Geohydrologic characterization: [Crandon Project waste disposal system: project report 13]. v. 13 1982

Atlanta, Georgia: Golder Associates, Inc., 1982

GEOHYDROLOGIC CHARACTERIZATION

CRANDON PROJECT

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report On

GEOHYDROLOGIC CHARACTERIZATION

CRANDON PROJECT

Submitted to:

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October 1982

824-1304

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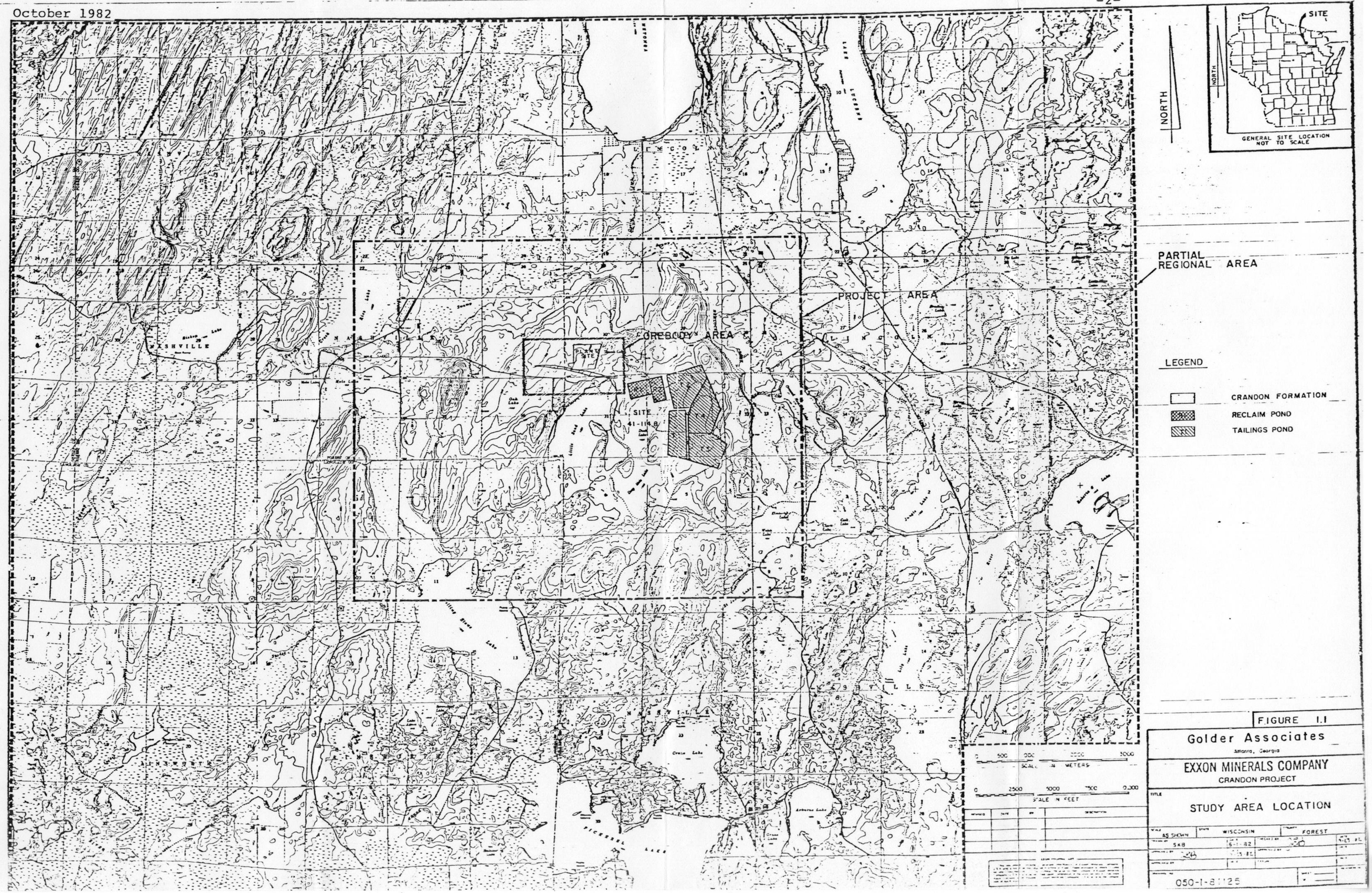
1.0 INTRODUCTION

Exxon Minerals Company is conducting a series of studies to evaluate the feasibility of mining a copper-lead-zinc orebody near Crandon, Wisconsin using underground mining techniques.

The proposed waste disposal facility, mine/mill complex and related activities will, to some extent, have an effect on the local hydrologic system. In order to quantify these effects, the surface and groundwater systems must be understood in their existing condition. The purpose of this report is to integrate the various data and studies relating to the hydrology, both surface and groundwaters of the project area in support of anticipated hydrologic impact assessment studies. This information has been reviewed in detail and has been synthesized into a coherent, unified picture of the existing site geohydrologic system which is presented in the following sections of this report.

Throughout this report three perspective views are used, as shown in Figure 1.1. The regional area is at scales of 1:30,000 or 1:24,000 and includes the surface and groundwater system boundaries. The project area includes the orebody, mill site and proposed waste disposal system area and is presented at a scale of 1:12,500. The orebody area includes the orebody itself and specific surrounding points of hydrologic interest, such as Swamp Creek and several perched lakes. These scales range from 1:1,000 to 1:5,000.

Metric units are used throughout this report with English units presented in parentheses. All figures are in S.I. units with the exception of the 1:30,000 and 1:24,000


SITE
GENERAL SITE LOCATION
NOT TO SCALE
NORTH
NORTH
PARTIAL
REGIONAL AREA
PROJECT AREA
"OREBODY" AREA
SITE
41-1148
NASHVILLE
LEGEND
CRANDON FORMATION
RECLAIM POND
TAILINGS POND
FIGURE 1.1
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
STUDY AREA LOCATION
SCALE IN METERS
SCALE IN FEET
WISCONSIN
FOREST
AS SHOWN
050-1-81125

scale regional area drawings which were developed from English basemaps and are in English units.

This report is divided into 8 sections. Following the introduction, Section 2 presents the many sources of information used in the compilation of this report; Sections 3 and 4 describe the geology and geohydrology of the study area; Section 5 discusses the surface water system; Section 6 presents the details of the orebody and overburden interconnection; and Section 7 discusses the interaction between the perched lakes and the regional groundwater system. Section 8 presents a summary of the geohydrologic system, highlighting various key features.

2.0 DESCRIPTION OF BACKGROUND INFORMATION

2.1 Review of Data Collection Efforts

Exxon Minerals Company initially began drilling exploratory boreholes at the Crandon orebody during 1975. Since that time there have been numerous data collection efforts relating to the geology, hydrogeology, and surface water hydrology of the study region. The major data collection efforts are summarized below.

- Orebody evaluation drilling program by Exxon Minerals,
- Environmental baseline study by Dames & Moore, covering geology, groundwater, and surface water,
- Waste management system preliminary design data collection by Golder Associates including boring program and pumping test,
- Orebody geohydrologic data collection and analysis including borings and pumping tests done by Camp Dresser and McKee and pumping test analysis by Thomas A. Prickett and Associates.

In addition, less extensive geologic, hydrologic and meteorologic data from several other sources were compiled and integrated into the review and synthesis of the study area geohydrology. In the following subsections each of the above major data collection efforts are discussed in detail.

The majority of the data and reports used in this study are in the form of final project reports prepared for Exxon Minerals or as public domain documents. All such data sources are listed in the reference list at the end of this report. Appendix A is a table of the soil boring information database which was developed as this data was accumulated. This listing contains boring data from studies by Exxon, Dames & Moore, Golder Associates, Camp Dresser and McKee, and several other boring programs. The borings are arranged alphabetically by boring name, and the table includes the S.I. and English equivalents of the boring location coordinates, ground elevation, bedrock elevation (if available), groundwater elevation and reading date (if available), and coarse stratified drift aquifer thickness (if available). Appendix B lists U.S.G.S. supplied groundwater levels in private wells in the regional area. Figures 2.1 and 2.2 show the plan location of this data on S.I. (1:12,500) and English (1:30,000) basemaps, respectively. Figure 2.3 shows the plan location of boring data in the orebody area (1:2,500). Appendix C contains miscellaneous data which were transmitted by letter.

2.2 Orebody Evaluation Drilling Program

The orebody evaluation drilling program by Exxon Minerals Company progressed from the initial exploratory drilling in 1975 to the completion of the surface exploration drilling program in August, 1978. These borings indicate the elevation of the bedrock surface and allow delineation of the various zones of weathering of the bedrock surrounding the orebody, as presented in Reference 18. In addition, some of these borings indicate the glacial overburden types which exist at the bedrock/overburden interface. This data was used, in conjunction with data from other drilling programs, to estimate the extent, thickness, and hydraulic conductivity of the various soil types which directly overlie the bedrock in the vicinity of the weathered orebody zones. Figure 2.3 shows the plan location of all the borings of primary interest in the vicinity of the orebody.

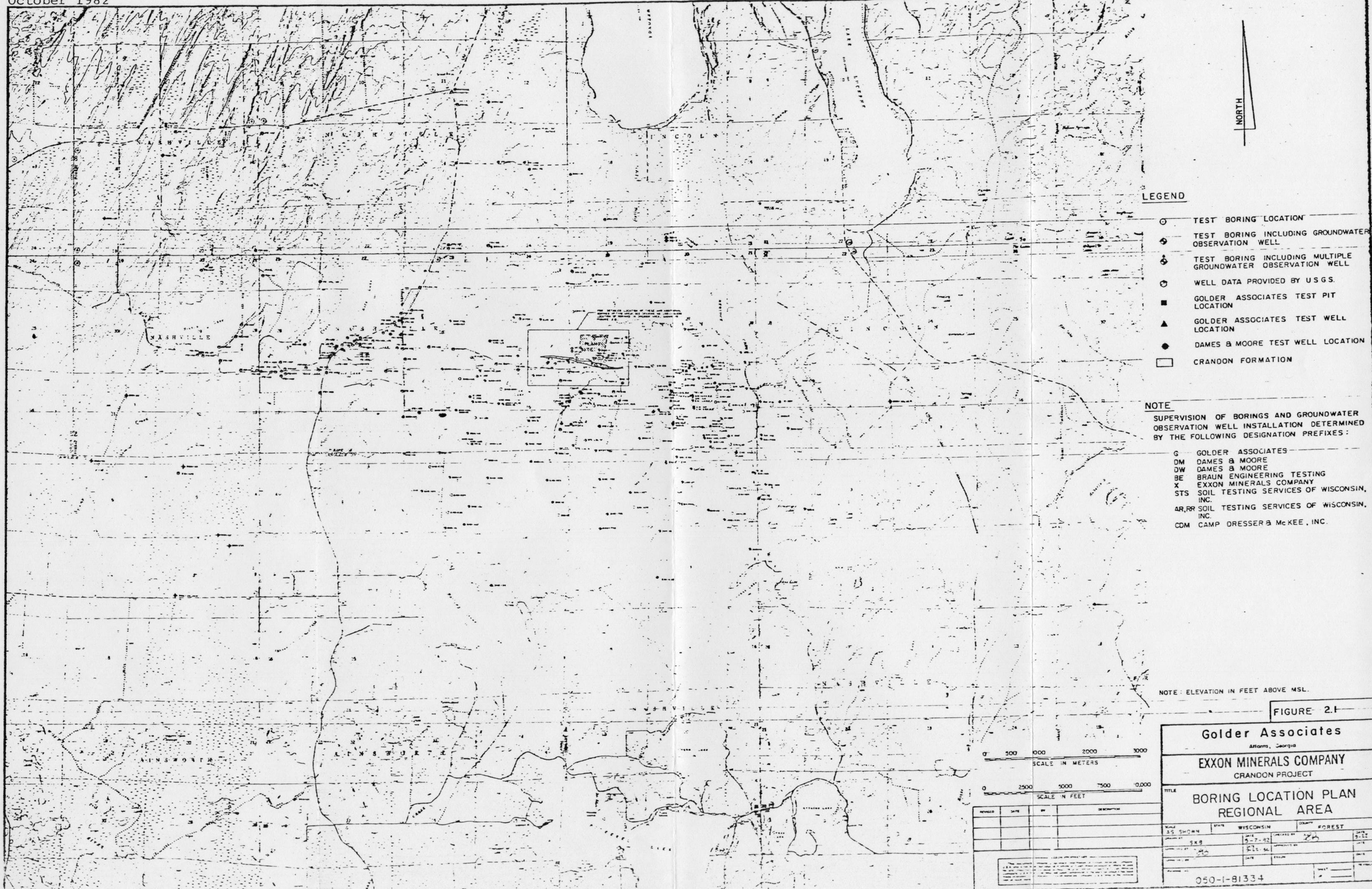
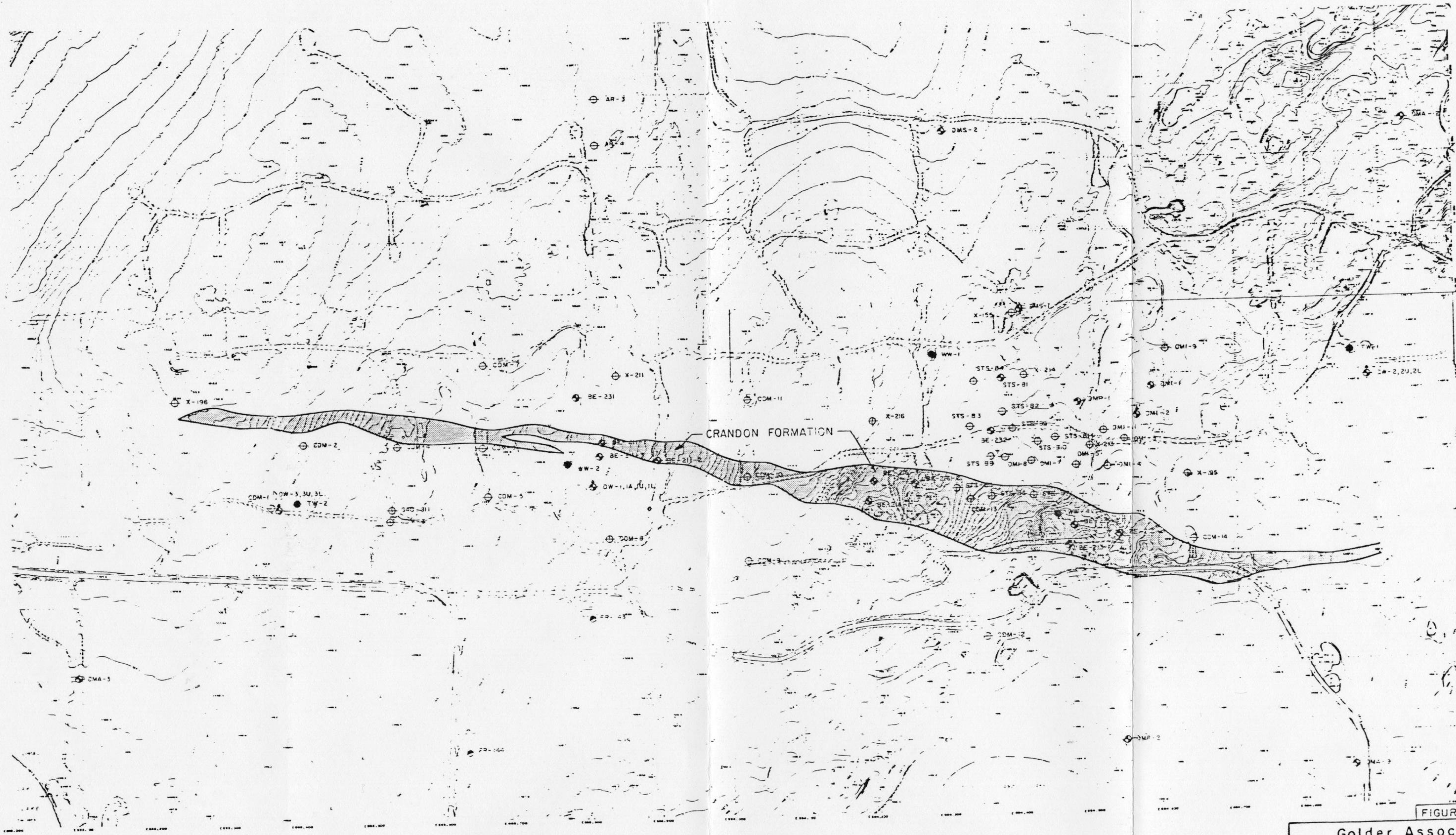

NORTH
NASHVILLE
LINCOLN
AINSWORTH
LEGEND
TEST BORING LOCATION
TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
WELL DATA PROVIDED BY U.S.G.S.
GOLDER ASSOCIATES TEST PIT LOCATION
GOLDER ASSOCIATES TEST WELL LOCATION
DAMES & MOORE TEST WELL LOCATION
CRANDON FORMATION
NOTE
SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:
G GOLDER ASSOCIATES
DM DAMES & MOORE
DW DAMES & MOORE
BE BRAUN ENGINEERING TESTING
X EXXON MINERALS COMPANY
STS SOIL TESTING SERVICES OF WISCONSIN, INC.
AR,RR SOIL TESTING SERVICES OF WISCONSIN, INC.
CDM CAMP DRESSER & McKEE, INC.
NOTE: ELEVATION IN FEET ABOVE MSL.
0 500 1000 2000 3000
SCALE IN METERS
0 2500 5000 7500 10,000
SCALE IN FEET
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
BORING LOCATION PLAN
REGIONAL AREA
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
5-7-82
050-1-81334

FIGURE 2.1


NORTH
FOR DETAILED LOCATION OF THESE AND ADDITIONAL BORINGS IN THIS AREA, SEE DRAWING NO. 050-1-81330, FIGURE 2.3
LEGEND
TEST BORING LOCATION
TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
WELL DATA PROVIDED BY USGS
GOLDER ASSOCIATES TEST PIT LOCATION
GOLDER ASSOCIATES TEST WELL LOCATION
DAMES & MOORE TEST WELL LOCATION
CRANDON FORMATION
NOTE
SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:
G GOLDER ASSOCIATES
DM DAMES & MOORE
DW DAMES & MOORE
BE BRAUN ENGINEERING TESTING
X EXXON MINERALS COMPANY
STS SOIL TESTING SERVICES OF WISCONSIN, INC.
AR,RR SOIL TESTING SERVICES OF WISCONSIN, INC.
CDM CAMP DRESSER & McKEE, INC
NOTE: ELEVATIONS IN METERS MSL
250 0 250 500 750 1000
SCALE IN METERS
FIGURE 2.2
Golder Associates
EXXON MINERALS COMPANY
CRANDON PROJECT
BORING LOCATION PLAN
PROJECT AREA
AS SHOWN
WISCONSIN
050-1-81333



LEGEND

- TEST BORING LOCATION
- TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
- TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
- DAMES & MOORE TEST WELL LOCATION
- WELL DATA ... BY U.S.G.S.

NOTE

SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:

G - GOLDER ASSOCIATES
DM - DAMES & MOORE
DW - DAMES & MOORE
BE - BRAUN ENGINEERING TESTING
X - EXXON MINERALS COMPANY
STS - SOILS TESTING SERVICE OF WISCONSIN
AR - SOILS TESTING SERVICE OF WISCONSIN
CDM - CAMP DRESSER & McKEE, INC.
TP - DAMES & MOORE
WW - DAMES & MOORE

FIGURE 2.3

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

BORING LOCATION PLAN
OREBODY AREA

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST
048	3-25-82	
050-1-81330		

2.3 Environmental Baseline Data and Reports

Dames & Moore performed an environmental baseline study of the Crandon Project between 1977 and 1981. References 2, 3 and 4 present the geology, groundwater, and surface water hydrology of the Crandon Project area. This effort produced several years of site specific streamflow data, approximately 50 observation wells, lake chemistry data, and a large number of soil borings and soil sample test results. In addition to the environmental baseline study, Dames & Moore performed a series of short duration pumping tests in the glacial overburden.

The Dames & Moore reports present the geologic, hydrologic, and meteorologic characterization of the Crandon Project area. This preliminary assessment was used in the subsequent, more detailed data collection efforts. Much of the data and the preliminary site evaluations presented in these subsequent reports formed the basis for this integrated site characterization report.

2.4 Preliminary Waste Management System Design

The preliminary design of the waste management system performed by Golder Associates between 1978 and 1982 required extensive geotechnical and geohydrologic data collection efforts as presented in References 5 through 8. The database of soil borings and soil test results initially established by Dames & Moore was more than doubled. Approximately 50 additional groundwater observation wells were installed and a large scale pumping test was performed.

In support of the selection process of various waste disposal system design alternatives, a groundwater flow/solute transport computer model was used to estimate the extent of possible waste disposal system seepage migration (Reference 25). This modeling effort required definition of the groundwater potentiometric surface, surface of the Precambrian bedrock, net infiltration rate, extent and thickness variation of the coarse glacial drift and several glacial overburden hydraulic parameters. These data were presented in several reports prepared by Golder Associates (References 5, 6, 7, 8, 25). Subsequent to the submittal of those reports, additional data have been developed under several other contracts and is included in this report. The additional soil boring and geohydrologic data have allowed updating of the groundwater potentiometric contour maps, bedrock contour maps, and coarse drift isopach maps.

2.5 Mine Water Control

A fourth major hydrogeologic data collection effort was performed in support of the mine water control study. This effort included a series of orebody pumping tests performed by Camp Dresser and McKee (CDM) (Reference 9), and a subsequent analysis of these data by Thomas A. Prickett and Associates (performed under contract with both Exxon and CDM and included in Reference 9). This data was augmented by slug tests in the orebody borings performed by Exxon (included in Appendix C). The orebody weathering data collected by Exxon and the Golder/Dames & Moore overburden characterization were also utilized in the analysis. The degree of hydraulic connection between the orebody and the overburden was also investigated by a series of glacial overburden borings and geophysical tests done by Camp Dresser and McKee (References 10 and 11).

The glacial overburden boring and geophysical test data provided by these studies was used in conjunction with other data to define the vertical flow resistance of the soils directly overlying the orebody and the orebody weathered zones and the hydraulic characteristics of the overburden. This potential hydraulic connection between the orebody and glacial overburden is discussed in detail in Section 6.

2.6 Other Related Data Collection Efforts

In addition to the four major data collection efforts discussed above, several other programs were undertaken which generated data used in this effort. Some of these efforts were designed to fill gaps in the general geohydrologic database while other efforts centered around unrelated activities, but generated useful hydrologic or geologic data. These efforts are briefly discussed in the following paragraphs.

Soil Testing Services of Wisconsin (STS Consultants) performed two soil boring programs and laboratory testing efforts in the mine access and ventilation shaft areas to characterize subsurface conditions (References 12 and 13). These data are included in the soil boring database in Appendix A of this report. A third STS drilling program was undertaken to determine the soil types and potentiometric head beneath Little Sand Lake (Reference 14). These data were utilized in the perched lake/groundwater interaction discussion presented in Section 7.

Two additional soil boring and laboratory testing programs were performed which provided additional soils data. Braun Engineering Testing performed borings in the area of the proposed mill facility (Reference 15) and Foth and VanDyke and Associates and STS performed a soils investigation along the proposed access road and the railroad spur to the mine/mill facility (Reference 16). The proposed access road crosses Swamp Creek north of the orebody and the soil types and bedrock elevation data from this study area were used in the groundwater/stream interaction definition.

Normandeau Associates performed a detailed wetland assessment study of the Crandon Project area (Reference 17). This work effort produced detailed surface water drainage divides which were used in this study. Normandeau's work also provided additional insight into the surficial geology of the study area.

Additional data on the elevation of the Precambrian bedrock surface across the study area was provided by two geophysical survey programs performed by Geoterrex (Reference 21 and 22). These data were provided at locations where the bedrock/overburden interface was not defined by the various boring programs and have been used in the preparation of the bedrock surface contour map. Bedrock surface definition was augmented by data provided by the U.S.G.S.

3.0 GEOLOGY

3.1 Geological Nomenclature

The geology of the Crandon project site area has been the subject of several investigations and reports (References 2, 5 and 10). These various reports describe different aspects of the site geology (e.g. orebody stratigraphy, glacial succession, glacial/orebody contact, etc.) and use differing geologic terminology. The purpose of this section is to present the consolidated terminology to be used in the hydrogeological interpretation of the Crandon site.

