scale: SEE BAR SCALE | Date: MAY, 1995
Prepared By: Foth & Van Dyke | By: KMP

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01/10/97 .dgn

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2,260,000 E | 2,265,000 E | 2,270,000 E | 2,275,000 E | 2,280,000 E | 2,285,000 E | 2,290,000 E

N

130,000 N | 125,000 N | 120,000 N | 115,000 N | 110,000 N | 105,000 N | 100,000 N

LAKE METONGA
SWAMP
OC-1
Z16
T4
T1
T2
T3
T5
Z14
Z15
Z12
Z13
Z10
Z6
Z3
Z4
Z5
Z2
Z1
Z9
Z8
Z7
W2
W1
RL-1
HC-1
SC-2
SC-1
P1
P2
O1
O3
O2
PLANT SITE
ORE BODY
SKUNK LAKE
TMA
RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
GROUND HEMLOCK LAKE
WALSH LAKE
CLARK LAKE
ST JOHNS LAKE
ROLLING STONE LAKE
PICKEREL CREEK
KIMBERLY CREEK
ML-1
PC-1
MS-1
CR129
Z18
Z19
Z17
Z22
Z21
Z20
Z24
Z25
Z23
Z26
R1
R1A
R2
R3
R4
R5
R6
R7
R7A
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A3
B1
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B4
B5
C1
D1
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D4
D4A
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F117
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F119
F121
F122
F125
F126
G1
X1
X2
X3
X4
K1
K2
K3
K4
M1
M2
M3
M4
M5
M6
M7
LN-1
1
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LEGEND

- ISOPACH CONTOUR
- CREEKS/RIVERS/LAKES
- PROPOSED ACCESS ROAD
- WETLAND DIVIDER
- ORE BODY
- PROPOSED ACCESS ROAD

- DISCHARGE WETLAND TO BE SIMULATED AS DRAINS.
- RECHARGE WETLAND TYPE 1. UNSATURATED ZONE EXISTS UNDER WETLAND.
- RECHARGE WETLAND TYPE 2. UNSATURATED ZONE EXISTS UNDER WETLAND. WETLAND IS CONNECTED LATERALLY TO A HEAD DEPENDENT SEEPAGE LAKE WATER BODY.
- RECHARGE WETLAND TYPE 3. HEAD DEPENDENT SEEPAGE WETLAND CONTINUOUSLY SATURATED SOIL FROM WETLAND SURFACE DOWN TO REGIONAL GROUNDWATER SYSTEM.

- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 10 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1000' 2000'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVD1	REVISED CONTOURING AROUND LITTLE SAND, DEEP HOLE, DUCK & SKUNK LAKES. REVISED TMA LIMITS OF DISTURBANCE.

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Crandon Mining Company

FIGURE 3.6-46

ISOPACH OF DEPTH FROM THE GROUND SURFACE TO GROUNDWATER SURFACE

Scale:	SEE BAR SCALE	Date:	MAY, 1995
Prepared By:	Foth & Van Dyke	By:	JRB2

93C049

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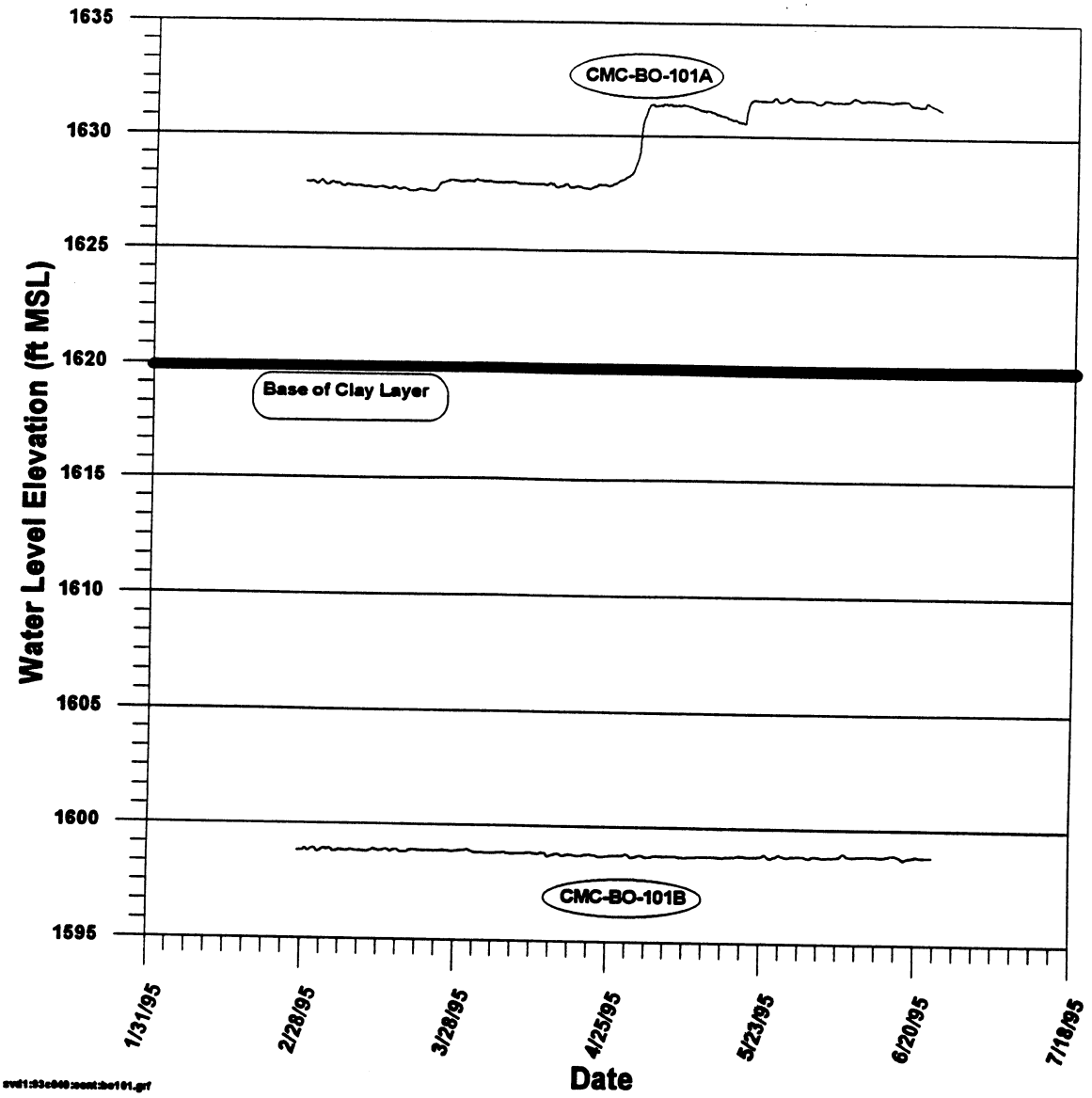

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JKSI		DATE: NOV.'95	
APPROVED BY:	SVDI		DATE: NOV.'95	
APPROVED BY:	JWS		DATE: NOV.'95	

Crandon Mining Company

FIGURE 3.6-47

TRANSIENT GROUNDWATER LEVELS IN THE BURR OAK WETLAND

Scale: AS SHOWN	Date: NOVEMBER, 1995
Prepared By: Foth & Van Dyke	By: GAM

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