When one is dealing with mineral resource investigations, waste management projects, or hydrogeological studies, it is convenient to use litho-stratigraphic rather than chrono-stratigraphic nomenclature. Litho-stratigraphic nomenclature divides sequences of deposits on the basis of physical characteristics and are therefore recognized and defined by physical features rather than by age or geological history. Since litho-stratigraphic units often cut across different time periods, physical terms may not be equated with chrono-stratigraphic terms. For example, the coarse stratified drift described herein may be a combination of the Greenbay and Langlade drifts (Reference 2) believed to be present at the Crandon site. The terms used in litho-stratigraphic classification, in order of decreasing rank are:

Group
Formation
Member
Bed

While reference is made to chronological events in this report the Crandon Project study area geology is described using the litho-stratigraphic nomenclature system. Figure 3.1 illustrates the geological succession for the study area, which consists of Pleistocene glacial deposits unconformably overlying Precambrian metamorphics.

3.2 Precambrian Bedrock Geology

3.2.1 Regional

The bedrock across northern Wisconsin is the southern extension of the Canadian Shield, referred to as the Southern Province. This Province is one of seven Canadian Shield rock provinces consisting of rocks ranging in age from 960 to 3,200 million years, Before Present (B.P.) (Reference 2). Three major ages of Precambrian rocks, Early, Middle and Late are found in Wisconsin. Of these, the Middle Precambrian rocks (1,600 to 2,500 million years B.P.) are present at the Crandon site. Approximately 2,100 million years B.P., volcanics and sediments were deposited in a large trough extending across Wisconsin from Ladysmith to Marinette. It is within this volcanic belt that the sulfide ore deposit at Crandon is found. About 1,800 million years B.P., this volcanic belt was faulted and folded and intruded by granite during the Penokean Orogeny (Reference 2). The volcanics and sediments were deformed into a series of east-west trending folds, and were regionally metamorphosed to greenschist facies. Greenberg (Reference 20) has suggested a general north-south structural trend for the Precambrian rocks based on rock foliations of outcrops within Forest County. This hypothesis is contrary to results obtained from the Exxon orebody drilling program. Dames & Moore (Reference 2) give the average strike of the Precambrian rocks as north 80 degrees west with the dip being 70 degrees north to vertical.

ERA	PERIOD	EPOCH	AGE (MILLIONS OF YEARS B.P.)
CENOZOIC	QUATERNARY	HOLOCENE	0.01
		PLEISTOCENE	2
UNCONFORMITY			
PRECAMBRIAN			600
		LATE	1600
		MIDDLE	2500
		EARLY	>2500

JOB NO. 824-1304	SCALE NOT TO SCALE	CRANDON PROJECT AREA GEOLOGICAL SUCCESSION
DRAWN CAB	DATE 4-15-82	
CHECKED JEB	DWG. NO. —	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 3.1

GAF DRAFTING MEDIA

3.2.2 Project Study Area

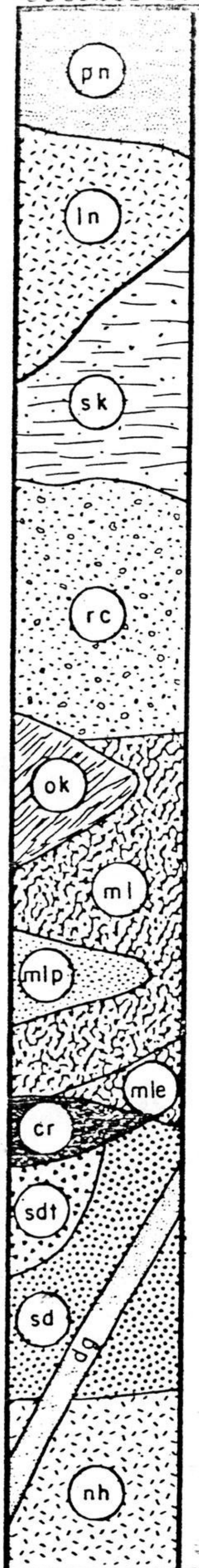
The Precambrian rocks of the project study area were deposited during two volcanic cycles referred to as the Hemlock Creek and Swamp Creek Groups. The formations and members that make up these two groups are illustrated with descriptions in Figure 3.2. The Precambrian geology of the site area is described in detail by Dames & Moore (Reference 2). Figures 3.3 and 3.4 are horizontal and vertical cross sections of the Precambrian strata respectively. Figures 3.5, 3.6 and 3.7 show the bedrock surface at the regional, project and orebody scales, respectively.

The Crandon sulfide deposit is identifiable for a distance of approximately 1,524 m (5,000 ft.) along strike and to a depth of approximately 823 m (2,700 ft.) below the bedrock surface (Reference 2). Its thickness varies from zero on the west to 76 m (250 ft.) near its center (Reference 2). These data indicate that the local bedrock trend is consistent with the regional trend previously discussed.

3.2.3 Sulfide Ore Genesis and Weathering

An understanding of sulfide ore genesis assists in estimating the modes and effects of subsequent orebody weathering. This weathering has a direct bearing on the site hydrogeology which is discussed in greater detail in Section 6.

The Crandon orebody may be classified as a volcanogenic deposit. Volcanogenic deposits are those that have been formed by volcanic processes and the activities of thermal springs beneath bodies of water (Reference 27). The Crandon deposit has features typical of subaqueous volcanogenic deposits:



SWAMP CREEK GROUP

PINE FORMATION (pn)
Predominately a basinal sequence of cherty tuff, argillite and slump breccia.

LINCOLN FORMATION (ln)
Porphyritic flows with minor interflow tuff, chert and argillite

HEMLOCK CREEK GROUP

SKUNK LAKE FORMATION (sk)
Predominately a basinal sequence of cherty tuff, chert, argillite and slump breccia.

RICE LAKE FORMATION (rc)
A series of volcanic debris flows (blocky choritic and minor siliceous lapilli and breccia size debris) and eutaxitic ash flows

OAK LAKE FORMATION (ok)
A predominately basinal sequence of cherty tuff and sericitic tuff

MOLE LAKE FORMATION (ml)
Predominately a homogenous, chlorific tuff.

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

EAGLE MEMBER (mle)
A volcanic greywacke

CRANDON FORMATION (cr)
A volcanic sequence comprised of massive sulfide, argillite, tuff, chert, and dolomite

SAND LAKE FORMATION (sd)
A volcanic sequence of fine tuffs and minor debris flows.

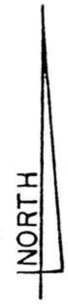
TOWNSHIP MEMBER (sdt)
A volcanic vent breccia complex consisting of poorly sorted, angular lithic debris

DUCK LAKE GABBRO (dg)

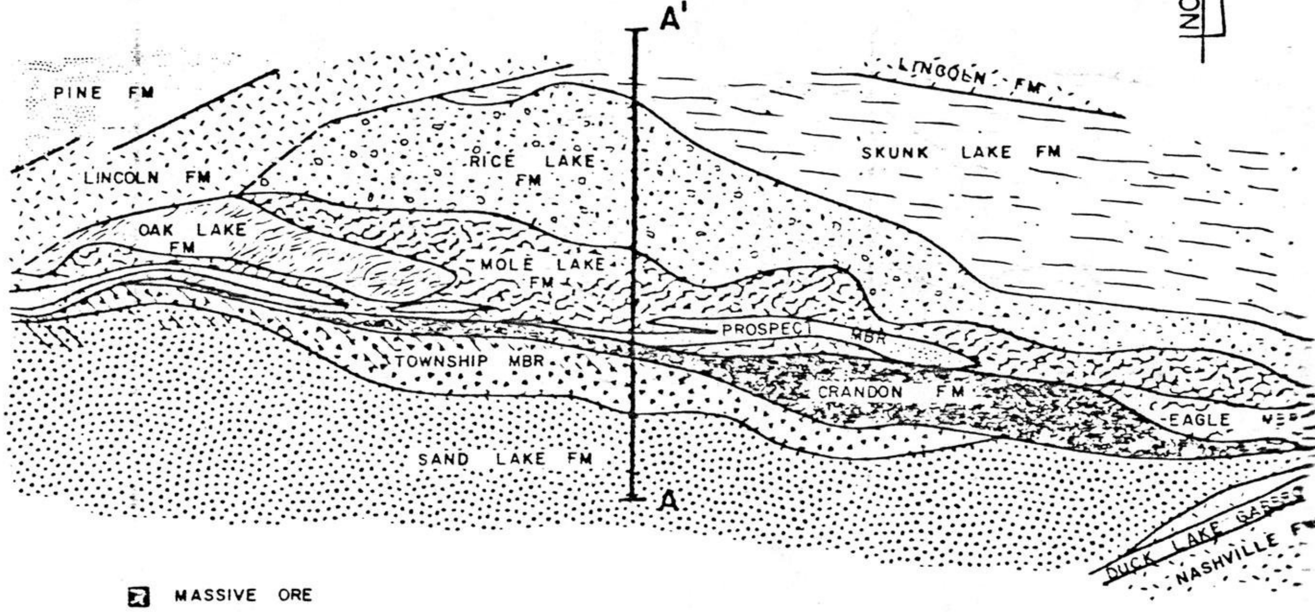
NASHVILLE FORMATION (nh)
Porphyritic flows

NOTE: TAKEN FROM DAMES & MOORE, REFERENCE 2.

JOB NO. 824-1304	SCALE NOT TO SCALE	PRECAMBRIAN STRATIGRAPHIC SUCCESSION
DRAWN SKB	DATE 4-15-82	
CHECKED EB	DWG. NO. ——	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 3.2



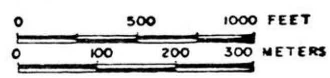
HORIZONTAL SECTION AT PROPOSED MINE LEVEL 185

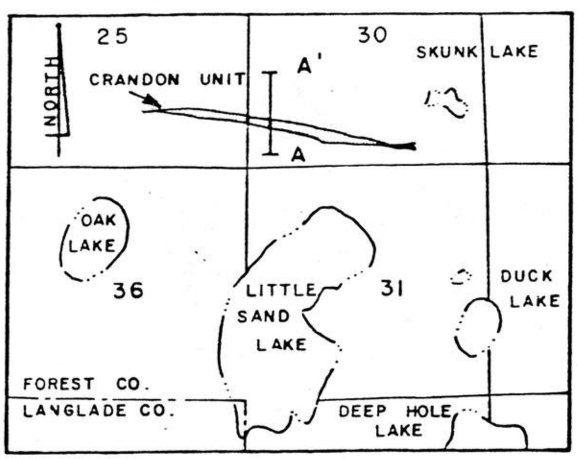


MASSIVE ORE

STRINGER ORE

NOTE: 185 METER MINE LEVEL
AT 1050 FEET ABOVE M.S.L.

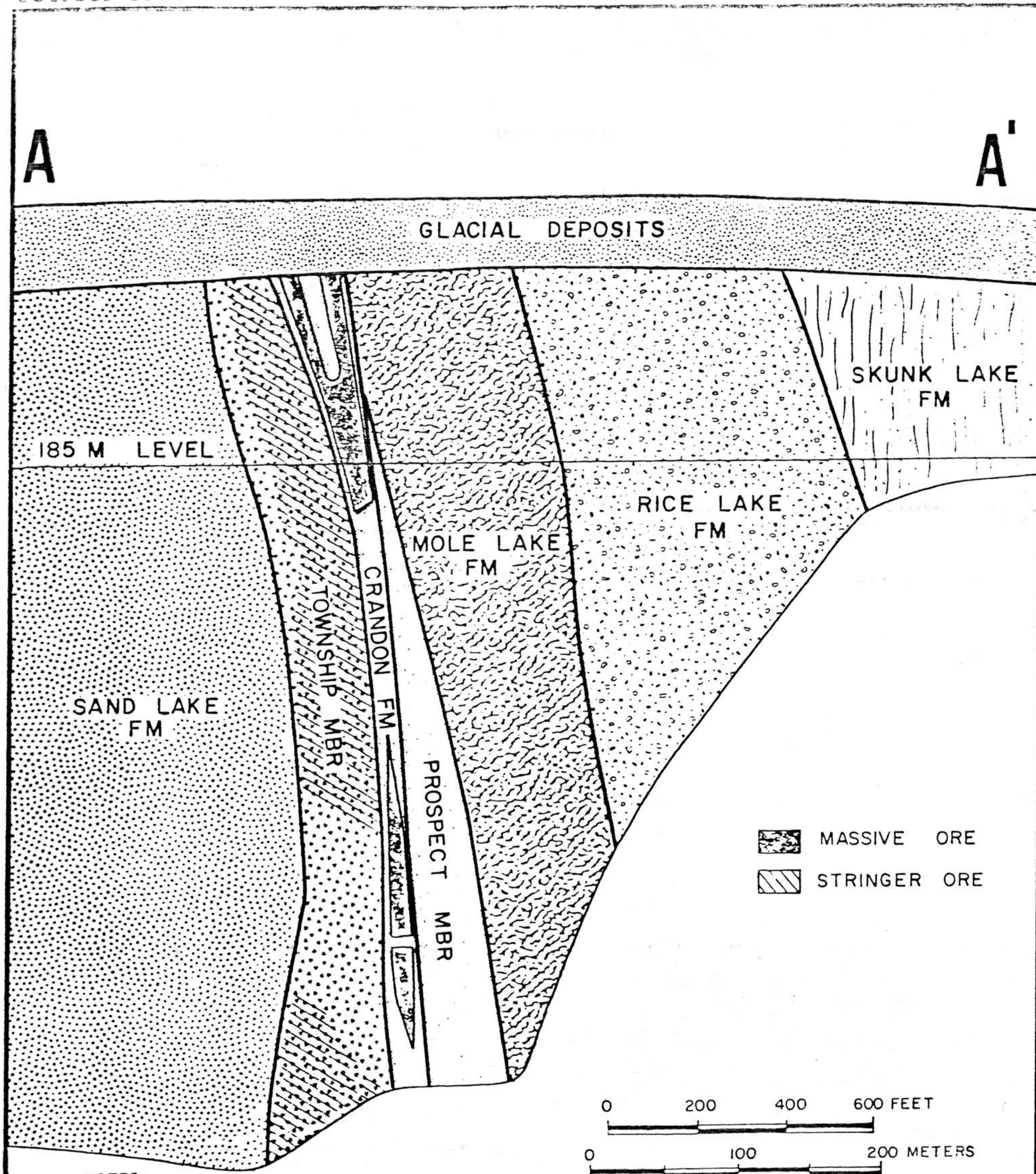




LOCATION MAP
NOT TO SCALE

NOTE: TAKEN FROM DAMES & MOORE, REFERENCE 2

JOB NO. 824-1304	SCALE AS SHOWN	HORIZONTAL PRECAMBRIAN GEOLOGIC SECTION
DRAWN CAB	DATE 4-15-82	
CHECKED JEB	DWG. NO. —	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 3.3



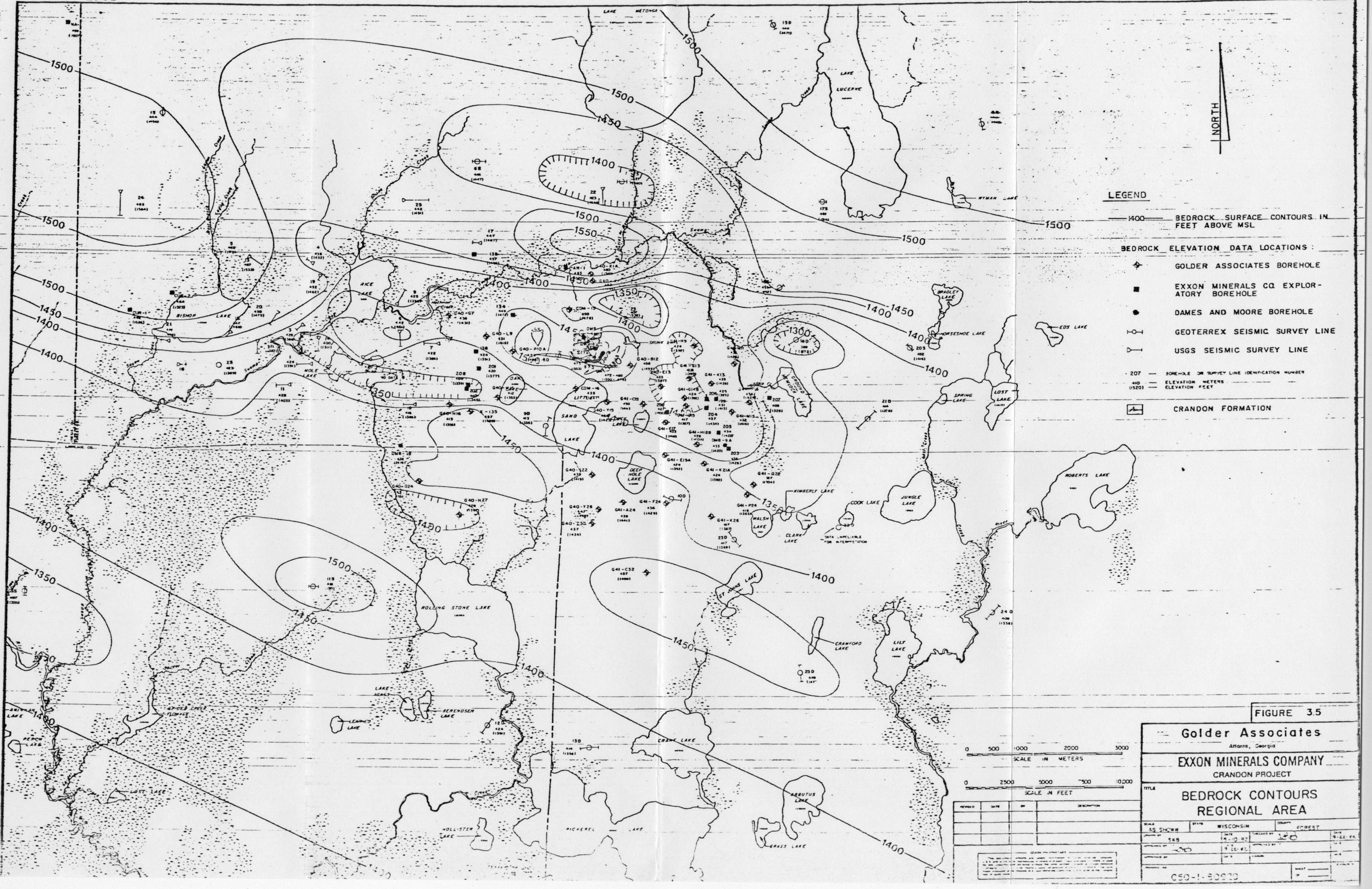
NOTES:

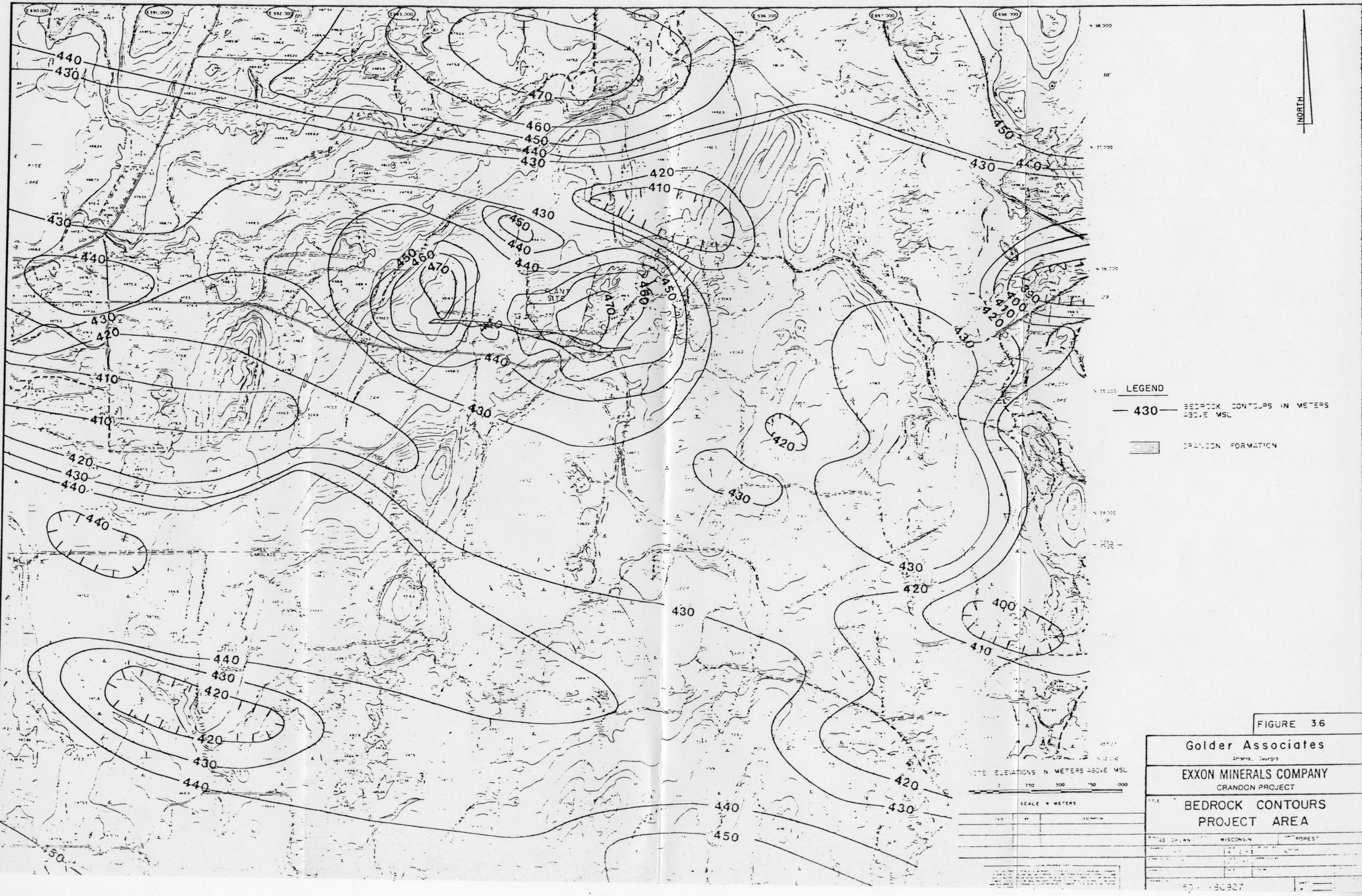
1.) SEE FIGURE 3.3 FOR SECTION LOCATION

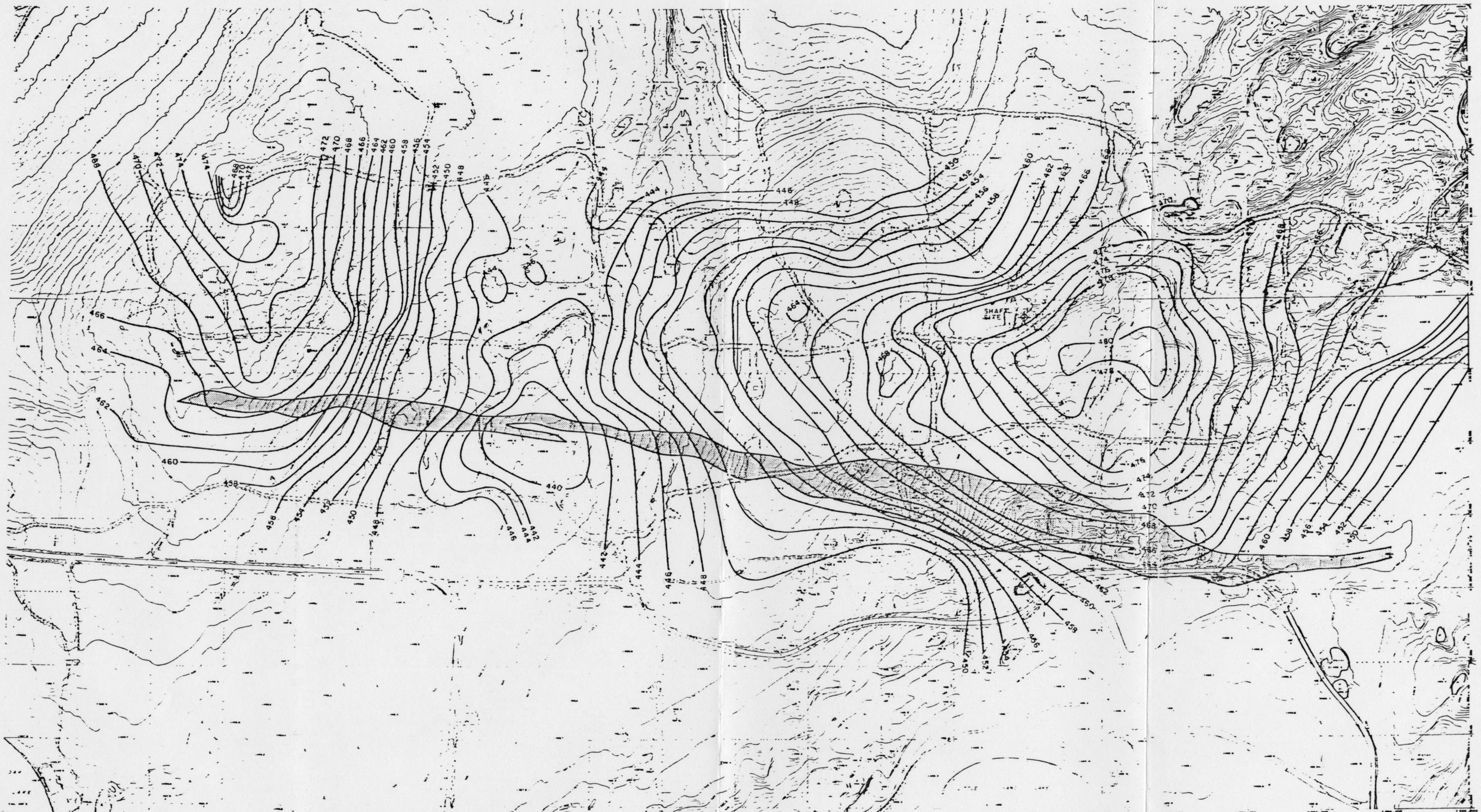
2.) 185 METER MINE LEVEL AT 1050 FEET ABOVE MSL.

3.) TAKEN FROM DAMES & MOORE, REFERENCE 2.

JOB NO. 824 - 1304	SCALE AS SHOWN	VERTICAL PRECAMBRIAN GEOLOGIC SECTION A – A'
DRAWN CAB	DATE 4-15-82	
CHECKED E.B.	DWG. NO. ____	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 3.4


NORTH
LEGEND
1400 BEDROCK SURFACE CONTOURS IN FEET ABOVE MSL
BEDROCK ELEVATION DATA LOCATIONS:
GOLDER ASSOCIATES BOREHOLE
EXXON MINERALS CO. EXPLORATORY BOREHOLE
DAMES AND MOORE BOREHOLE
GEOTERREX SEISMIC SURVEY LINE
USGS SEISMIC SURVEY LINE
207 — BOREHOLE OR SURVEY LINE IDENTIFICATION NUMBER
410 — ELEVATION METERS
(1520) — ELEVATION FEET
CRANDON FORMATION
LAKE METONGA
LAKE LUCERNE
BISHOP LAKE
RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
SAND LAKE
SKUNK LAKE
DEEP HOLE LAKE
DUCK LAKE
SKELLY LAKE
BRADLEY LAKE
HORSESHOE LAKE
EDS LAKE
WYMAN LAKE
SPRING LAKE
LOST LAKE
ROBERTS LAKE
JUNGLE LAKE
COOK LAKE
KIMBERLY LAKE
WALSH LAKE
CLARK LAKE
DATA UNRELIABLE FOR INTERPRETATION
ST JOHNS LAKE
CRAWFORD LAKE
LILY LAKE
ROLLING STONE LAKE
LAKE AGNES
BERENOSER LAKE
SPIDER CREEK FLOWAGE
PERCH LAKE
CRANE LAKE
ARBUTUS LAKE
HOLLISTER LAKE
PICKEREL LAKE
GRASS LAKE
1500
1450
1400
1350
1300
1550
0 500 1000 2000 3000
SCALE IN METERS
0 2500 5000 7500 10,000
SCALE IN FEET
FIGURE 3.5
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
BEDROCK CONTOURS
REGIONAL AREA
AS SHOWN
WISCONSIN
FOREST
C50-1-80920


NORTH
LEGEND
— 430 — BEDROCK CONTOURS IN METERS ABOVE MSL
CRANDON FORMATION
PLANT SITE
NOTE: ELEVATIONS IN METERS ABOVE MSL
SCALE IN METERS
FIGURE 36
Golder Associates
EXXON MINERALS COMPANY
CRANDON PROJECT
BEDROCK CONTOURS
PROJECT AREA
WISCONSIN
FOREST



NOTES:

1. BEDROCK CONTOURS FROM SUBCROP ELEVATION MAPS, DRAWING NUMBERS C-GE-1001 and C-GE-1002, PROVIDED BY EXXON MINERALS COMPANY
2. BEDROCK CONTOURS IN METERS, MSL.
3. ⌖ MINE SHAFT LOCATION, COORDINATES N 35,676 911, E 694,396.749

LEGEND

—442— BEDROCK CONTOURS IN METERS ABOVE MSL

[shaded] CRANDON FORMATION

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

FIGURE 3.7

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE BEDROCK CONTOURS OREBODY AREA

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

050-1-30926

a) It is associated with submarine volcanic rocks.

b) The mineralized zones are flat to lenticular.

c) It consists of two main types of mineralization, massive sulfide and stringer sulfide. At the Crandon site, the zinc-rich massive sulfide is conformable with the surrouding sediments whereas the stringer sulfide zones consist of copper-rich quartz-chalcopyrite veins disseminated through the hyrdothermally silicified volcanics and sediments of the underlying Sand Lake Formation.

Subsequent consolidation, deformation, and uplift exposed the orebody and surrounding rock to weathering.

Exxon (Reference 13) has listed four destructive weathering processes that were active at the Crandon site;

a) Oxidation
b) Leaching
c) Argillization
d) Fracturing

The degree of weathering is a function of a combination of the above processes. The weathering categories are as follows:

a) <u>Strong</u>. Weathering is considered strong if there is extensive development of two or more of the above destructive processes.

b) <u>Moderate</u>. Strong development of one of the destructive processes and moderate development of at least one additional destructive process.

c) <u>Low</u>. If the primary destructive characteristic is only moderate leaching, the rock is in the low weathering category.

d) Weak. Weathering is considered weak if there is only weak development of one of the destructive processes.

Figure 6.1 illustrates the characteristic "V" shape of the North-South weathering profile of Crandon deposit and surrounding rocks. The weathering profile and active destructive processes vary considerably between the footwall (rock underlying orebody), Crandon formation (orebody), and hanging wall (rock overlying orebody). This is in response to the primary chemistry of the rocks, and the physical-chemical conditions acting upon these rocks.

Footwall - The footwall rocks follow a relatively uniform weathering pattern compared to the Crandon formation (Figure 6.1). The lower boundaries of the various weathering intensities are relatively horizontal, but may contain small root-like zones which penetrate deeper. This uniform weathering is a direct result of the siliceous nature of the footwall rocks. The primary destructive process is leaching, with very little oxidation associated with the footwall rocks (Reference 18).

Crandon Formation - The Crandon formation is more deeply weathered than the footwall (Figure 6.1). The base of the weathering is highly irregular due to a variety of rock types. The most prominent feature is a large weathering "spike" along the hanging wall side of the Crandon formation, which locally may extend 200 m (656 ft.) into the bedrock (Reference 18).

Hanging Wall - The hanging wall rocks have weathered differently than either the Crandon formation or footwall deposits. The dominant destructive process has been argillization (clay formation). This is due to the rock being a relatively homogeneous, non-siliceous, fine-grained, chloritic tuff which contains very small amounts (less than 1 percent) of sulfides (Reference 18). The deepening of the strong and moderate weathering profile near the Crandon formation, is a chemical weathering response to the acidic ground water solutions generated by the leaching of sulfides from the Crandon formation. The variation of rock permeability as a function of weathering is discussed further in Section 6.

3.3 Pleistocene Overburden Geology

3.3.1 Regional

The bedrock throughout much of northern Wisconsin is overlain by glacial deposits (commonly referred to as glacial drift) deposited during the Pleistocene Epoch (2 million to 10,000 years B.P.). There were four major glacial advances during the Pleistocene Epoch. Deposits from three of these have been recognized in Wisconsin. The majority of the surficial deposits resulted from the most recent advance, the Wisconsin Age (75,000 to 10,000 years B.P.).

3.3.2 Project Study Area

Over the Project study area, the Precambrian bedrock is everywhere overlain by glacial drift and till that ranges in thickness from 8 m (25 ft.) to more than 91 m (300 ft.). The glacial materials were deposited during the Woodfordian Substage (22,500-13,000 years B.P.). The region was glaciated numerous times prior to the Woodfordian, but only Woodfordian deposits have been identified.

The Woodfordian ice advanced as a series of lobes. Glacial materials from the Langlade Lobe and Green Bay Lobe were deposited at the Crandon Project area. For a detailed review of the glacial history of the site, the reader is referred to Normandeau (Reference 17). To aid in understanding the site hydrogeology the following simplified litho-stratigraphic system is presented for the glacial deposits.

TABLE 3.1
GLACIAL DEPOSITS

Formation	Group	(Epoch)
Lacustrine and Wetland Sediments	--	Holocene
Outwash	Crandon Glacial Group	Pleistocene
Till		
Stratified Drift		

A brief description of the various formations that comprise the Crandon Glacial Group follows.

Till

This deposit consists of a well graded mixture of silt, sand, gravel, cobbles, boulders and traces of clay. It is devoid of any significant area wide internal structure (bedding, stratification, etc.) and occurs as two main layers over the site; 1) a lower layer directly overlying the Precambrian bedrock, and 2) a surficial deposit that forms the drumlin uplands of the site.

In addition, a fairly extensive deposit of till has been mapped within stratified drift deposits on the eastern side of the project area. The surface till locally contains sand and gravel layers that grade and interbed with adjacent fluvioglacial sands and gravels.

A commonly observed feature of the lower till layer is the local presence of coarse sands and gravels.

Stratified Drift

The stratified drift is a poorly graded deposit ranging from sandy silt to sand and gravel. The formation may be subdivided into a fine member and a coarse member, as described below.

(a) Fine Grained Stratified Drift Member. A well sorted, interlayered fine sand, silt and clay (Unified Soil Classification ML-SP) deposit, believed to be of glaciolacustrine origin, comprises this drift member. This deposit has been mapped over the eastern half of the project area (Reference 5) and generally overlies the lower till although it has been found directly on bedrock.

(b) Coarse Grained Stratified Drift Member. This fluvioglacial deposit varies from a well sorted fine to medium sand (Unified Soil Classification SP) to a medium to coarse silty sand (Unified Soil Classification SP-SM). The gradation occurs both laterally and vertically over the site area. The coarse drift member overlies either the lower till and/or fine stratified drift. It is continuous over the site but thins and becomes interbedded with layers of till over the orebody.

Throughout the remainder of this document the fine and coarse grained stratified drift will be termed "fine drift" and "coarse drift".

Outwash

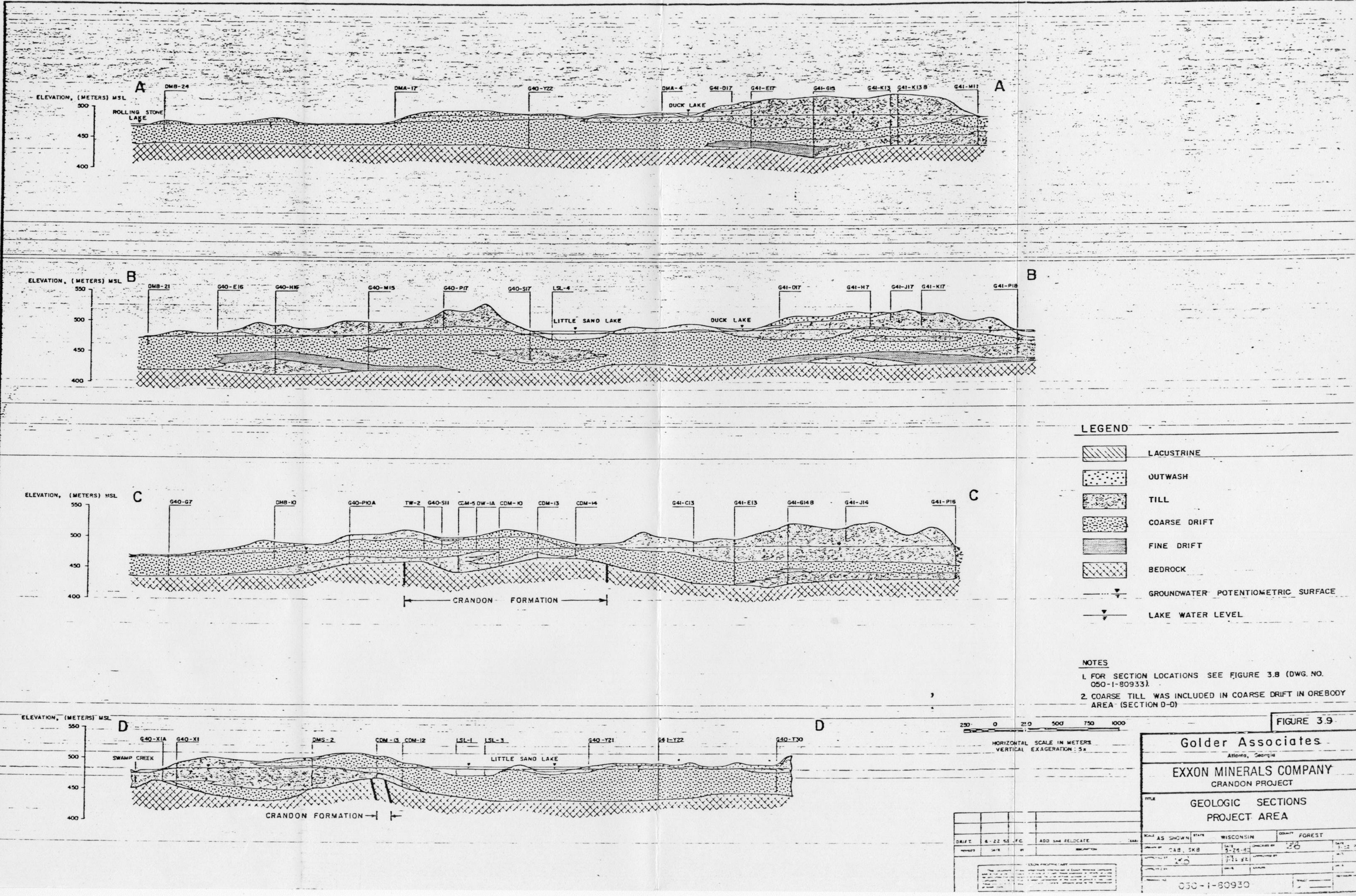
These are fluvioglacial sands and gravels that have been mapped extensively at the surface and tend to be deposited in the relatively flat areas between the till drumlins. At some site locations these deposits directly overlay the coarse drift and the boundary contact between the two formations becomes indistinguishable at depth.

Lacustrine and Wetland Deposits

This grouping includes all post-glacial (Holocene) deposits in the site area. They are predominantly fine grained silts and clays with varying amounts of sand that have been deposited directly from the lakes. They are associated with the wetland areas and have been found adjacent to and beneath lakes on the site.

Figure 3.9 shows four geological cross sections through the glacial deposits of the project area and Figure 3.8 shows the section locations. These sections illustrate the vertical and horizontal variation in facies together with the variation in thickness of these deposits.


NORTH
LEGEND
TEST BORING LOCATION
TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
WELL DATA PROVIDED BY U.S.G.S.
GOLDER ASSOCIATES TEST PIT LOCATION
GOLDER ASSOCIATES TEST WELL LOCATION
DAMES & MOORE TEST WELL LOCATION
CRANDON FORMATION
NOTE
SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:
G GOLDER ASSOCIATES
DM DAMES & MOORE
DW DAMES & MOORE
BE BRAUN ENGINEERING TESTING
X EXXON MINERALS COMPANY
STS SOIL TESTING SERVICES OF WISCONSIN, INC.
AR,RR SOIL TESTING SERVICES OF WISCONSIN, INC.
CDM CAMP DRESSER & McKEE, INC
FOR GEOLOGIC SECTIONS A-A, B-B, C-C AND D-D SEE FIGURE 3.9, DWG NO 050-1-80930.
FOR GEOLOGIC SECTION E-E SEE FIGURE 6.1 DWG. NO. 050-1-80932.
FOR DETAILED LOCATION OF THESE AND ADDITIONAL BORINGS IN THIS AREA, SEE DRAWING NO. 050-1-81330
PLANT SITE
RICE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
GROUND HEMLOCK LAKE
WALSH LAKE
ROLLING STONE LAKE
NOTE: ELEVATIONS IN METERS MSL
SCALE IN METERS
FIGURE 3.8
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
PROJECT AREA
GLACIAL GEOLOGIC SECTION LOCATION
AS SHOWN
WISCONSIN
FOREST
050-1-80933



A
A
ELEVATION, (METERS) MSL
ROLLING STONE LAKE
DUCK LAKE
DMB-24
DMA-17
G40-Y22
DMA-4
G41-O17
G41-E17
G41-G15
G41-K13
G41-K13B
G41-M11
B
B
ELEVATION, (METERS) MSL
DMB-21
G40-E16
G40-H16
G40-M15
G40-P17
G40-S17
LSL-4
LITTLE SAND LAKE
DUCK LAKE
G41-O17
G41-H7
G41-J17
G41-K17
G41-P18
C
C
ELEVATION, (METERS) MSL
G40-G7
DMB-10
G40-P10A
TW-2
G40-S11
CDM-5
OW-1A
CDM-10
CDM-13
CDM-14
G41-C13
G41-E13
G41-G14B
G41-J14
G41-P16
CRANDON FORMATION
D
D
ELEVATION, (METERS) MSL
SWAMP CREEK
G40-X1A
G40-X1
DMS-2
CDM-13
CDM-12
LSL-1
LSL-3
LITTLE SAND LAKE
G40-Y21
G41-Y22
G40-T30
CRANDON FORMATION
550
500
450
400
LEGEND
LACUSTRINE
OUTWASH
TILL
COARSE DRIFT
FINE DRIFT
BEDROCK
GROUNDWATER POTENTIOMETRIC SURFACE
LAKE WATER LEVEL
NOTES
1. FOR SECTION LOCATIONS SEE FIGURE 3.8 (DWG. NO. 050-1-80933).
2. COARSE TILL WAS INCLUDED IN COARSE DRIFT IN OREBODY AREA (SECTION D-D)
250 0 250 500 750 1000
HORIZONTAL SCALE IN METERS
VERTICAL EXAGERATION: 5x
FIGURE 3.9
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GEOLOGIC SECTIONS
PROJECT AREA
AS SHOWN
WISCONSIN
FOREST
CAB, SKB
050-1-80930
ADD and RELOCATE

4.0 HYDROGEOLOGY

4.1 Regional Hydrogeology

On a regional basis, the glacial overburden directly overlies the Precambrian deposits of northern Wisconsin and may exceed 91 m (300 ft.) in thickness, in buried, pre-glacial valleys. The sheets of coarse drift and outwash which are contained in this glacial overburden are the most prolific groundwater aquifers in the region.

The Precambrian bedrock deposits, although locally fractured and showing secondary permeability, typically yield small amounts of water to wells (Reference 3). With respect to regional movement of groundwater under natural conditions, the bedrock is functionally impermeable.

4.2 Study Area Hydrogeology

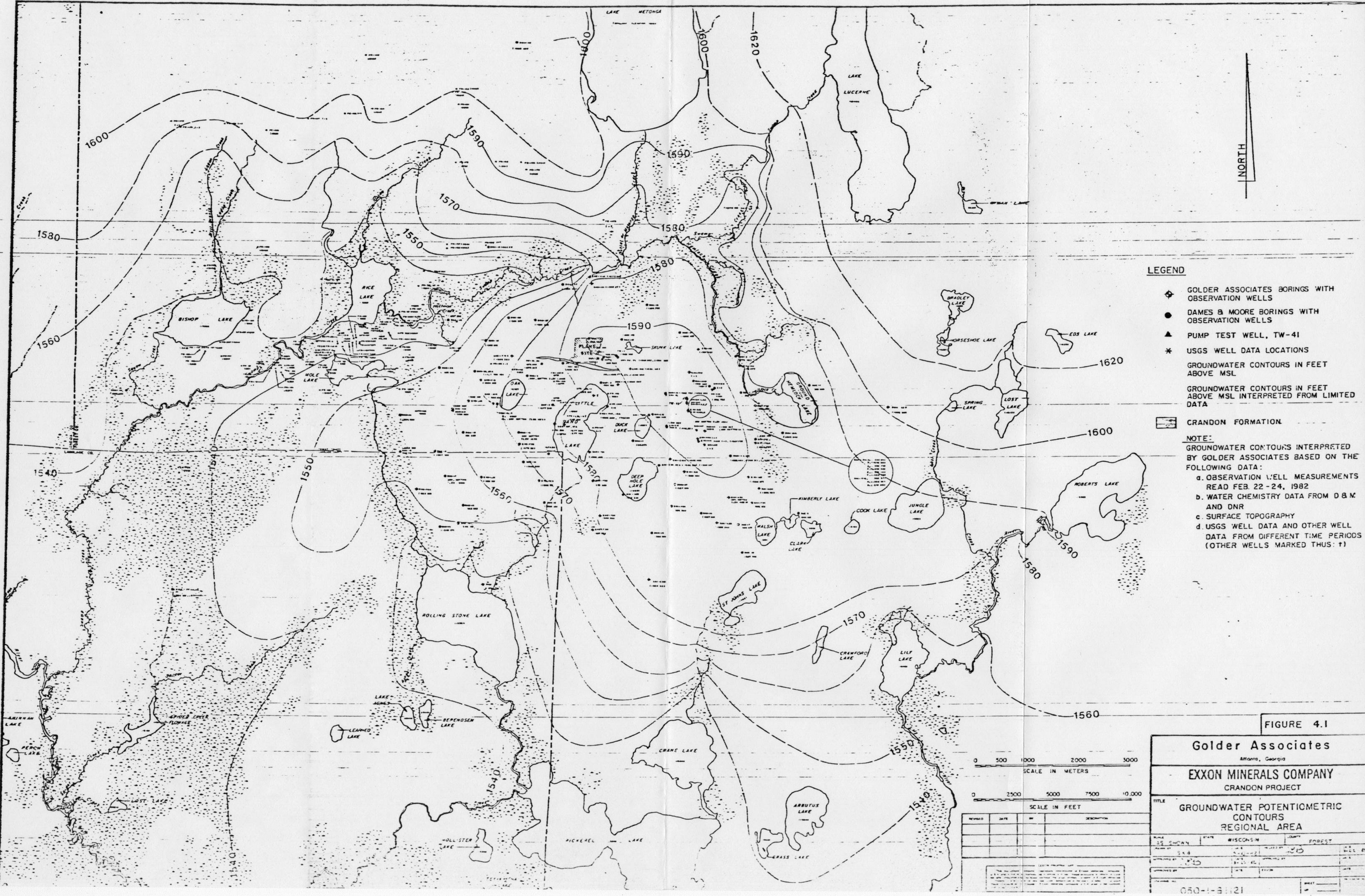
4.2.1 General

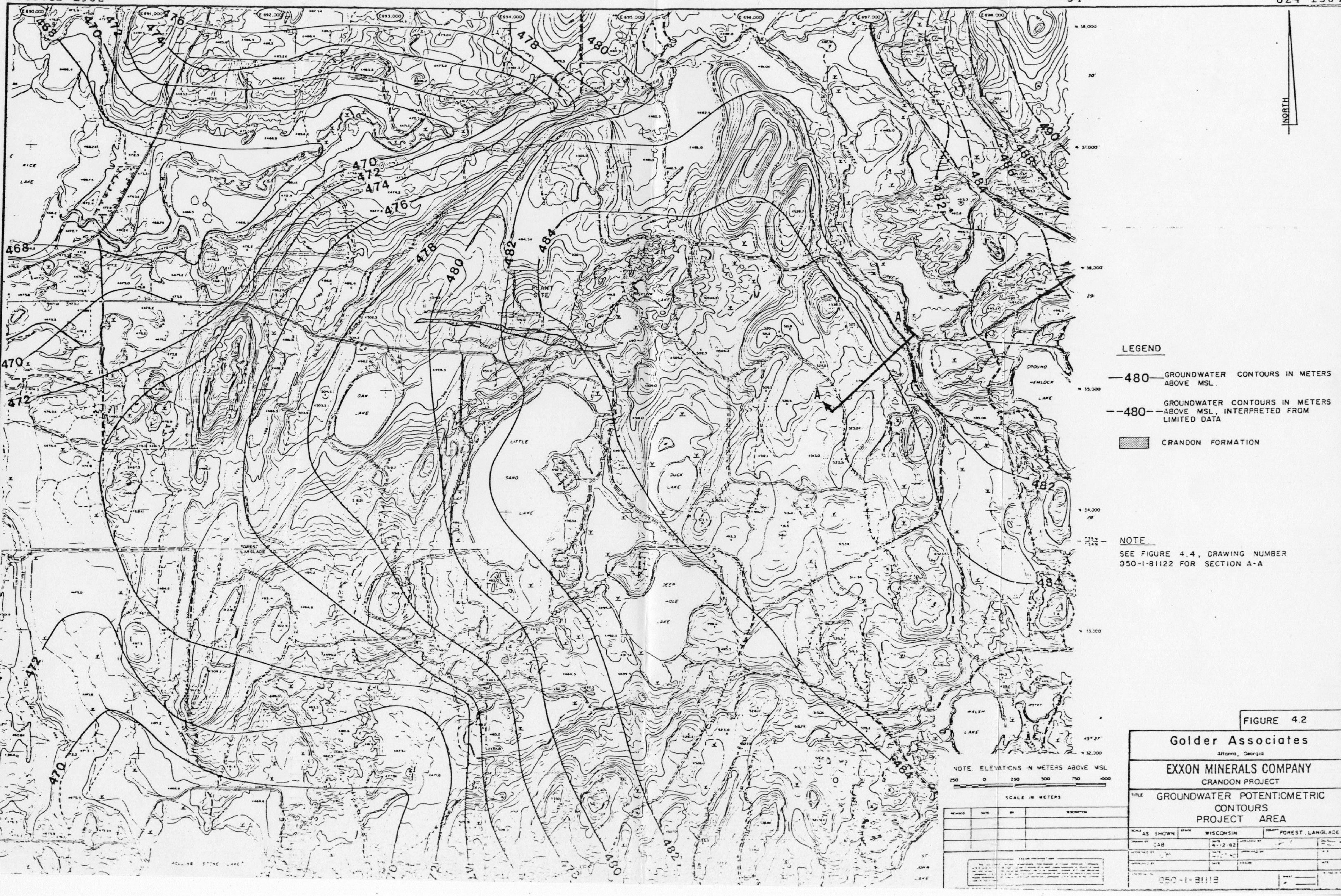
The glacial deposits constitute the main water bearing unit within the project area. The coarse drift is the primary transmissive unit in the project area and although it laterally pinches out or grades into till in some areas and exhibits vertical variation, over the project area as a whole these effects become minimal. The coarse drift behaves essentially as an unconfined aquifer that is locally semi-unconfined where it is overlain by till. Pumping of the bedrock strata indicates hydraulical connection in some areas to the overlying glacial materials.

4.2.2 Groundwater Levels

In general, the upland portion of the project area is a groundwater recharge area with groundwater discharging to the surrounding lowlying streams, lakes and wetlands. This pattern is shown in Figures 4.1 and 4.2. Figure 4.1 shows the regional area potentiometric surface with the data used to construct the contours in English units. Figure 4.2 covers the project area and shows the potentiometric surface contours in S.I. units. These contour maps are based primarily on water level readings taken in February 1982 at the various observation wells which exist around the Crandon Project area. The date of the readings and groundwater level for each well are included in Appendix A. In addition, a series of groundwater elevations provided by the U.S.G.S. were used. However, these measurements were made at various times and are not considered to be as reliable as the Crandon Project data. A listing of the well data provided by the U.S.G.S. and water level readings for each is included in Appendix B.

The Crandon Project observation wells (i.e., those included in Appendix A) are screened at various depths in several types of glacial overburden. The variation in potentiometric level in clusters of adjacent wells screened at different depths indicates that the potentiometric levels in the various types of glacial overburden vary less than 0.27 m (9 inches) relative to each other (Reference 8). This leads to the characterization of the coarse drift as a semi-unconfined aquifer which is in direct connection with free draining, though considerably less permeable, underlying and overlying layers of till. This is further corroborated by the response of the clusters of observation wells screened in the various glacial materials during the large scale pumping test performed by Golder Associates (Reference 7).


LAKE METONGA
LAKE LUCERNE
NORTH
1600
1620
1590
1580
1570
1560
1550
1540
BISHOP LAKE
RICE LAKE
HOLE LAKE
PLANT SITE
SKUNK LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
BRADLEY LAKE
HORSESHOE LAKE
EDS LAKE
SPRING LAKE
LOST LAKE
ROBERTS LAKE
KIMBERLY LAKE
COOK LAKE
JUNGLE LAKE
WALSH LAKE
CLARK LAKE
ST JOHNS LAKE
CRAWFORD LAKE
LILY LAKE
ROLLING STONE LAKE
LAKE AGNES
BERENDSEN LAKE
LEAMMED LAKE
SPIDER CREEK FLOWAGE
PERCH LAKE
LOST LAKE
CRANE LAKE
ARBUTUS LAKE
GRASS LAKE
HOLLISTER LAKE
PICKEREL LAKE
LEGEND
GOLDER ASSOCIATES BORINGS WITH OBSERVATION WELLS
DAMES & MOORE BORINGS WITH OBSERVATION WELLS
PUMP TEST WELL, TW-41
USGS WELL DATA LOCATIONS
GROUNDWATER CONTOURS IN FEET ABOVE MSL
GROUNDWATER CONTOURS IN FEET ABOVE MSL INTERPRETED FROM LIMITED DATA
CRANDON FORMATION
NOTE:
GROUNDWATER CONTOURS INTERPRETED BY GOLDER ASSOCIATES BASED ON THE FOLLOWING DATA:
a. OBSERVATION WELL MEASUREMENTS READ FEB. 22-24, 1982
b. WATER CHEMISTRY DATA FROM D & M AND DNR
c. SURFACE TOPOGRAPHY
d. USGS WELL DATA AND OTHER WELL DATA FROM DIFFERENT TIME PERIODS (OTHER WELLS MARKED THUS: †)
0 500 1000 2000 3000
SCALE IN METERS
0 2500 5000 7500 10,000
SCALE IN FEET
FIGURE 4.1
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GROUNDWATER POTENTIOMETRIC CONTOURS REGIONAL AREA
AS SHOWN
WISCONSIN
FOREST

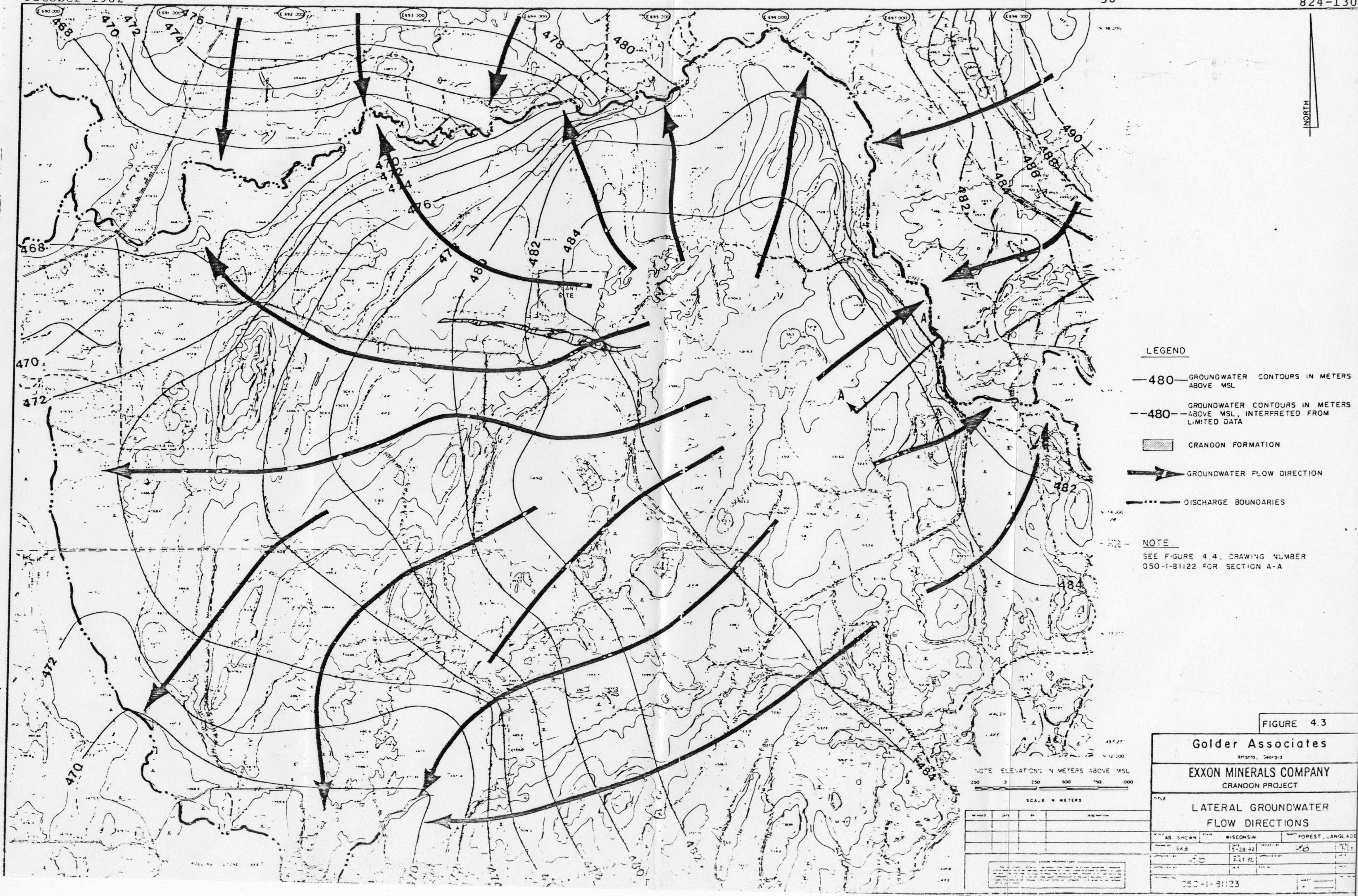

NORTH
LEGEND
—480— GROUNDWATER CONTOURS IN METERS ABOVE MSL.
--480-- GROUNDWATER CONTOURS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA
CRANDON FORMATION
NOTE.
SEE FIGURE 4.4, DRAWING NUMBER 050-1-81122 FOR SECTION A-A
NOTE. ELEVATIONS IN METERS ABOVE MSL
SCALE IN METERS
FIGURE 4.2
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GROUNDWATER POTENTIOMETRIC CONTOURS PROJECT AREA
AS SHOWN
WISCONSIN
FOREST, LANGLADE
050-1-81118
RICE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
WALSH LAKE
GROUND HEMLOCK LAKE
PLANT SITE
468
470
472
474
476
478
480
482
484
486
488
490

As previously discussed, the potentiometric heads in the glacial materials are essentially equal. However, they do show a downward trend from the overlying till into the underlying coarse drift. This fact is in agreement with the concept of groundwater recharge in the till covered highlands and groundwater discharge in the lowlands which are predominantly coarse drift and outwash at the surface.

4.2.3 Typical Groundwater Flow Patterns

The general direction of groundwater movement is lateral through the coarse drift overburden and discharging into the surrounding lakes and streams. The lateral direction of groundwater movement is perpendicular to the contours. Figure 4.3 shows the typical direction of lateral groundwater movement across the Crandon Project area. However, this general trend is not exhibited beneath the perched lakes, as discussed in Section 7.

Movement of groundwater in cross section across the Project area is generally downward through the overlying till into the coarse drift. The surrounding groundwater fed streams and lakes drain the coarse grained stratified drift, inducing lateral movement of groundwater in this material. To illustrate this pattern of movement, a flow net was constructed along section A-A indicated on Figure 4.3. This flow net is bounded on the west end by a groundwater divide and constitutes a no-flow boundary. The east end of the flow net is bounded by Hemlock Creek and its contiguous wetland, which constitutes a discharge boundary. The rising groundwater gradients on the east side of Hemlock Creek also direct discharge to the creek, insuring that flow along the section analyzed drains toward



NORTH
LEGEND
480 GROUNDWATER CONTOURS IN METERS ABOVE MSL
480 GROUNDWATER CONTOURS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA
CRANDON FORMATION
GROUNDWATER FLOW DIRECTION
DISCHARGE BOUNDARIES
NOTE
SEE FIGURE 4.4, DRAWING NUMBER 050-1-81122 FOR SECTION A-A
NOTE: ELEVATIONS IN METERS ABOVE MSL
SCALE IN METERS
PLANT SITE
FIGURE 4.3
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
LATERAL GROUNDWATER FLOW DIRECTIONS
AS SHOWN
WISCONSIN
FOREST, LANGLADE
050-1-81123

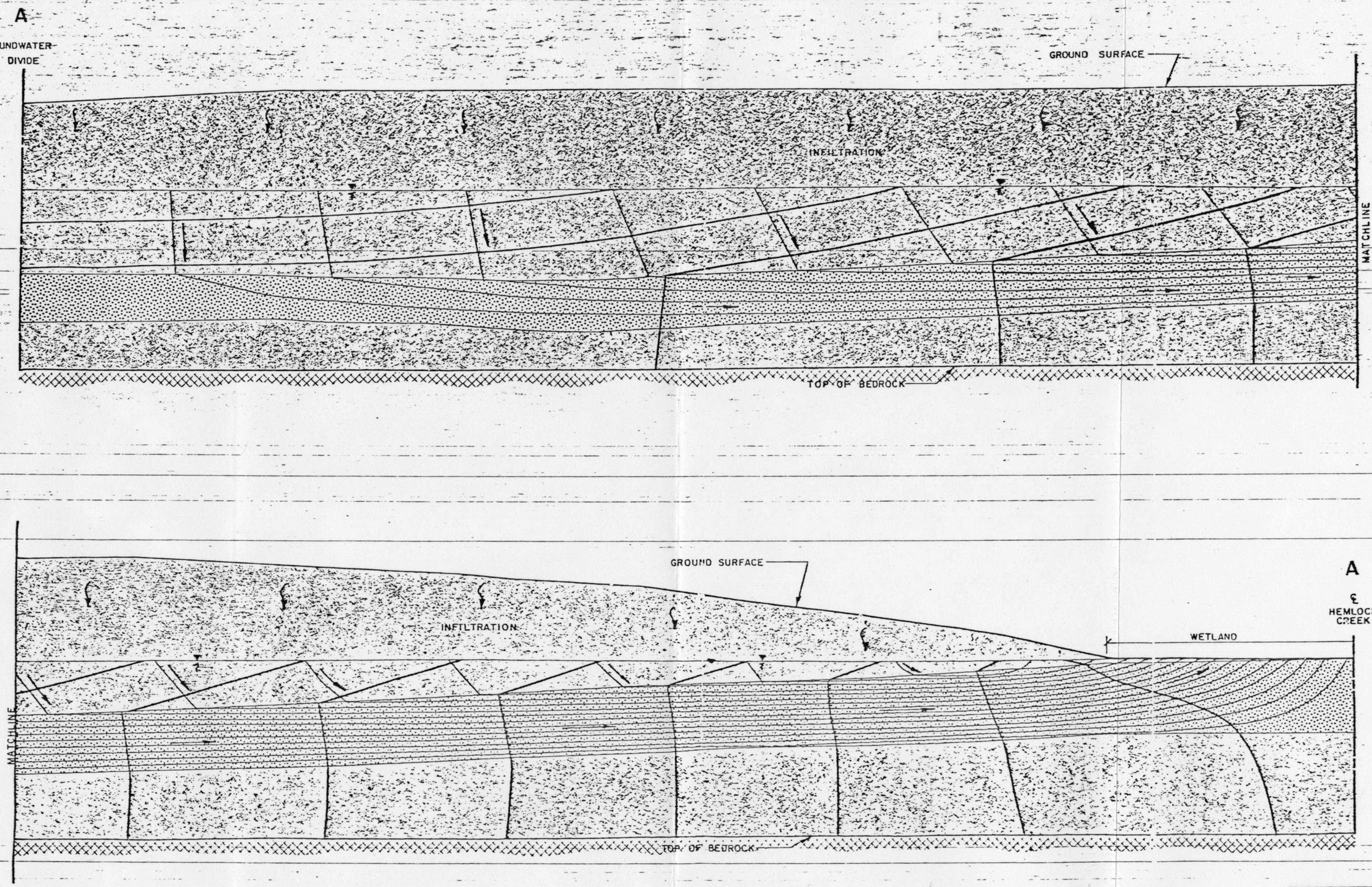
the wetland or creek channel. The flow net analysis considers the material boundaries between the drift and the till, as well as the differing hydraulic conductivity and anisotropy of the two materials. Due to the scale of the section analyzed, and the different order of magnitude and anisotropy of the hydraulic conductivity of the materials, a finite element computer model was employed. Figure 4.4 presents the final flow net. The flow directions indicated on the flow net are parallel to the rigorously constructed flow lines and show that groundwater movement in the overlying till is primarily downward and that movement in the coarse drift is laterally toward the groundwater fed streams and lakes.

4.2.4 Hydraulic Parameters

In order to gain a detailed understanding of the groundwater system in the Crandon Project area the hydraulic parameters of the various glacial and bedrock materials must be known. These parameters include hydraulic conductivity, storativity, and total porosity. In addition, the thickness of the primary transmissive unit, the coarse drift and how this thickness varies across the project area should be known.

These parameters have been estimated in several studies, including pumping tests, drilling programs, and soil tests. Sources of these parameters are listed below.

1. Golder Associates large scale pumping test (Reference 7).
2. Dames & Moore pumping tests (Reference 1).
3. Soil testing by Golder Associates and Dames & Moore (References 5 and 2).
4. Orebody pumping test by Camp Dresser and McKee (Reference 9).



LEGEND

- TILL ($K_h = 3 \times 10^{-6}$ m/s, $K_v = 9 \times 10^{-7}$ m/s)
- DRIFT ($K_h = 1 \times 10^{-4}$ m/s, $K_v = 1 \times 10^{-5}$ m/s)
- BEDROCK (Functionally Impermeable)
- GROUNDWATER POTENTIOMETRIC SURFACE
- INFILTRATION
- SATURATED FLOW DIRECTION
- FLOW LINES
- EQUIPOTENTIAL LINES

NOTES:

1. NO VERTICAL EXAGERATION
2. SEE FIGURE 4.2, DRAWING NUMBER 050-1-81118 FOR SECTION LOCATION

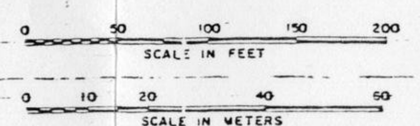


FIGURE 4.4

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

VERTICAL GROUNDWATER FLOW DIRECTIONS

SCALE AS SHOWN | STATE WISCONSIN | COUNTY FOREST

DRAWN BY MTF, SKB | DATE 5-25-82

050-1-81122

5. Boring and soil testing program by STS Consultants (Reference 14).

6. Varied soil tests by other contractors.

Although pumping tests and other borehole tests (rising and falling head tests) measure the in situ hydrogeologic properties of the glacial overburden and are valid only over the area influenced by the test, these methods yield bulk formation parameter values which are most appropriate for use in project scale analytical procedures. These types of in situ tests are considered to be the most reliable parameter estimates available, but they do not indicate the range of values which can exist across the project area or within a given material class. Therefore, data from the various soils test results were used to indicate the range of hydraulic conductivity and porosity across the project area.

Values of hydraulic conductivity were estimated from grain size analyses using Hazen's approximation. Hazen found from numerous tests with loose filter sands that the hydraulic conductivity of these sands depends upon the effective particle size and the uniformity coefficients; thereby relating permeability to grain size distribution. For loose sands having a uniformity coefficient between 2 and 5, the Hazen empirical equation is:

$$k = C(D_{10})^2 \qquad (4.1)$$

where k is the hydraulic conductivity in centimeters per second and D_{10} is the effective size (10 percent of the sample, by weight, being smaller than this size) in centimeters. The value of the coefficient 'C' ranges from 90 to 120, with a value of 100 normally used. For soils other than loose uniform sands, permeability values computed from the Hazen equation should be considered only approximate.

Estimated coefficients of permeability for the glacial materials have been made using Hazen's approximation and the D_{10} particle sizes from the grain size curves. These estimates have been made using a value of 100 for the coefficient term 'C' in Hazen's equation. The grain size distribution curves give the particle diameters in millimeters. Therefore, with C=100, and grain sizes in millimeters (not centimeters), Hazen's equation may be rewritten as:

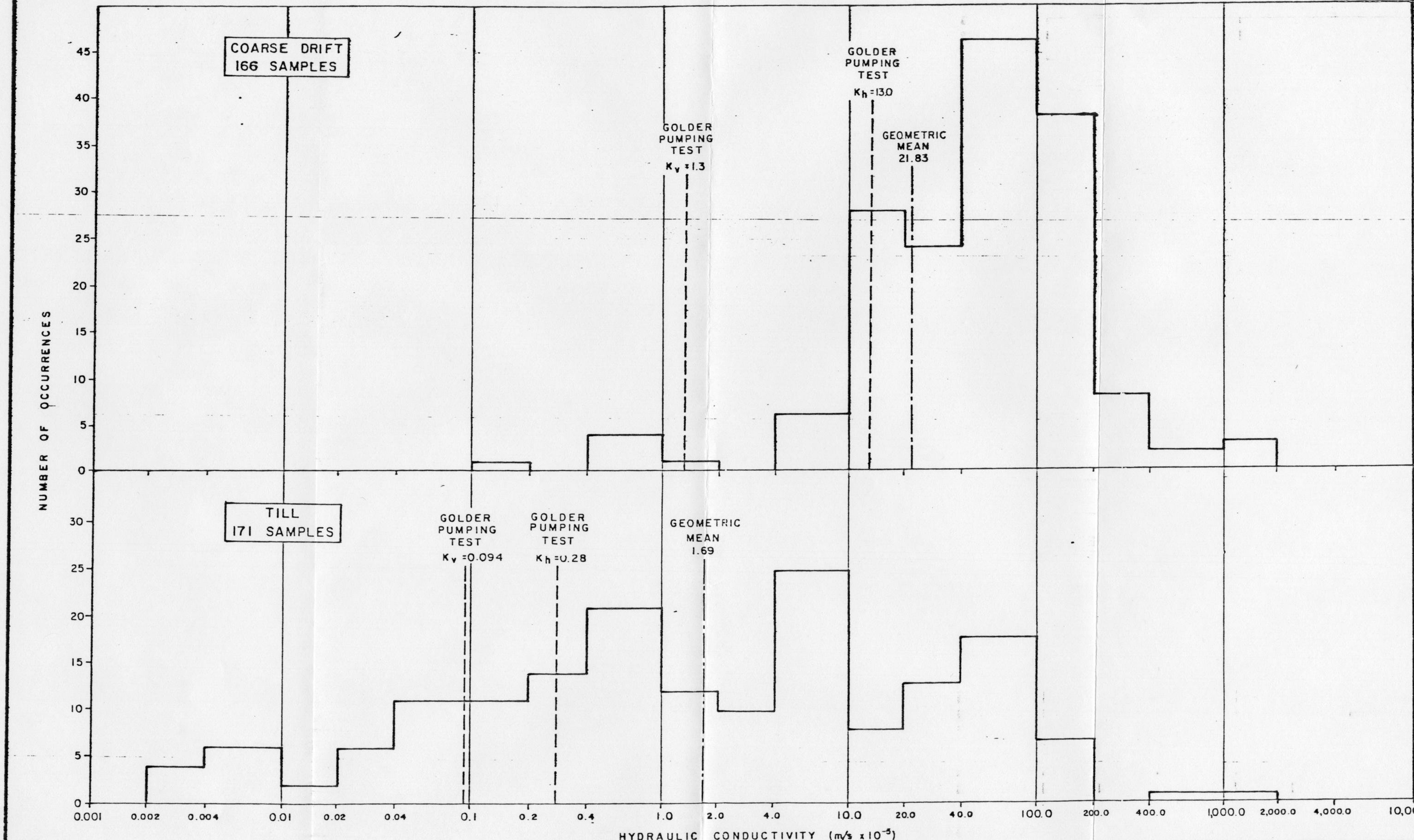
$$k = \frac{(D_{10})^2}{100} \qquad (4.2)$$

with the result in meters per second to be consistent with S.I. units.

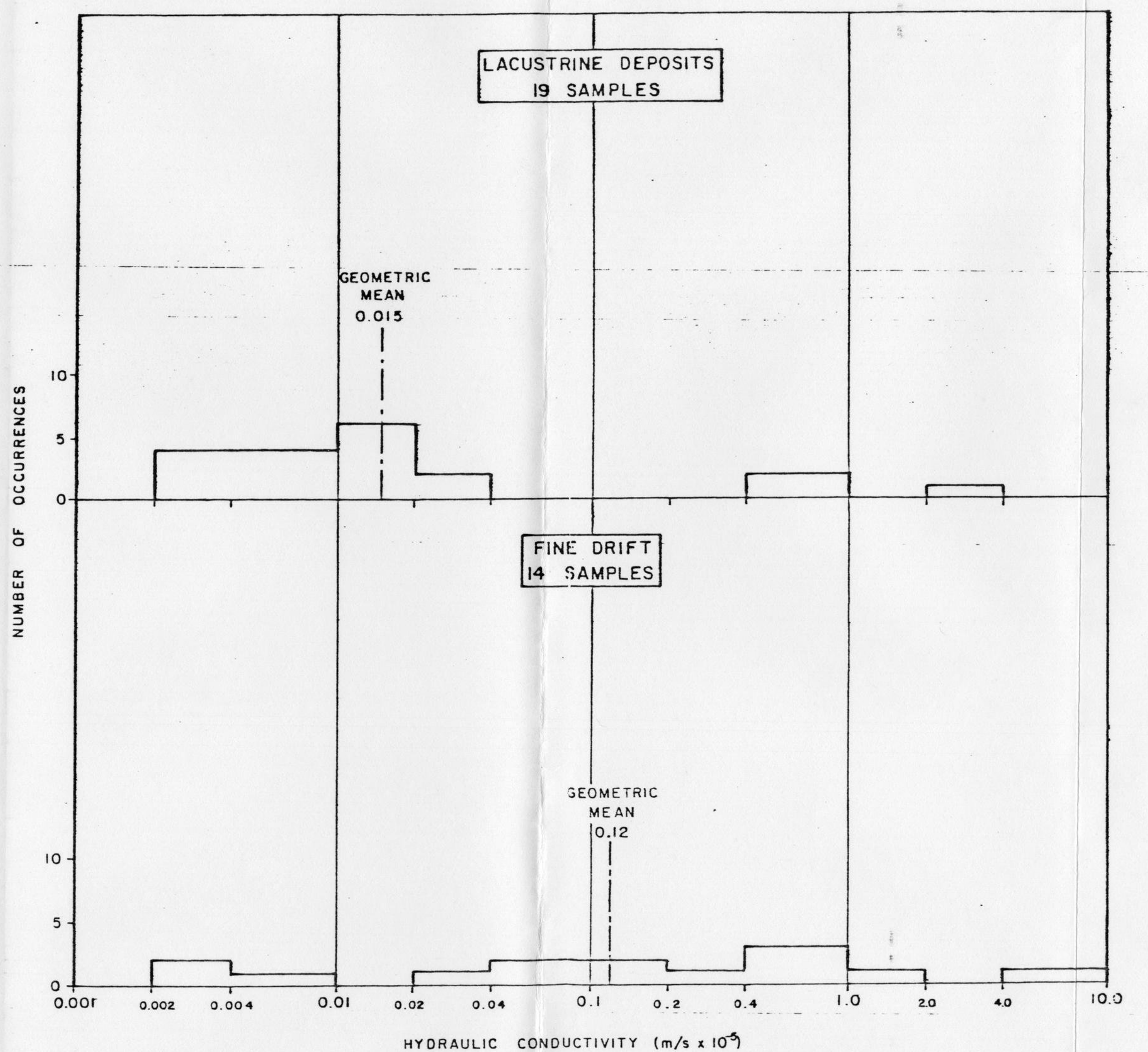
Figure 4.5 shows the distribution of computed hydraulic conductivity for samples of coarse drift and till and Figure 4.6 shows the hydraulic conductivity for samples of lacustrine deposits and fine drift. Insufficient data exists on outwash to show a meaningful distribution.

Values of porosity were estimated from the bulk density of the various soils as determined from relatively undisturbed samples assuming a specific gravity of 2.71, based on the minerology of the overburden (Reference 2). Figure 4.7 shows the distribution of computed porosity for samples of the fine drift and coarse drift and Figure 4.8 shows the distribution of porosity for the till samples. Insufficient data exists to prepare distributions for the lacustrine and outwash materials.

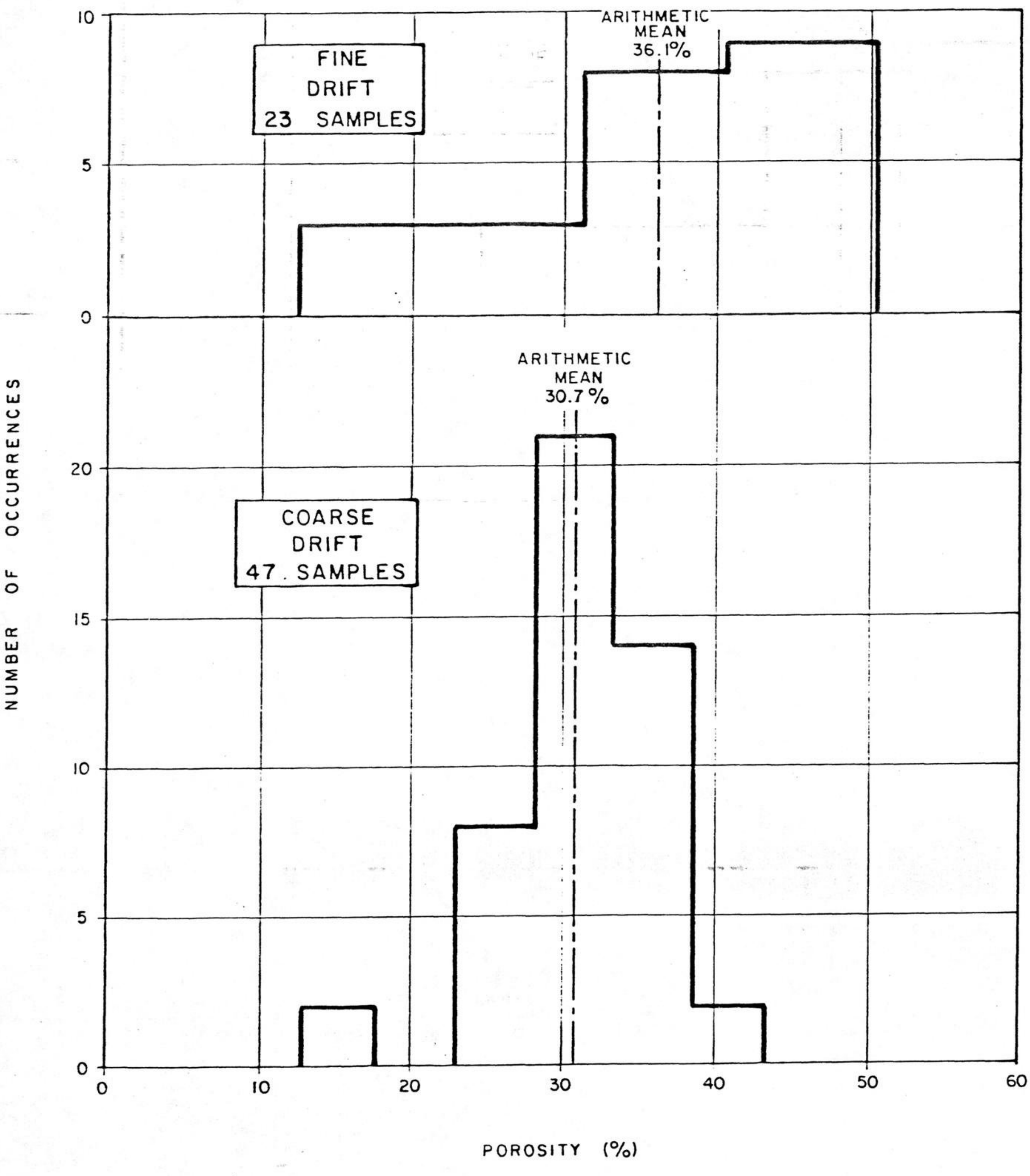
All of the various overburden hydraulic parameters values are shown on Table 4.1 and the orebody hydraulic



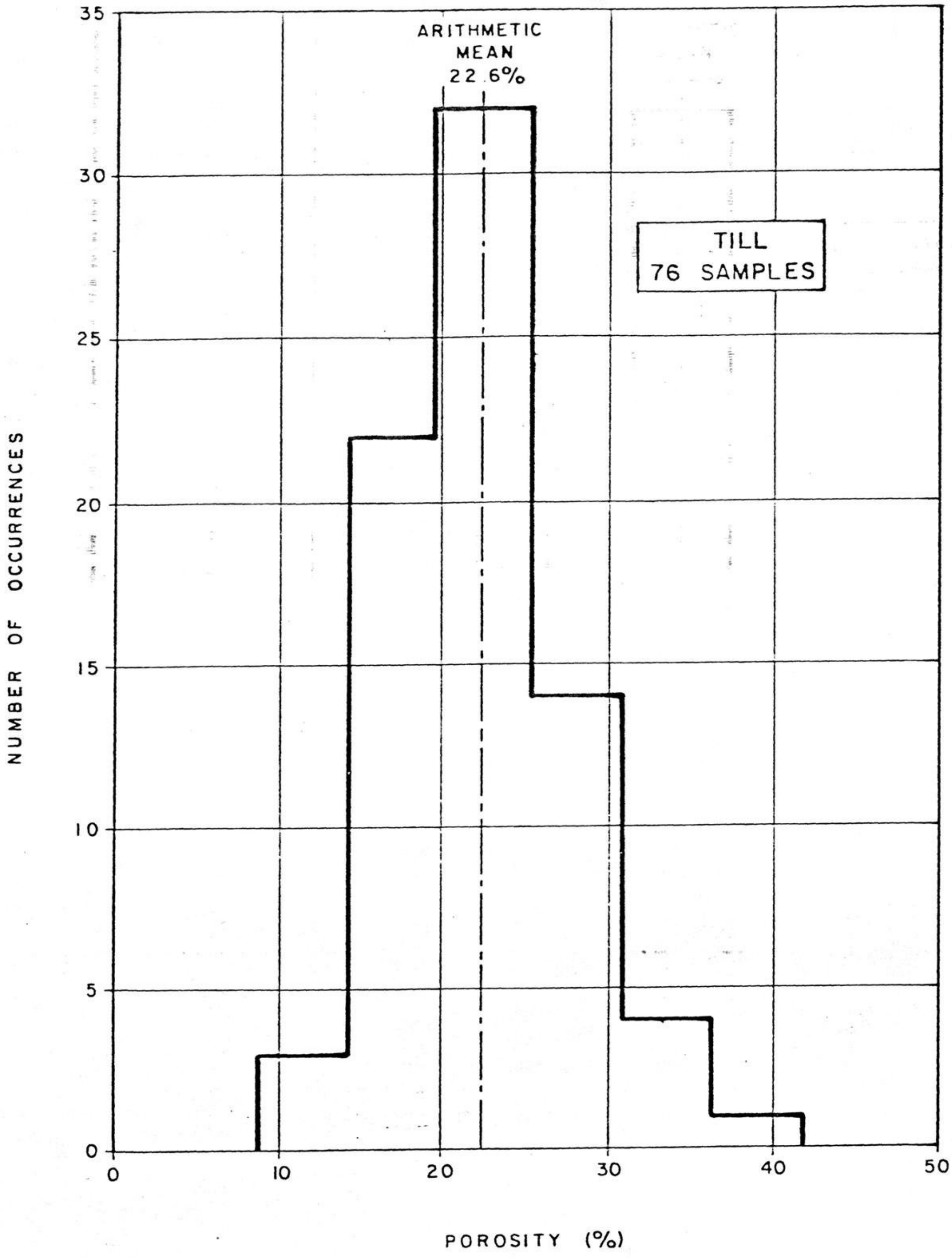
JOB NO. 824-1304	SCALE AS SHOWN	HYDRAULIC CONDUCTIVITY BY HAZEN APPROXIMATION FOR COARSE DRIFT AND TILL
DRAWN SKB	DATE 5-18-82	
CHECKED JB	DWG. NO. —	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 4.5



JOB NO. 824-1304	SCALE AS SHOWN	HYDRAULIC CONDUCTIVITY BY HAZEN APPROXIMATION FOR LACUSTRINE DEPOSITS AND FINE DRIFT
DRAWN SKB	DATE 5-14-82	
CHECKED JEB	DWG. NO. —	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 4.6



JOB NO. 824-1304	SCALE AS SHOWN	POROSITY DISTRIBUTION OF FINE AND COARSE DRIFT
DRAWN SKB	DATE 5-20-82	
CHECKED JEB	DWG. NO.	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 4.7



JOB NO. 824-1304	SCALE AS SHOWN	POROSITY DISTRIBUTION OF TILL
DRAWN SKB	DATE 5-20-82	
CHECKED JEB	DWG. NO. ______	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 4.8

TABLE 4.1

HYDRAULIC PARAMETERS OF GLACIAL OVERBURDEN

(MOST REPRESENTATIVE VALUES ARE SHADED)

Material	Horizontal Hydraulic Conductivity (10^{-5} M/S)	Vertical Hydraulic Conductivity (10^{-5} M/S)	Storativity	Porosity (%)	Data Source	Reference
Coarse Grained Stratified Drift	13.0	1.3	0.07	-	Golder Pumping Test	7
	43.0	-	0.05(1)	-	Dames & Moore Pumping Test	3
	21.84	-	-	-	Hazen Approximations	6,3
	-	-	-	30.7	Laboratory Density	6,3
Till	0.28	0.094	0.054	-	Golder Pumping Test	7
	19.5 (3)	0.016(1)	0.0015(4)	-	Dames & Moore Pumping Test	3
	-	1.69	-	-	Hazen Approximations	6,3
	-	0.16	-	-	Borehole Tests	3
	-	-	-	22.6	Laboratory Density	6,3
Fine Grained Stratified Drift	0.12	0.012(1)	-	-	Hazen Approximations	6,3
	-	-	0.06(1)	-	Golder Pumping Test	7
	-	-	-	36.1	Laboratory Density	6,3
Lacustrine	0.015	-	-	-	Hazen Approximations	6,3
	-	0.016(1)	-	-	Dames & Moore Estimate	6
	0.0003(1)	0.0003	-	-	Constant Head Laboratory Test	14
Outwash	14.4	1.4(1)	-	-	Hazen Approximation	6,3
	-	-	0.07(1)	-	Golder Pumping Test	7
	-	-	-	30.7(1)	Laboratory Density	6,3

Notes: (1) Estimated Values
(2) Value from one reading only
(3) Coarse Layer within Till
(4) Early (elastic) response

conductivity on Table 4.2, with the most representative values shaded, based on assessment of the reliability of the test method. Also given in Table 4.1 are the data sources and appropriate references.

TABLE 4.2

HYDRAULIC CONDUCTIVITY OF OREBODY

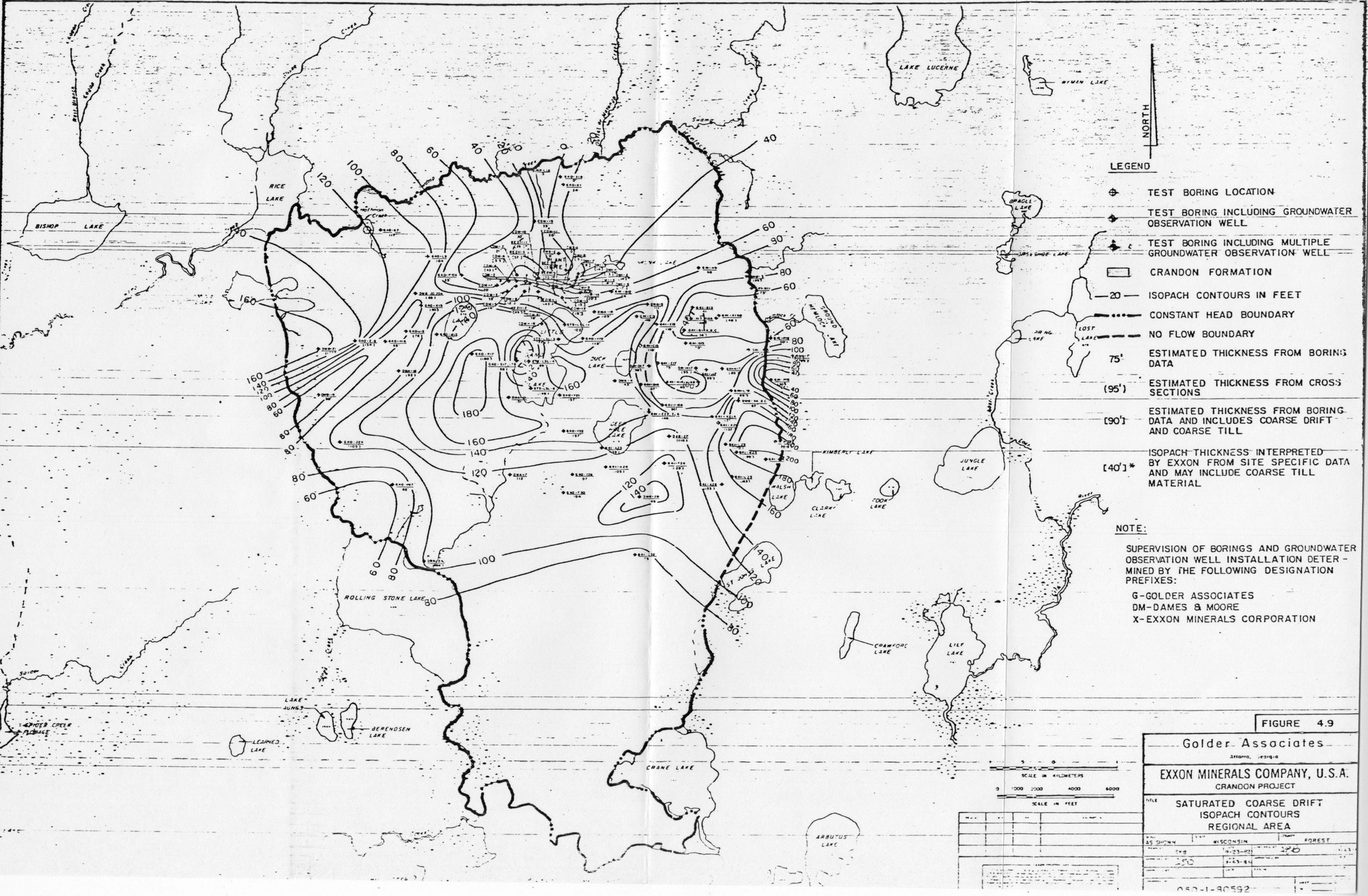
Degree of Weathering	Footwall m./sec. x10^{-5}	Footwall ft./sec. x10^{-5}	Orebody 10^{-5} m./sec.	Orebody ft./sec.	Hanging Wall 10^{-5} m./sec.	Hanging Wall ft./sec.
Weak	0.0076*	0.025	--	--	0.0017	0.0056
Low	0.0070	0.023	--	--	--	--
Moderate	0.0034	0.011	0.098	0.32	0.0064	0.021
Strong	--	--	0.89	2.92	0.017	0.056

Source: Letter from Charles R. Glore, dated 5/22/82, in Appendix C.

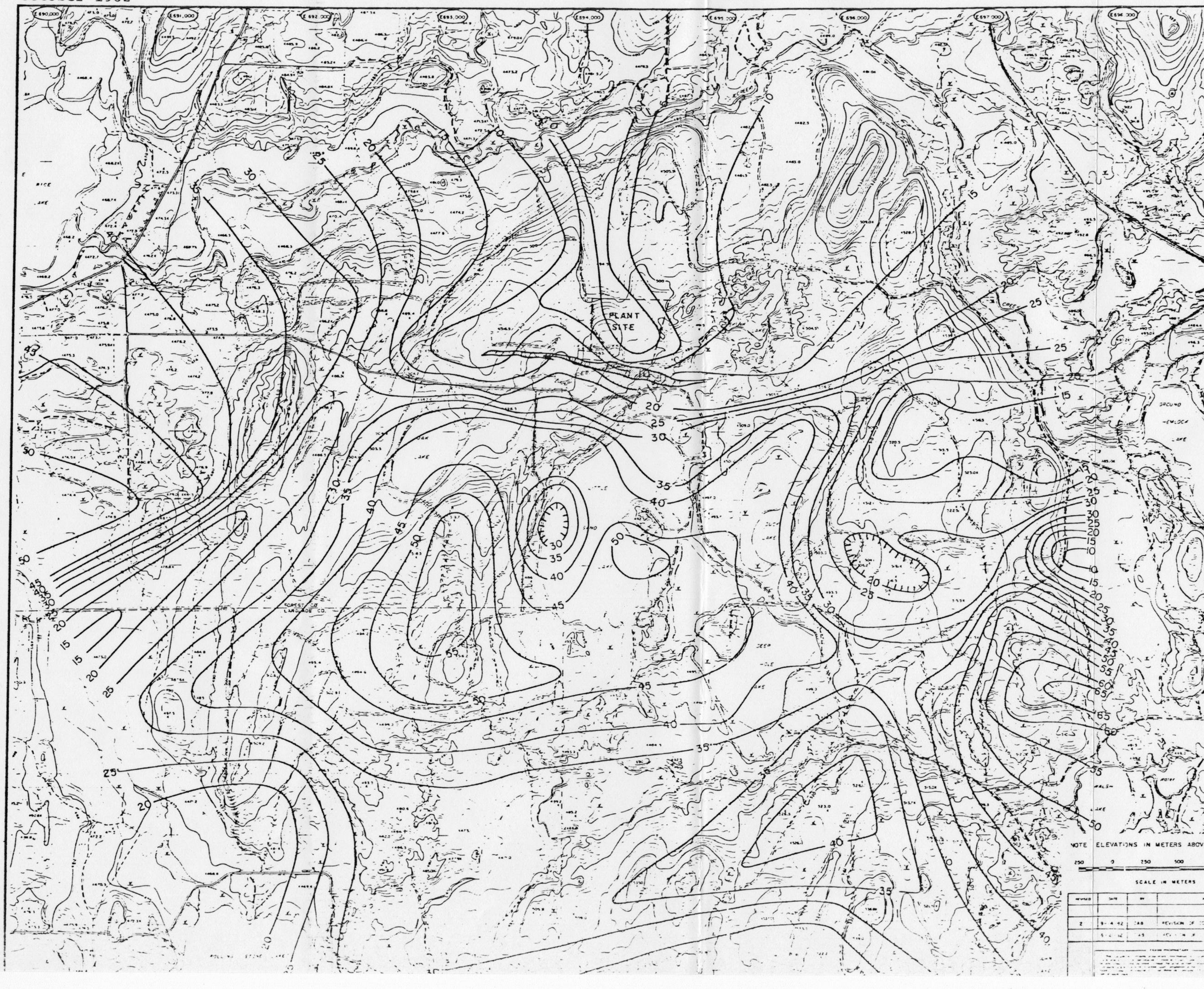
*Hydraulic conductivity of highest mine level tested.

As stated previously, the coarse drift is the most prolific highly transmissive unit in the study area. Given the horizontal hydraulic conductivity specified in Table 4.1, the overall transmissivity of this unit can be determined based on its thickness. The variation in thickness of the saturated coarse drift across the study area is shown in Figures 4.9 and 4.10 in English and S.I. units, respectively. The total saturated coarse drift thickness data is included in Appendix A where boring data is available. This data was augmented with inferred data interpreted from geologic sections to construct the isopach contours shown on Figures 4.9 and 4.10.

Over the majority of the project area the saturated coarse drift isopach includes only the coarse grained stratified drift. However, in the area between the orebody (Crandon Unit) and Swamp Creek, the base of the coarse grained stratified drift material is higher in elevation than the groundwater level, resulting in very small to non-existent saturated thicknesses, as is shown in Figure 6.1. In the vicinity of the orebody itself, deposits of coarse, highly permeable till were encountered. These highly permeable glacial materials have the potential to influence the hydraulic connection between the glacial overburden and the weathered zones of the orebody, as is discussed in detail in Section 6. Therefore, geologic interpretations by both Golder Associates and Exxon, based on boring logs and sieve analyses, where available, lead to the inclusion of this coarse till material in the orebody area for the isopach presented in Figures 4.9 and 4.10.



NORTH
LEGEND
TEST BORING LOCATION
TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
CRANDON FORMATION
—20— ISOPACH CONTOURS IN FEET
CONSTANT HEAD BOUNDARY
NO FLOW BOUNDARY
75' ESTIMATED THICKNESS FROM BORING DATA
(95') ESTIMATED THICKNESS FROM CROSS SECTIONS
[90'] ESTIMATED THICKNESS FROM BORING DATA AND INCLUDES COARSE DRIFT AND COARSE TILL
[40']* ISOPACH THICKNESS INTERPRETED BY EXXON FROM SITE SPECIFIC DATA AND MAY INCLUDE COARSE TILL MATERIAL
NOTE:
SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:
G-GOLDER ASSOCIATES
DM-DAMES & MOORE
X-EXXON MINERALS CORPORATION
LAKE LUCERNE
BISHOP LAKE
RICE LAKE
DUCK LAKE
JUNGLE LAKE
KIMBERLY LAKE
WALSH LAKE
CLARK LAKE
ROLLING STONE LAKE
CRAWFORD LAKE
LILY LAKE
CRANE LAKE
LAKE JONES
BERENDSEN LAKE
LEARNED LAKE
ARBUTUS LAKE
LOST LAKE
SCALE IN KILOMETERS
SCALE IN FEET
FIGURE 4.9
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
SATURATED COARSE DRIFT
ISOPACH CONTOURS
REGIONAL AREA
AS SHOWN
WISCONSIN
FOREST



LEGEND

—15— ISOPACH CONTOURS IN METERS

CRANDON FORMATION

NOTE

1. ISOPACH THICKNESS REPRESENTS TO THICKNESS OF ALL SATURATED COAR GRAINED STRATIFIED DRIFT.
2. IN THE CRANDON UNIT AND PLANT VICINITY COARSE TILL MATERIAL ADDED TO TOTAL ISOPACH THICKNE
3. IN ALL AREAS OTHER THAN THE C UNIT AND THE PLANT SITE ONLY COARSE GRAINED STRATIFIED DRIFT ADDED TO THE ISOPACH.

FIGURE 4.10

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

SATURATED COARSE DRIFT
ISOPACH CONTOURS
PROJECT AREA

AS SHOWN | WISCONSIN | FOREST, LA

CAB | 2-14-82

050-1-80604

5.0 SURFACE WATER HYDROLOGY

5.1 Regional Hydrology

5.1.1 Regional Drainage Basins

The regional area lies within the area of northwest Wisconsin that is drained by the Wisconsin, Wolf, Fox, Peshtigo, Oconto, and Menominee Rivers. The Crandon Project area is entirely within the northern headwaters of the Wolf River drainage basin as shown on Figure 5.1. The Wolf River originates approximately 32 km (20 mi.) northwest of the site area and flows south to Lake Poygan in Winnebago County, which is approximately 161 km (100 mi.) south of the project area. The Fox River drains the Lake Poygan-Winnebago system in a northeasterly direction to Green Bay. The Wolf River basin is bordered on the west by the Wisconsin River basin. The Wisconsin River flows south and then west to the Mississippi River. To the north and east of the Wolf River basin, drainage is provided by the Menominee, Peshtigo, and Oconto Rivers, which all flow southeast to Green Bay.

In the upper Wolf River basin, the relatively slow-flowing streams frequently pass through lakes and wetlands. Stream gradients were determined from topographic maps and are generally in the range of 1.5 to 1.9 m/km (7.7 to 10 ft./mi.) (Reference 4).

5.1.2 Regional Precipitation

Average annual precipitation (rainfall plus snow) in the regional area is 781.6 mm (30.77 in.) (Reference 4). Precipitation is greatest during late spring and early summer and least during mid-winter when it generally occurs as snow. The mean annual accumulation of snow is 1,270 mm (50 in.) (Reference 4). Precipitation records from the

NOTE: TAKEN FROM FIGURE 2.4-3, DAMES & MOORE, REFERENCE 4

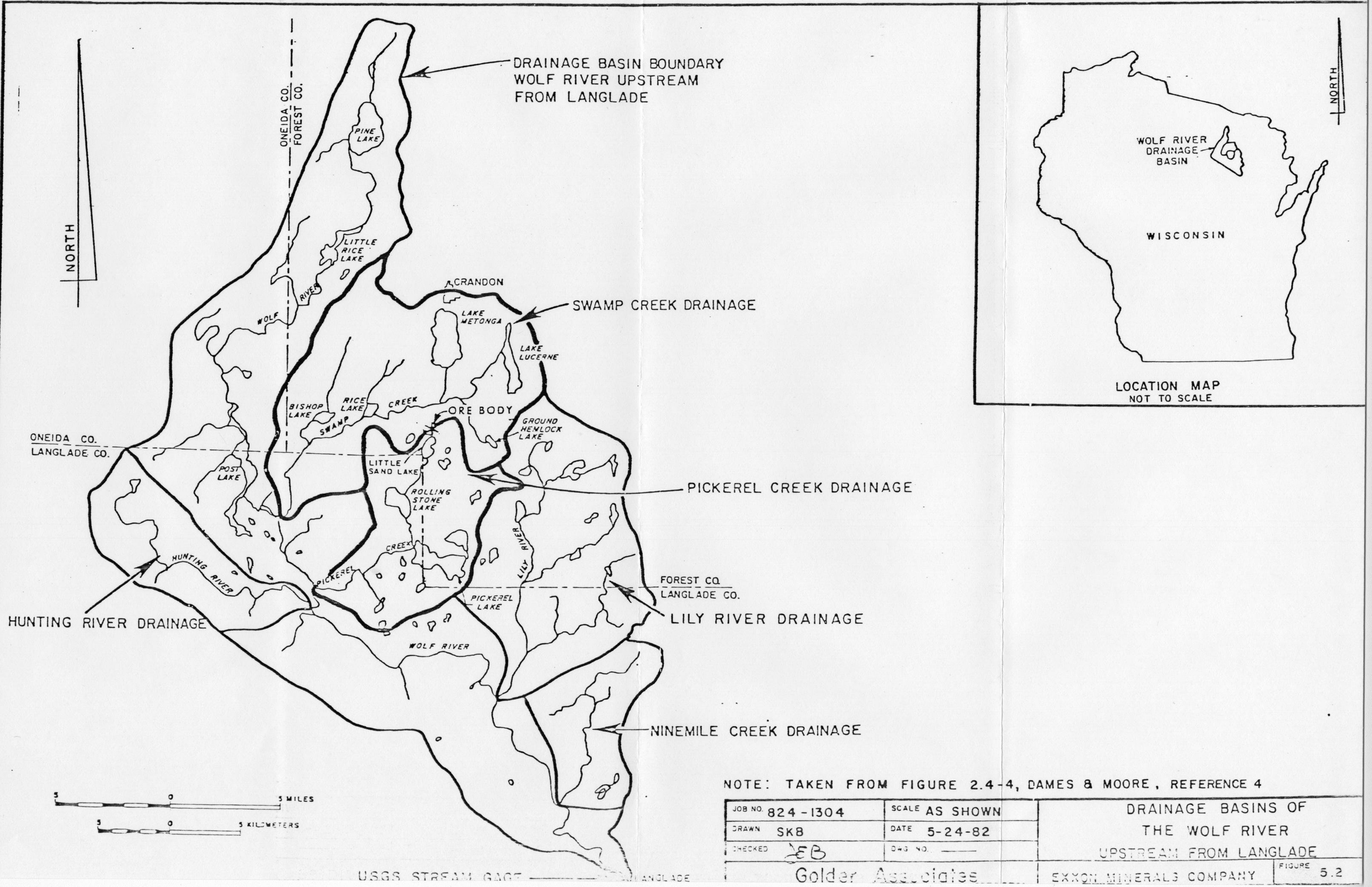
JOB NO. 824 - 1304	SCALE AS SHOWN	MAJOR DRAINAGE BASINS IN NORTHEASTERN WISCONSIN
DRAWN SKB	DATE 5-24-82	
CHECKED JEB	DWG. NO.	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 5.1

Nicolet College weather station at Rhinelander, Wisconsin, the nearest long-term data record, are assumed to be representative of the region. Rhinelander is approximately 39 km (24 mi.) northwest of the project area. Average monthly precipitation values for the period 1908 through 1977 inclusive are given in Table 5.1. On the average, the wettest month is June with almost 15 percent of the annual precipitation and the driest month is February with only 3.3 percent.

5.1.3 Regional Streamflow

Total annual stream discharge in the drainage basins in the regional area ranges from 279 mm (11 in.) to 330 mm (13 in.) (Reference 4). For the Wolf River basin the annual stream discharges range from 254 mm (10 in.) to 330 mm (13 in.) (Reference 4).

The nearest long-term stream gaging station in the area is the United States Geologic Survey (U.S.G.S.) station on the Wolf River at Langlade, as shown on Figure 5.2. The surface drainage area upstream from this gage encompasses 1,191 km^2 (460 sq. mi.) and includes the project area. Based on U.S.G.S. records, mean annual discharge at the Langlade station for the period 1966-1978 is approximately 13.2 m^3/s (466 cfs). This discharge rate corresponds to an average water depth of 352 mm (13.87 in.) for the drainage area of the Wolf River upstream of this gage. Monthly stream flow data for the Wolf River at Langlade are given in Table 5.2. The highest average monthly stream discharge of 56.4 mm (2.22 in.) occurs during April when snowmelt runoff is highest. January and February are the months of lowest stream discharge, with 20.6 mm (0.81 in.) and 17.5 mm (0.69 in.), respectively, because most precipitation is retained on the ground surface as snow and ice.



NOTE: TAKEN FROM FIGURE 2.4-4, DAMES & MOORE, REFERENCE 4

JOB NO. 824-1304	SCALE AS SHOWN	DRAINAGE BASINS OF THE WOLF RIVER UPSTREAM FROM LANGLADE
DRAWN SKB	DATE 5-24-82	
CHECKED EB	DWG NO. ———	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 5.2

TABLE 5.1

AVERAGE MONTHLY PRECIPITATION AT
NICOLET COLLEGE, RHINELANDER, WISCONSIN
1908 THROUGH 1977[a]

MONTH	AVERAGE PRECIPITATION (mm)[b]	PERCENT OF ANNUAL PRECIPITATION
October	59.4	7.6
November	47.8	6.1
December	28.2	3.6
January	26.9	3.4
February	25.4	3.3
March	38.4	4.9
April	59.4	7.6
May	85.3	10.9
June	115.6	14.8
July	97.3	12.4
August	102.6	13.1
September	95.2	12.2
Total	781.6	100

[a]Reference 4.

[b]25.4 mm = 1 inch.

TABLE 5.2

USGS MONTHLY STREAM DISCHARGE RECORD FOR THE
WOLF RIVER AT LANGLADE, WISCONSIN
USGS STATION NUMBER 04074950

WATER YEAR	MEAN MONTHLY STREAM DISCHARGE (cfs)												ANNUAL TOTAL (inches of runoff)
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
1965-1966	-	-	-	-	-	-	685	540	365	240	280	231	—
1966-1967	317	288	295	284	265	300	1,319	515	507	518	362	395	13.18
1967-1968	423	386	344	279	263	448	643	642	911	874	473	813	16.03
1968-1969	518	447	466	548	440	463	964	606	541	436	270	260	14.65
1969-1970	340	351	320	281	262	339	426	533	469	228	206	298	9.97
1970-1971	380	683	476	369	348	401	1,142	572	421	283	224	256	13.64
1971-1972	569	437	421	364	297	361	896	887	322	300	632	618	15.07
1972-1973	723	612	359	397	351	1,227	1,100	1,312	649	369	384	483	19.66
1973-1974	386	447	311	315	301	445	712	463	457	265	436	455	12.28
1974-1975	331	465	345	312	287	356	885	785	493	290	266	483	13.02
1975-1976	295	430	518	241	292	698	1,330	713	344	229	254	216	13.71
1976-1977	196	204	226	193	223	589	775	339	263	255	228	445	9.67
1977-1978	505	441	384	305	258	294	693	494	460	592	526	538	13.53
1978-1979	441	349	321	311	334	671	1,219	933	727	470	362	336	15.93
Max. Month	723	683	518	548	440	1,227	1,330	1,312	911	874	632	813	—
Max. Day	1,330	1,040	880	660	540	2,200	1,770	1,780	1,510	1,380	1,030	1,400	—
Min. Month	196	204	226	193	223	294	426	339	263	228	206	216	—
Min. Day	185	164	166	190	200	235	250	248	226	166	156	166	—

	MEAN MONTHLY STREAM DISCHARGE												
(cfs)	417	426	368	323	302	507	914	667	495	382	350	416	--
Inches of Runoff	1.04	1.03	0.92	0.81	0.69	1.27	2.22	1.67	1.20	0.96	0.88	1.01	13.87

Notes: Location: see Figure 2.4-4.
Drainage Area, 1191 km^2 (460 square miles).
Period of Record: March 1966 to September 1979, discontinued after September 1979.
To convert to m^3/s, multiply cfs by 0.02832.
— Indicates no data.

Source: USGS, 1979.

Review of the Wolf River stream discharge data (Table 5.2) indicates that the 1977 water year had the lowest surface water flow measured during the 13-year period of record. The annual total surface water runoff for this year was 246 mm (9.67 in.) compared to the average annual total surface water runoff of 352 mm (13.87 in.). The 1979 water year was the second wettest recorded during the period of record with an annual total runoff of 405 mm (15.93 in.).

5.1.4 Regional Evapotranspiration

Evapotranspiration is defined as the movement of water through vegetation to the atmosphere and the evaporation of water from soil moisture and free water surfaces to the atmosphere. Evapotranspiration is generally computed as the difference between precipitation and stream discharge, assuming that there is no net flux of groundwater from the regional area. On this basis, average annual evapotranspiration for the Wolf River surface drainage area measured by the U.S.G.S. station at Langlade is approximately 429 mm (16.9 in.). However, localized drainage basins may experience significant groundwater flux and would show correspondingly higher or lower evapotranspiration amounts.

5.1.5 Surface Water Use

In Wisconsin, permits for diversion of surface water are required. Water law in Wisconsin is essentially riparian, which means that water rights are acquired with and are inseparable from land adjacent to surface waters.

In the Wolf River basin in Forest and Langlade Counties, there are eight diversions of surface water for irrigation registered with the Wisconsin Department of Natural Resources (Reference 4). The diversion closest to the site area withdraws 0.062 m^3/s (2.22 cfs) and is located on Swamp Creek below Rice Lake at County Road M. All other diversions are outside the study area.

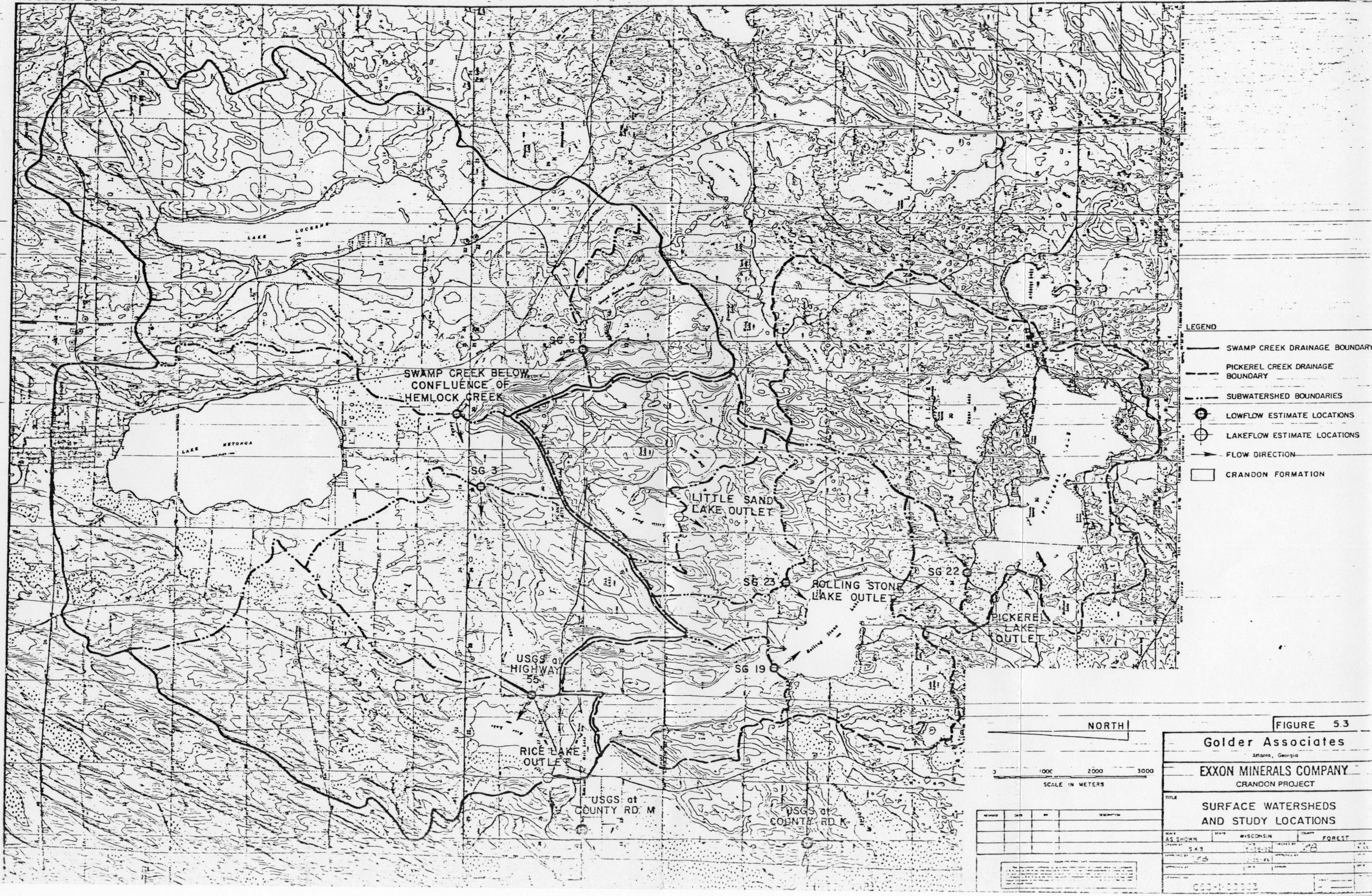
5.2 Project Area Hydrology

5.2.1 General Description

The Crandon Project area lies within the Wolf River drainage basin (see Figure 5.2) and is characterized by forested land, lakes, wetland areas, and perennial streams providing drainage paths. Portions of the orebody, proposed plant site, and the proposed waste disposal system lie in the subbasins defined by the watersheds above Rice Lake and Pickerel Lake as shown on Figure 5.3. In general the project area is bounded by Ground Hemlock Lake, Hemlock Creek and associated wetlands to the east, by Swamp Creek and Rice Lake to the north, and by the chain of lakes and wetlands from Mole Lake to Rolling Stone Lake, Pickerel Lake and Crane Lake to the west and south. This series of wetlands, lakes and creeks comprise the surface and groundwater discharge boundaries for the project area.

5.2.2 Study Area Water Balance

In an effort to quantify the annual net recharge to the groundwater system, a detailed water balance was made on the Swamp Creek drainage basin above Rice Lake. This drainage basin is large enough to contain a representative sampling of the main surface characteristics of the area such as forests, wetlands, lakes and creeks. A water balance is a quantification of the total water gains and losses of a basin for a given time period. The balance accounts for all waters entering, leaving, and stored within a hydrologic system and its various components so that


LAKE LUCERNE
SWAMP CREEK BELOW
CONFLUENCE OF
HEMLOCK CREEK
SG 6
LAKE METONGA
SG 3
LITTLE SAND
LAKE OUTLET
SG 23
ROLLING STONE
LAKE OUTLET
SG 22
PICKEREL
LAKE
OUTLET
SG 19
USGS at
HIGHWAY
55
RICE LAKE
OUTLET
USGS at
COUNTY RD. M
USGS at
COUNTY RD. K
LEGEND
SWAMP CREEK DRAINAGE BOUNDARY
PICKEREL CREEK DRAINAGE BOUNDARY
SUBWATERSHED BOUNDARIES
LOWFLOW ESTIMATE LOCATIONS
LAKEFLOW ESTIMATE LOCATIONS
FLOW DIRECTION
CRANDON FORMATION
NORTH
0 1000 2000 3000
SCALE IN METERS
FIGURE 5.3
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
SURFACE WATERSHEDS
AND STUDY LOCATIONS
AS SHOWN
WISCONSIN
FOREST

continuity is honored. The general description of the continuity statement is (Reference 30):

$$\text{Inflow} = \text{Outflow} \pm \text{Change in Storage} \quad (5.1)$$

The various terms of this basic continuity equation can be divided into those components which are appropriate for the watershed being studied. The following equation and its further subdivided forms follow the approach presented in Reference 30.

$$P = SF + ET \pm U \pm S_S \pm S_G \quad (5.2)$$

where

- P = Precipitation
- SF = Streamflow
- ET = Evapotranspiration
- U = Subsurface underflow (beneath the stream gage)
- S_S = Change in surface water and soil moisture storage
- S_G = Change in groundwater storage

The project area drainage basin and each of the above listed water balance components are discussed below.

Drainage Basin - The drainage basin above the U.S.G.S. gage on Swamp Creek at Highway 55 upstream of Rice Lake was selected for a detailed water budget analysis. Golder Associates considers this gage to have the most accurate streamflow measurements in the project area due to its hydraulic control section (concrete weir), continuous data record, and complete period of record.

The surface water and groundwater drainage areas above the U.S.G.S. gage on Swamp Creek at Highway 55 are shown on Figure 5.4. The surface water drainage area is about 11,200 ha (43.1 sq. mi.) and the groundwater drainage area is about 10,600 ha (40.9 sq. mi.). These two catchments roughly coincide as can be seen in Figure 5.4. Since the groundwater system is the focus of this analysis and the surface and groundwater catchment areas are very similar, the groundwater catchment area was used to equate total volumes to areally distributed depths in this water balance analysis.

Precipitation - The mean annual precipitation presented in Reference 4 and shown in Table 5.1 for the region is 781.6 mm (30.77 in.). However, streamflows at the study point are not known for a comparable time period. A more representative estimate of the precipitation for the project area for use in detailed water balance analysis was obtained from The National Oceanic and Atmospheric Administration (NOAA) precipitation gaging station at Laona 6 S.W. This gage is the nearest station to the site and has available recorded data corresponding to the time period of streamflow measurements used in the water balance analysis. For the period of 1974 to 1980 the average annual precipitation of 840.0 mm (33.07 in.) was used. Use of the lower value of 781.6 mm (30.77 in.) in the water balance computation would decrease the evapotranspiration and groundwater recharge components approximately proportionately. The annual precipitation data for Laona 6 S.W. for this period is presented in Table 5.3 with the Rhinelander NOAA data shown for comparison.

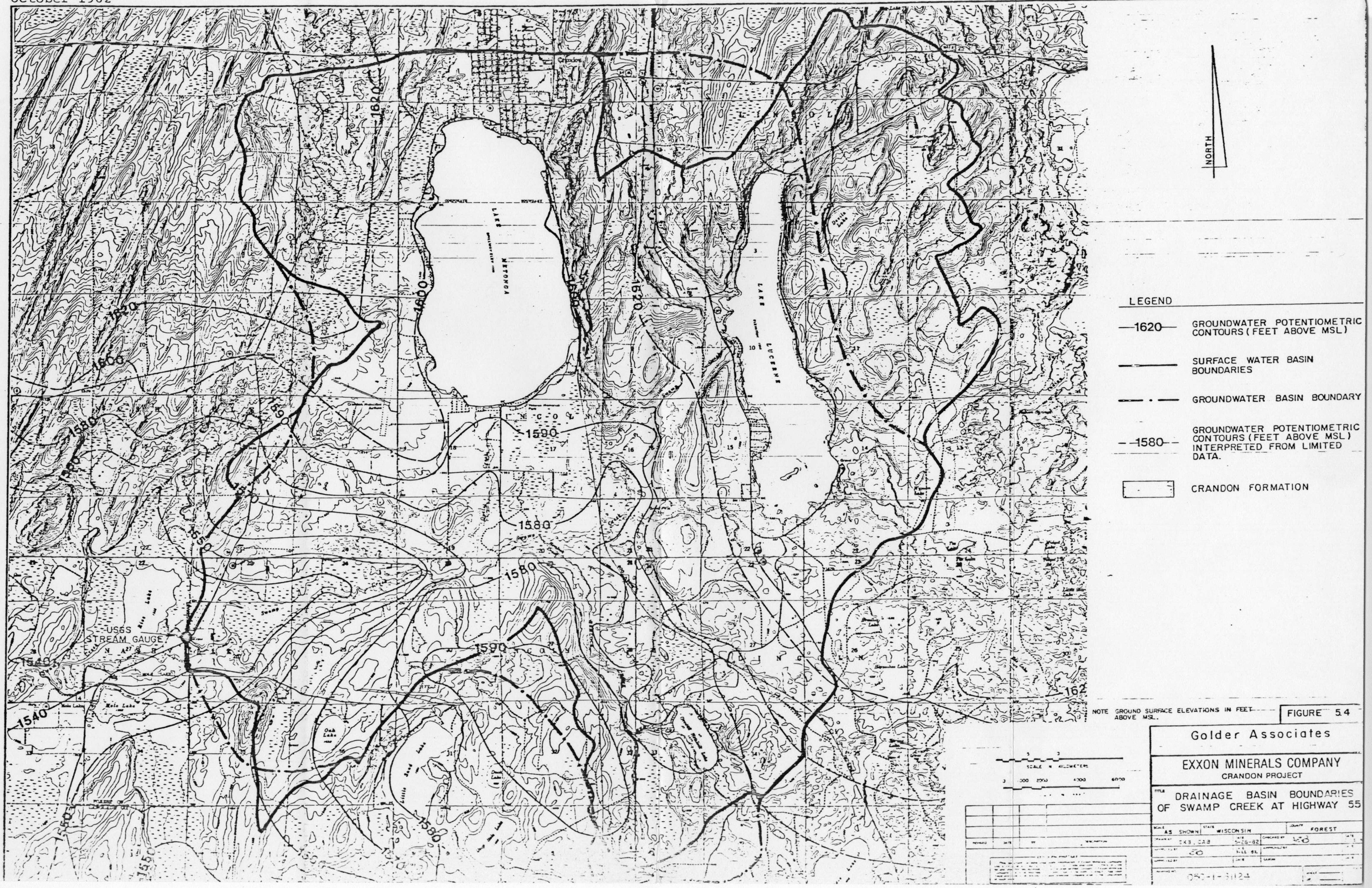

NORTH
LEGEND
1620 GROUNDWATER POTENTIOMETRIC CONTOURS (FEET ABOVE MSL)
SURFACE WATER BASIN BOUNDARIES
GROUNDWATER BASIN BOUNDARY
1580 GROUNDWATER POTENTIOMETRIC CONTOURS (FEET ABOVE MSL) INTERPRETED FROM LIMITED DATA.
CRANDON FORMATION
NOTE GROUND SURFACE ELEVATIONS IN FEET ABOVE MSL.
LAKE METONGA
LAKE LUCERNE
USGS STREAM GAUGE
1620
1600
1590
1580
1550
1540
Golder Associates
EXXON MINERALS COMPANY
CRANDON PROJECT
DRAINAGE BASIN BOUNDARIES OF SWAMP CREEK AT HIGHWAY 55
AS SHOWN
WISCONSIN
FOREST

FIGURE 5.4

TABLE 5.3
ANNUAL PRECIPITATION

Year	Laona 6 S.W. mm	Laona 6 S.W. inches	Rhinelander mm	Rhinelander inches
1974	750.0	29.53	715.5	28.17
1975	818.4	32.22	773.9	30.47
1976	606.3	23.87	447.8	17.63
1977	1,052.6	41.44	990.9	39.01
1978	895.6	35.26	1,014.0	39.92
1979	912.1	35.91	796.0	31.34
1980	845.3	33.28	814.3	32.06
Average	840.0	33.07	793.2	31.23

The period of 1974 through 1980 was used to correspond with the available streamflow data. The Laona precipitation gage was used due to its proximity to the study area and complete record.

Streamflow - Total streamflow includes both surface runoff and subsurface discharge or baseflow, and can be divided as shown in the following equation.

$$SF = RO + BF \qquad (5.3)$$

where:
SF = Total streamflow
RO = Surface runoff
BF = Baseflow

Baseflow separation was performed by Dames & Moore (Reference 4) at the Swamp Creek at Highway 55 station for 1978, 1979, and 1980 and is presented in Table 5.4. This data shows that about 58 percent of the total flow is baseflow. Using the average values, the total annual streamflow is about 278.9 mm (10.98 in.) with about 161.8 mm (6.37 in.) being of groundwater origin (baseflow), and about 117.1 mm (4.61 in.) resulting directly from surface runoff.

TABLE 5.4

ANNUAL STREAMFLOW COMPONENTS[1]
SWAMP CREEK AT HIGHWAY 55

Water Year	Streamflow[3] mm	Streamflow[3] in.	Surface Runoff mm	Surface Runoff in.	Baseflow[2] mm	Baseflow[2] in.
1978	282.7	11.13	119.[illegible]	4.72	162.8	6.41
1979	307.3	12.10	133.6	5.26	173.7	6.84
1980	246.6	9.71	97.8	3.85	148.8	5.86
Average	278.9	10.98	117.1	4.61	161.8	6.37

Notes:
(1) Streamgage maintained by U.S.G.S.
(2) Baseflow separations from Reference 4
(3) Volumes distributed over groundwater catchment area to determine areal depth.

Underflow - Underflow is the volume of water flowing into or out of the Swamp Creek basin through the saturated groundwater zone. By constructing the groundwater catchment boundary perpendicular to the groundwater potentiometric contours at the stream gage station, as shown in Figure 5.4, this component is limited to flow beneath the stream gage itself. Underflow leaving the Swamp Creek basin was estimated using Darcy's equation:

$$U = k \cdot i \cdot A \qquad (5.4)$$

where: U = Underflow

k = Hydraulic conductivity of coarse drift

i = Slope of groundwater surface

A = Saturated flow area beneath the gage

Using the following values (k from Table 4.1, i from Figure 4.1); $k = 1.3 \times 10^{-4}$ m/s; $i = 0.0052$; $A = 23{,}000\ m^2$ (23 m thick x 1,000 m wide estimated from surficial geology and surrounding soil borings) the average annual underflow rate is estimated to be 0.0156 m^3/s (0.55 cfs). This is about 4.6 mm/yr. (0.18 in./yr.) distributed over the groundwater basin.

Storage Changes - Changes in both surface and subsurface storage were assumed to be negligible for the water balance analysis. This assumption is considered valid since full water years were used in the analysis and year-to-year groundwater level variations are small. The minor variations which may occur would not significantly affect the results of this analysis.

Evapotranspiration - Evapotranspiration, as indicated in Section 5.1.4, is the primary mechanism by which water returns to the atmosphere. Evapotranspiration consists of evaporation from free water surfaces and soil moisture, evaporation of precipitation interception from the plant surfaces, and transpiration of soil moisture by plants. An accurate breakdown of the components of evaporation and transpiration is beyond the scope of this study. A common method for estimating evapotranspiration is by the equation below (Reference 31).

$$ET = P - SF - U \qquad (5.5)$$

where:
- ET = Evapotranspiration
- P = Precipitation
- SF = Streamflow
- U = Groundwater underflow

Therefore, using previously estimated values for the right side of the above equation the estimated annual ET distributed over the groundwater basin is 556.5 mm (21.91 in.).

As discussed at the beginning of this section, one of the purposes of defining the water balance of the study area is to estimate the amount of net groundwater recharge. Net groundwater recharge, or deep infiltration, is that portion of precipitation that seeps into the saturated groundwater system. Therefore, in estimating the net groundwater recharge the sum of baseflow and stream gage underflow (as previously defined) must be augmented by evapotranspiration which is from groundwater origin and does not flow past or beneath the stream gage. This breakdown of evapotranspiration is described below.

Large portions of the project area are groundwater discharge areas as shown by the groundwater potentiometric contours in Figure 4.1. A significant portion of these areas are covered by groundwater fed surface waters, such as lakes and wetlands. These areas, which include Ground Hemlock Lake, Lake Metonga, Rice Lake, Hemlock Creek, Swamp Creek, Outlet Creek and their associated wetlands, constitute about 23 percent of the total groundwater drainage basin. Because the surface water system in the region is groundwater fed, a large portion of the evapotranspiration from these lowlying areas is of groundwater origin rather than from direct precipitation or surface runoff. The portion of the total evapotranspiration originating from groundwater must therefore be considered in determining the net groundwater recharge as shown in the following equation:

$$R_g = BF + U + ET_g \qquad (5.6)$$

where terms not previously defined are:

R_g = net groundwater recharge
ET_g = evapotranspiration of groundwater origin

Separation of the total evapotranspiration into a groundwater origin component and a direct precipitation origin component requires detailed water budget data for small areas in which groundwater underflow is well known and does not exist for the Swamp Creek basin. In order to estimate the portion of evapotranspiration which originates from groundwater, the total evapotranspiration was partitioned between that originating from upland (recharge) areas and that originating from lowland (discharge) areas. Area measurements indicate that about 23 percent of the study area is lowland area and 77 percent is upland area. Therefore, 77 percent of the total evapotranspiration is considered to be from highland areas and 23 percent from lowland areas.

The lowland evapotranspiration, 128.0 mm (5.04 in.), was further divided into its groundwater origin and direct precipitation/runoff origin components. Based on the determination previously presented that 58 percent of the streamflow is baseflow, a value of 60 percent was used to estimate the fraction of lowland evapotranspiration originating from groundwater. This leads to a value of 76.8 mm (3.02 in.) for ET_g in equation 5.6 and a net annual groundwater recharge of 243.1 mm (9.57 in.). The sensitivity of this assumption was investigated by varying the groundwater origin component over a range of 40 percent to 80 percent. This resulted in a range of net annual groundwater recharge of 217.7 mm (8.57 in.) to 268.7 mm (10.58 in.).

The water budget equation previously presented in this section can be re-written to include the various subdivisions of each component and omitting the negligible change in storage terms:

$$P = RO + BF + U + ET_H + ET_{LP} + ET_{LG} \quad (5.7)$$

where terms not previously defined are:

ET_H = Evapotranspiration from highland areas
ET_{LP} = Evapotranspiration from lowland areas of direct precipitation and runoff origin
ET_{LG} = Evapotranspiration from lowland areas of groundwater origin

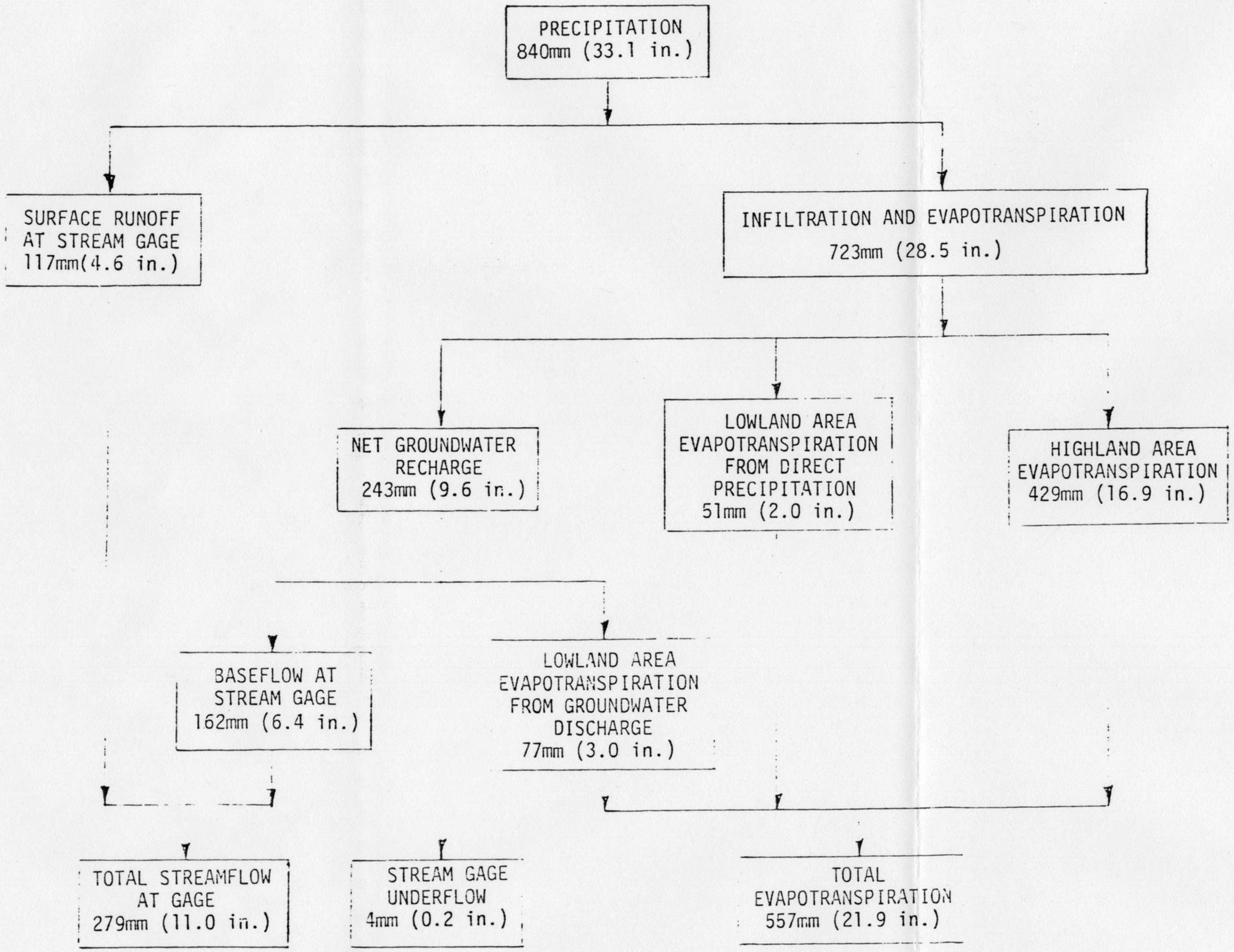
The above relationship is shown schematically with the annual value in depth over the groundwater basin given for each component in Figure 5.5.

5.3 Low-Flow Analysis

5.3.1 Purpose

Although the Crandon Project waste disposal system is designed to minimize leakage into the hydrologic system, it may be necessary to analyze various potential leakage scenarios with respect to the surrounding surface water system. It is anticipated that any potential waste pond seepage which eventually reaches the surface waters will do so by way of groundwater discharge, i.e. the baseflow component of streamflow. Therefore, the period in which groundwater discharge provides the majority of input to the surface water system is that in which baseflow is the primary component of streamflow.

The common standard used by the Wisconsin Department of Natural Resources to assess the impact of various activities on surface waters is the 7 day-10 year low-flow



NOTES:

1. Estimated annual volumes are distributed over the groundwater drainage basin (10,600 ha) shown in Figure 5.4.
2. Highland area evapotranpsiration is 77% of total evapotranspiration.
3. Reminaing 23% of total evapotranspiration from lowland areas is divided by assuming that 60% is from groundwater recharge. Lowland area evapotranspiration from direct precipitation is assumed to be the remaining 40%.

JOB NO. 824-1304	SCALE NOT TO SCALE	ANNUAL WATER BALANCE FLOW CHART
DRAWN SKB	DATE 9-24-82	
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Golder Associates		EXXON MINERALS COMPANY — FIGURE 5.5

(Reference 24). The 7 day-10 year low-flow is defined as that average rate over a 7 day period which the flow will drop below on an average of once in 10 years. This statistical low-flow rate is commonly used with mass loading of waste material to determine critical in-stream concentrations. These concentrations can then be compared to the applicable water quality standards.

Low-flow estimates ($Q_{7,10}$) were made at nine locations in the Crandon Project area. The locations and the drainage basin boundaries above each estimate point are shown on Figure 5.3. All of these points are within the Swamp Creek and Pickerel Creek drainage basins. As can be seen in Figure 5.3, five of the nine points are Dames & Moore stream gage sites, three are U.S.G.S. stream gage sites, and one site is ungaged. The U.S.G.S. stream gage at County Road K is not shown at its exact location on Figure 5.3.

5.3.2 Analysis Methodology

As previously stated, most surface water quality assessments are approached by combining a minimum flow rate at some level of probability (i.e. 10 year recurrence interval) with a point source waste load, yielding a critical in-stream concentration. However, the Crandon Project differs in that any potential waste system seepage which may occur would be transported to surface streams by way of groundwater discharge. Therefore, the critical period for in-stream waste system seepage concentrations will be when baseflow comprises the maximum percentage of total streamflow. During this period the baseflow will have the minimum dilution from surface runoff. The first step in this analysis was to determine the period at which baseflow represents the maximum portion of streamflow rather than the absolute minimum low-flows.

The critical low-flow period described above can be determined by comparing the daily variation in streamflow exhibited during annual low-flow periods. Periods with relatively constant flow rates are controlled by baseflow, while periods with variable flow rates show that relatively constant baseflow is augmented with surface runoff. Inspection of the flow records of the U.S.G.S. maintained stream gage on Swamp Creek at Highway 55 (August 1977 to 1980) indicated that while the absolute low-flow occurs during late summer, the winter period low-flow (late winter/early spring) is virtually all baseflow. This was based on the daily flow variation in the late summer and the near constant flow during the late winter. Therefore, 7 day-10 year low-flow estimates were prepared considering flows during the entire year (annual $Q_{7,10}$) and considering only the winter period (winter $Q_{7,10}$). Both sets of analysis results are presented.

5.3.3 <u>Analysis Results</u>

Stream gaging stations were installed and are maintained by the U.S.G.S. and Dames & Moore across the Crandon Project area. However, most of these gages were installed in 1977 and others in 1978 and 1979. This period of record is sufficient for water balance analysis but is too short for use in a statistical low-flow analysis. Therefore, the annual low-flow analysis was performed using the procedures and equations presented in Reference 23, which provide low-flow analysis procedures based on limited or no streamflow data. Although the Crandon Project area is not in the basins included in Reference 23, it is stated that the procedures are considered to be applicable in Forest and Langlade Counties. Equations are presented which allow estimates of the 7 day-10 year low-flows to be made based on watershed characteristics. Procedures are presented for both ungaged basins and for basins with limited streamflow data. The estimation equation for basins with limited streamflow data is as follows (Reference 23):

$$Q_{7,10} = 0.627A^{1.08}\left[\frac{Q_m\ Q_{90}}{A\ Q_r}\right]^{1.45} \qquad (5.8)$$

where:
- $Q_{7,10}$ = 7 day-10 year low-flow (cfs)
- A = drainage area (mi.^{2})
- Q_m = mean annual flow (cfs)
- Q_{90} = flow which is exceeded 90 percent of the year (cfs)
- Q_r = average daily flow during index period of August 12-15 (cfs)

The estimation equation for ungaged basins is as follows (Reference 23):

$$Q_{7,10} = (1.22\text{x}10^{-5})A^{0.894}S^{1.06}T^{0.619} \qquad (5.9)$$

where:
- $Q_{7,10}$ = 7 day-10 year low-flow (cfs)
- A = drainage area (sq. mi.)
- S = main channel slope (ft./mi.)
- T = transmissivity of drift in basin (gpd/ft.).

The value of T represents an areal approximation of basin transmissivity and may be computed by the equation (Reference 23):

$$T = D \cdot \left[\frac{K_T\ A_T + K_D\ A_D}{A_T + A_D}\right] \qquad (5.10)$$

where:
- D = saturated drift thickness in basin (ft.)
- A_T, A_D = area in basin of till and drift or outwash (sq. mi.), respectively.
- K_T, K_D = hydraulic conductivity of till and drift or outwash in basin (gpd/ft.^{2}) respectively.

Equation 5.8 was used for all low-flow estimates where the index flow (Q_r) could be determined from limited stream gage data, as was the case with eight of the nine estimate sites. Values of hydraulic conductivity and transmissivity used were selected from Table 4.1 and average material thickness across the basin. The low-flow estimate on Swamp Creek below the confluence of Hemlock Creek was performed by combining flows from upstream gaged areas using Equation 5.8 with flows from the ungaged portion of the watershed using Equation 5.9. Table 5.5 presents the results of this analysis.

As stated previously, review of the streamflow data from the U.S.G.S. gage on Swamp Creek at Highway 55 indicated that in the late winter period the streamflow is essentially all from groundwater. Due to lack of dilution from surface runoff during this period, potential waste disposal system seepage may be at a peak concentration in the surface streams. This winter season 7 day-10 year low-flow is defined as the minimum 7 day mean winter (December through March) flow below which the flow will fall on the average of once in 10 years. The low-flow report used to estimate the annual low-flows (Reference 23) does not present a winter season low-flow estimation equation. Therefore, it was necessary to develop a ratio between the winter $Q_{7,10}$ and the annual $Q_{7,10}$.

Two sources of information were used in developing the ratio of winter $Q_{7,10}$ to annual $Q_{7,10}$. First, three stream gaging stations near the Crandon Project area were studied, Wolf River at Keshena Falls (1907-1980), Wolf River at Langlade (1965-1979), and Popple River near Fence (1964-1980). Daily streamflow data for the above indicated periods were

TABLE 5.5

LOW FLOW ANALYSES RESULTS

Station or Location	Surface Water Drainage Basin (Note 1) ha	mi^2	Mean Annual Flow Qm (Note 2) m^3/s	cfs	Estimated Annual 10% Low Flow Q 90 m^3/s	cfs	Estimated Index Flow Qr m^3/s	cfs	Estimated Annual $Q_{7,10}$ m^3/s	cfs	Estimated Winter $Q_{7,10}$ (Note 3) m^3/s	cfs
On Swamp Creek at County Road K	18,260	70.50	2.005	70.79	0.510	18.00	1.589	56.1	0.894	31.55	1.162	41.02
On Swamp Creek at County Road M	14,686	56.70	1.283	45.29	0.496	17.50	1.192	42.1	0.329	11.62	0.428	15.11
On Swamp Creek at Highway 55	11,170	43.12	0.884	31.22	0.481	17.00	0.657	23.2	0.413	14.60	0.538	18.98
SG-3 on Swamp Creek below confluence of Outlet Creek	9,306	35.93	0.936	33.04	0.453	16.00	0.813	28.7	0.319	11.27	0.415	14.65
On Swamp Creek below confluence of Hemlock Creek	5,859	22.62	-	-	-	-	-	-	0.028	1.00	0.037	1.30
SG-6 on Hemlock Creek below Ground Hemlock Lake	648	2.50	0.122	4.79	0.014	0.50	0.091	3.2	0.008	0.29	0.011	0.38
SG-19 on N.W. Creek into Rolling Stone Lake	829	3.20	0.129	4.54	0.034	1.20	0.057	2.0	0.015	0.53	0.020	0.69
SG-23 on N.E. Creek into Rolling Stone Lake	1,699	6.56	0.131	4.63	0.043	1.50	0.130	4.6	0.016	0.56	0.021	0.73
SG-22 on Pickerel Creek at East Shore Road	3,593	13.87	0.484	17.10	0.227	8.00	0.612	21.6	0.097	3.44	0.127	4.47

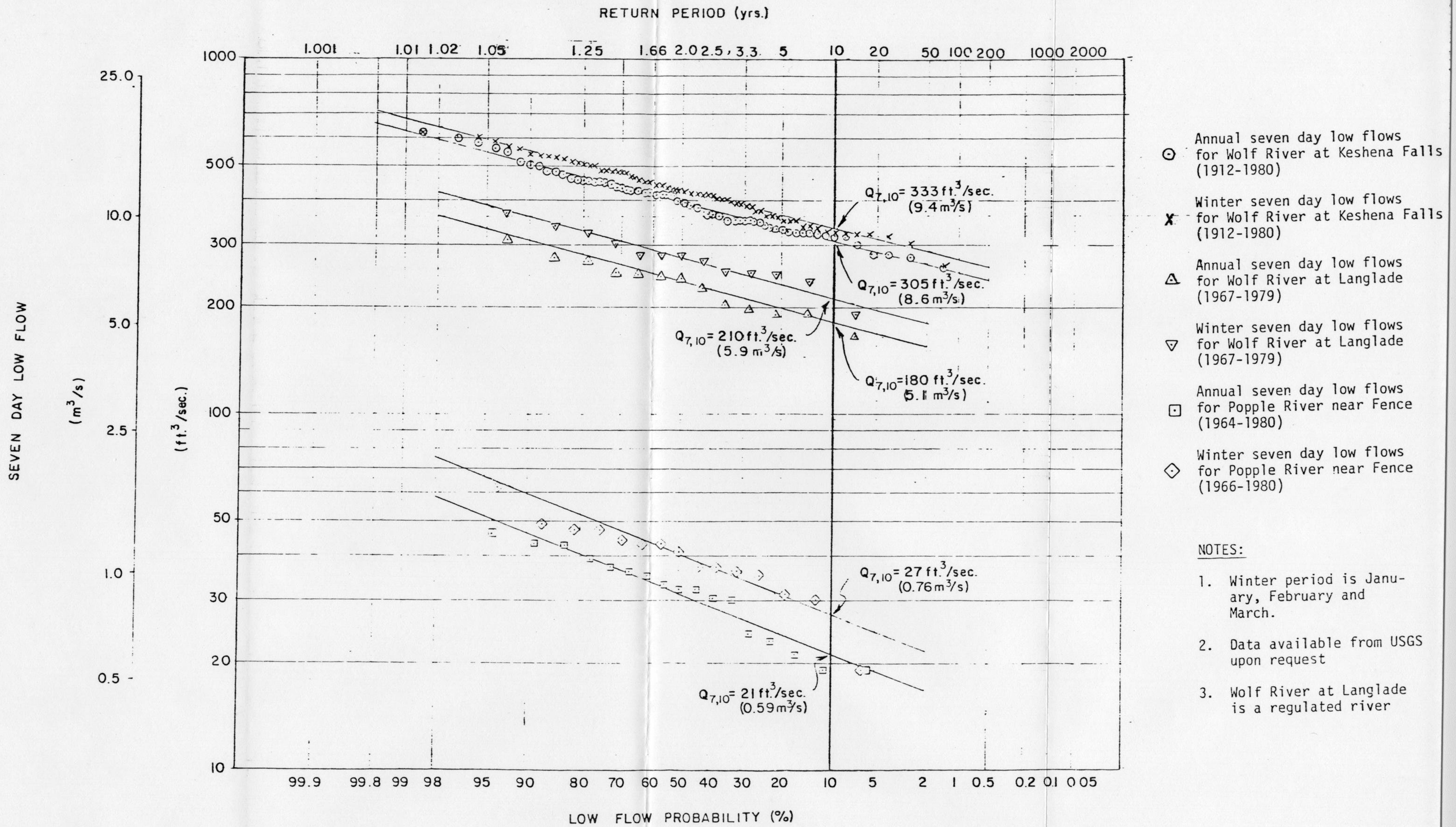
NOTES:
1. Drainage areas may differ from those presented in Reference 4 due to measurement differences.
2. Data from Dames & Moore, see letter dated 4/14/82 in Appendix C.
3. Winter low flow estimated using a factor of 1.3 times annual low flow.

provided by the U.S.G.S. for these stations and both winter season and annual 7 day low-flow analyses were performed on each of the 3 stations. Figure 5.6 shows the annual and winter 7 day low-flow frequency curves for each of these stations. In addition, Reference 24 presents both annual and winter season 7 day-10 year low-flows for 11 gages on the Wisconsin, Fox and Wolf Rivers. The average ratio of the winter $Q_{7,10}$ to the annual $Q_{7,10}$ for these 14 stream gages is 1.30; i.e., winter $Q_{7,10}$ is 30 percent larger than the annual 7 day-10 year low-flows. Winter $Q_{7,10}$ were then computed by applying this factor to the annual 7 day-10 year low-flows. Table 5.5 also presents the winter $Q_{7,10}$ values based on this ratio.

5.4 Lake Storage and Annual Flow

In addition to the streams surrounding the Crandon Project site, the groundwater fed lakes may eventually receive potential seepage from the waste disposal system. Four lakes around the Project study area are receiving waters from the site streams and include Little Sand Lake, Pickerel Lake, Rolling Stone Lake and Rice Lake. In order to assess how these lakes may respond to inflows during critical low-flow periods, an average replacement time, or time required for the inflow to replace the lake volume, was computed for each lake. This required estimation of the total volume of each lake and the annual yield of the basin draining into the lake. The total lake volumes were computed based on the depth contours shown on the U.S.G.S. topographic maps of the Project area and are shown in Table 5.6.

The annual flow volume into each lake was computed by using the U.S.G.S. and Dames & Moore streamflow data presented in Reference 4 and the drainage areas of each lake



NOTES:

1. Winter period is January, February and March.
2. Data available from USGS upon request
3. Wolf River at Langlade is a regulated river

JOB NO. 824-1304	SCALE AS SHOWN	ANNUAL AND WINTER LOW FLOW FREQUENCY CURVES
DRAWN SKB	DATE 5-28-82	
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Golder Associates		EXXON MINERALS COMPANY — FIGURE 5.6

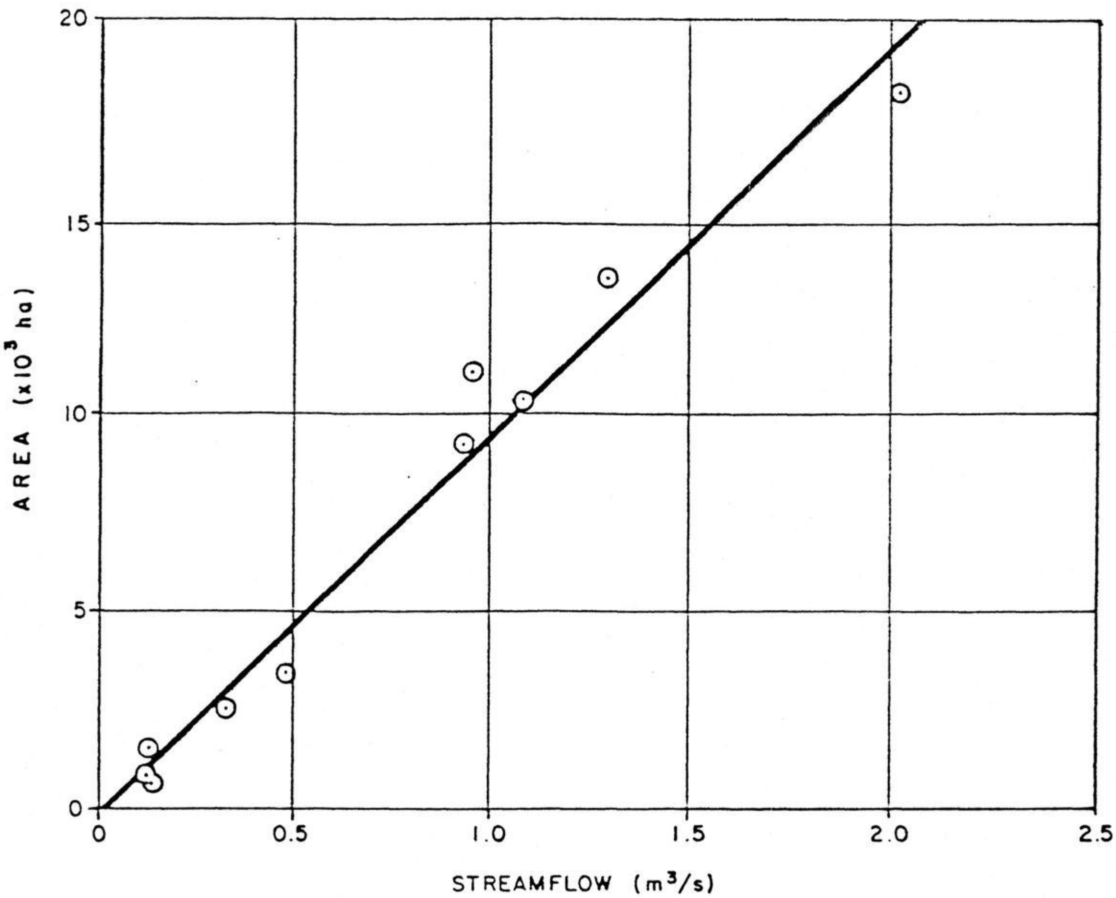
TABLE 5.6

LAKE VOLUMES AND ANNUAL FLOWS

	Little Sand Lake	Pickerel Lake	Rolling Stone Lake	Rice Lake
Drainage Area (ha)	1,060	6,810	3,370	13,490
($mi.^2$)	4.1	26.3	13.0	52.1
Streamgage Used	SG23	SG22	SG22	U.S.G.S. at Highway 55
Gaged Area (ha)	1,710	3,600	3,600	11,160
($mi.^2$)	6.6	13.9	13.9	43.1
Gaged Annual Yield ($10^6 m^3$)	4.10	15.14	15.14	29.96
(ac.-ft.)	3,323	12,270	12,270	24,285
Area Correction (ha)	-650	+3,210	-230	+2,330
($mi.^2$)	-2.5	+12.4	-0.9	+9.0
Annual Yield Correction ($10^6 m^3$)	-2.13	+10.50	-0.75	+7.62
(ac.-ft.)	-1,727	+8,512	-608	+6,178
Annual Lake Yield ($10^6 m^3$)	1.97	25.64	14.39	37.58
(ac.-ft.)	1,597	20,787	11,666	30,467
Lake Volume ($10^6 m^3$)	2.54	13.78	4.18	1.15
(ac.-ft.)	2,059	11,170	3,388	932
Average Replacement Period (days)	470	196	106	11

watershed. The watershed boundaries above each lake are shown on Figure 5.3. Several of the stream gages in the Project area are located upstream or downstream of the various lakes of interest. The annual yields of these gages can be used to determine total annual lake flows by correcting for the difference in drainage areas. This correction was performed by developing a relationship between annual yield and drainage area for the Project area stream gages. Figure 5.7 shows the relationship between annual yield and drainage area. The data from gage SG-5B were not used in the analysis due to the fact that all other stations gaged heavily groundwater fed streams while gage SG-5B gages an upland area.

The total annual flow volume into each lake was computed by correcting the annual yield at the nearest stream gage by adding or subtracting a flow volume based on the appropriate drainage area. Table 5.6 shows the stream gages used and results of this analysis. From these results it is clear that short term (7 to 30 days) inflow characteristics will probably not significantly alter the water quality of Little Sand, Pickerel or Rolling Stone Lakes. However, Rice Lake is a relatively small lake on a large stream and has an average replacement time of 11 days, making it much more sensitive to short duration fluctuations in inflow characteristics.



ANNUAL BASIN YIELD

STREAMFLOW DATA		
Stream Gage	DRAINAGE Area ($x10^3$ ha)	AVERAGE Streamflow (m^3/s)
1	18.26	2.00
2	10.44	1.08
3	9.30	0.93
4	2.20	0.33
6	0.65	0.14
19	0.83	0.13
22	3.60	0.48
23	1.71	0.13
USGS @ 55	11.17	0.95
USGS @ M	13.65	1.28

Note: Streamflows for water year 1978. See Appendix C for gages 1 through 23.

JOB NO. 824 - 1304	SCALE NOT TO SCALE	ANNUAL BASIN YIELD ANALYSIS RESULTS
DRAWN SKB	DATE 5-24-82	
CHECKED JEB	DWG. NO. ____	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 5.7

6.0 OREBODY/OVERBURDEN INTERACTION

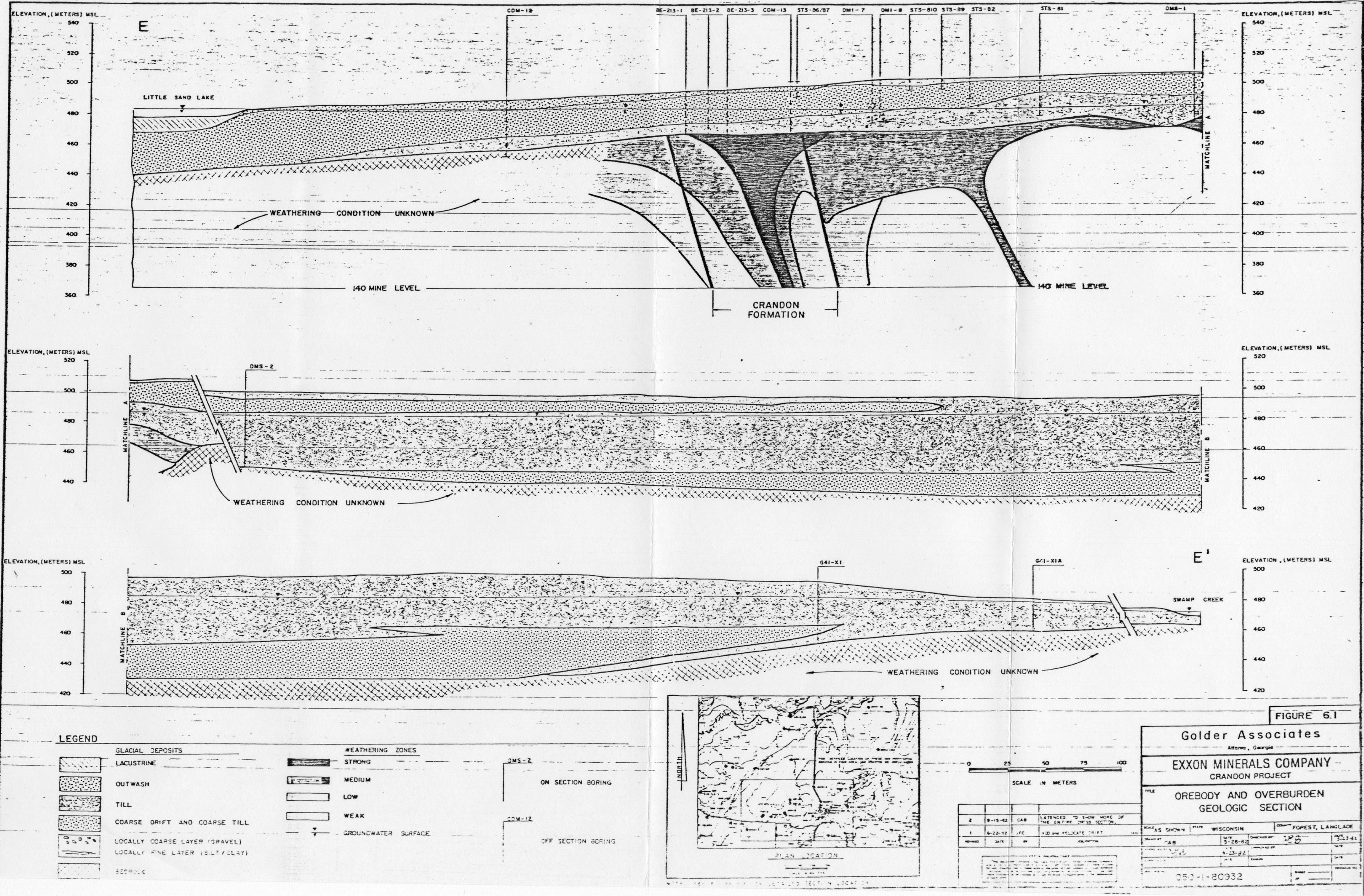
6.1 Overburden Contact Geology

The hydrogeology of the orebody area is of particular interest, and the degree of hydraulic connection between the glacial overburden and the underlying Precambrian strata will determine the mine water control requirements.

Figures 3.5 and 4.9 show that the glacial deposits thin in the orebody area with an associated decrease in the thickness of coarse grained stratified drift. Figure 6.1 illustrates the overburden/bedrock contact with glacial stratigraphy and bedrock weathering zones. Camp Dresser and McKee (Reference 10) mapped the orebody area glacial deposits in detail, designating the local glacial deposits as shown in Table 6.1. Figure 6.1 is a North-South section of deposits overlying the orebody.

TABLE 6.1
GLACIAL OVERBURDEN CLASSIFICATION

CDM Classification and Description		Golder Classification
T1	Highly compact gravelly, pebbly silt and clay	Till
T2	Silty, gravelly sand	Till
T3	Gravelly, bouldery sand	Coarse Drift
T4	Silty sand	Outwash
S1	Clean sand, some gravel and pebbles	Coarse Drift
S2	Medium to coarse sand	Coarse Drift
S3	Sand and gravel	Coarse Drift
S4	Stratified sands and silts	Coarse Drift

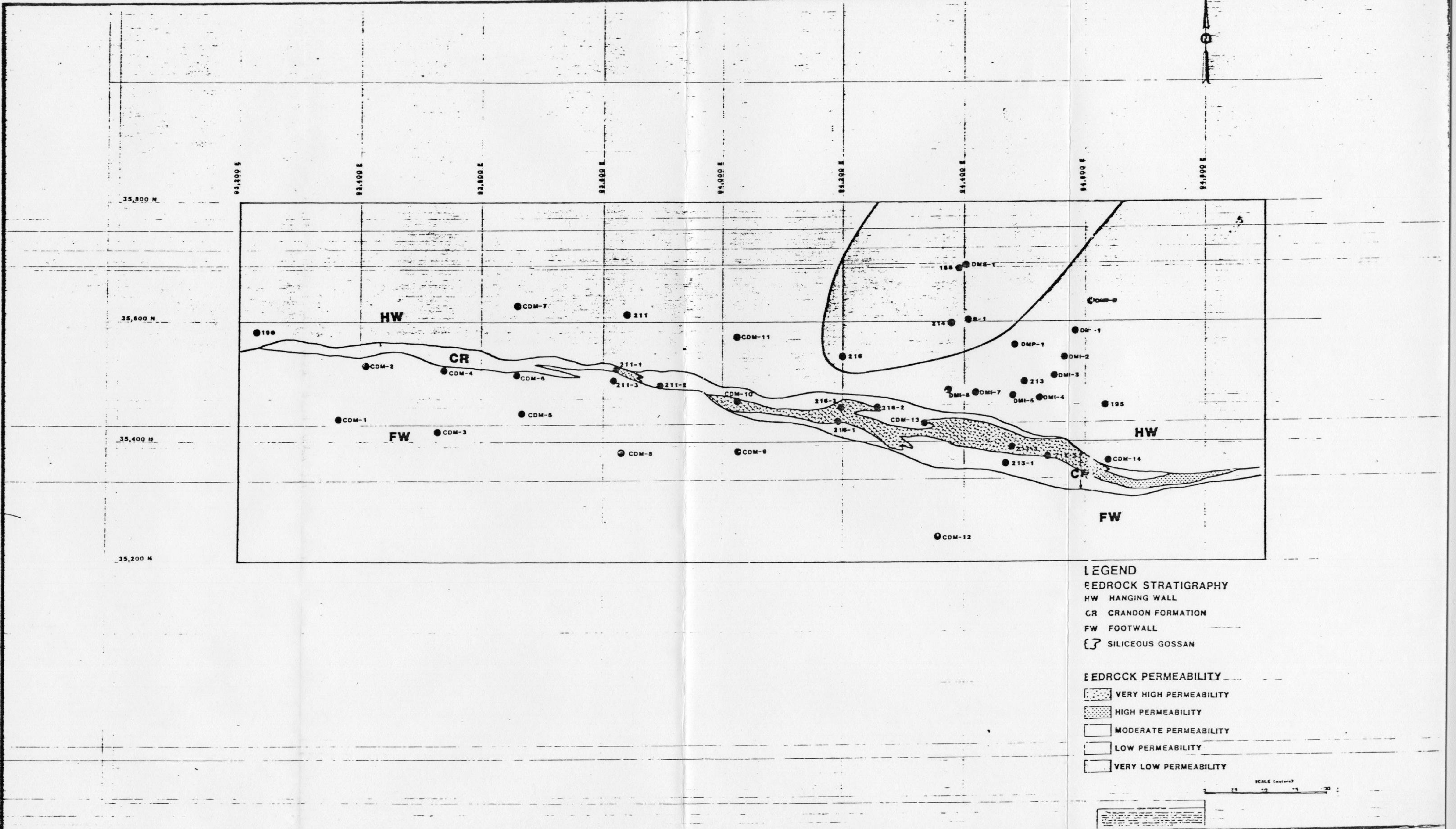

E
E'
ELEVATION, (METERS) MSL
COM-12
BE-213-1
BE-213-2
BE-213-3
COM-13
STS-86/87
DMI-7
DMI-8
STS-810
STS-89
STS-82
STS-81
DMS-1
LITTLE SAND LAKE
WEATHERING CONDITION UNKNOWN
140 MINE LEVEL
CRANDON FORMATION
MATCHLINE A
DMS-2
MATCHLINE B
G41-X1
G41-X1A
SWAMP CREEK
LEGEND
GLACIAL DEPOSITS
LACUSTRINE
OUTWASH
TILL
COARSE DRIFT AND COARSE TILL
LOCALLY COARSE LAYER (GRAVEL)
LOCALLY FINE LAYER (SILT/CLAY)
BEDROCK
WEATHERING ZONES
STRONG
MEDIUM
LOW
WEAK
GROUNDWATER SURFACE
DMS-2
ON SECTION BORING
COM-12
OFF SECTION BORING
NORTH
PLAN LOCATION
0 25 50 75 100
SCALE IN METERS
2 9-15-82 CAB EXTENDED TO SHOW MORE OF THE ENTIRE CROSS SECTION
1 6-22-82 JFC ADD and RELOCATE DRIFT
FIGURE 6.1
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
OREBODY AND OVERBURDEN
GEOLOGIC SECTION
AS SHOWN
WISCONSIN
FOREST, LANGLADE
CAB
5-26-82
9-23-82
050-1-80932

Various mine water control techniques could have a range of effects on the groundwater levels in the glacial overburden. Those methods which would create a significant drawdown pattern in the overburden might also affect the surrounding surface waters. The two water bodies adjacent to the orebody are Little Sand Lake to the south and Swamp Creek to the north. Figure 6.1 shows the coarse grained stratified drift pinching out south of Swamp Creek. Swamp Creek therefore flows over till in this area and is somewhat isolated from potential mine water control activities. Little Sand Lake is underlain by thick drift that is laterally connected to the drift overlying the orebody. However, the relatively thick lacustrine deposits immediately beneath Little Sand Lake effectively perch and isolate the lake above the drift and underlying groundwater. Perched lakes are discussed in detail in Section 7.2.

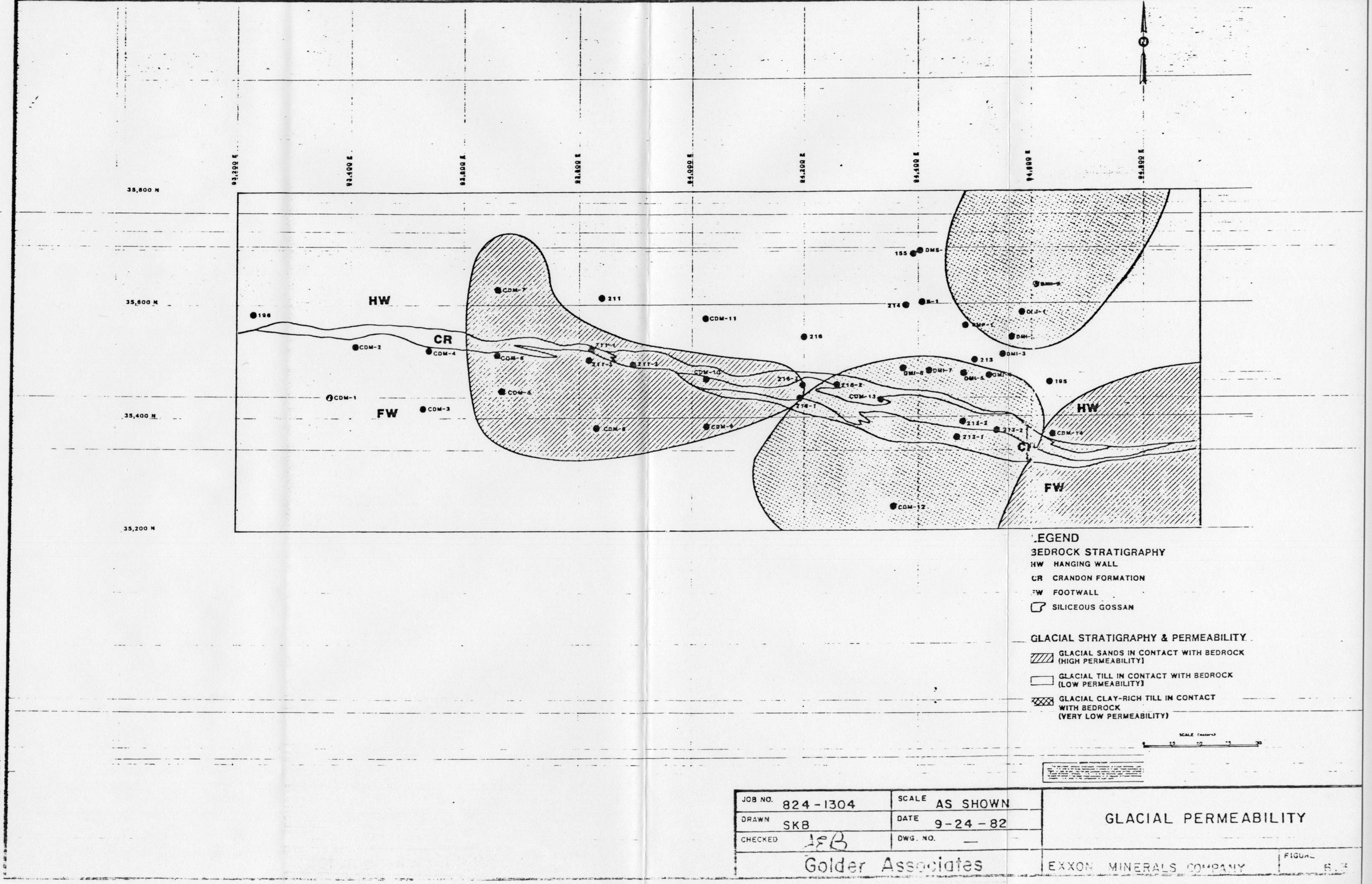
6.2 Orebody Weathering at Overburden Contact

Weathering of the orebody subcrop strata has been extensive, one result of which is a potential for hydraulic connection between the bedrock and overburden (Reference 18). The degree of connection varies spatially, being a function of the hydraulic conductivity of the glacial deposits and weathered bedrock at their contact. To aid in identifying those areas with a high degree of connection, Figures 6.2, 6.3 and 6.4 were prepared.

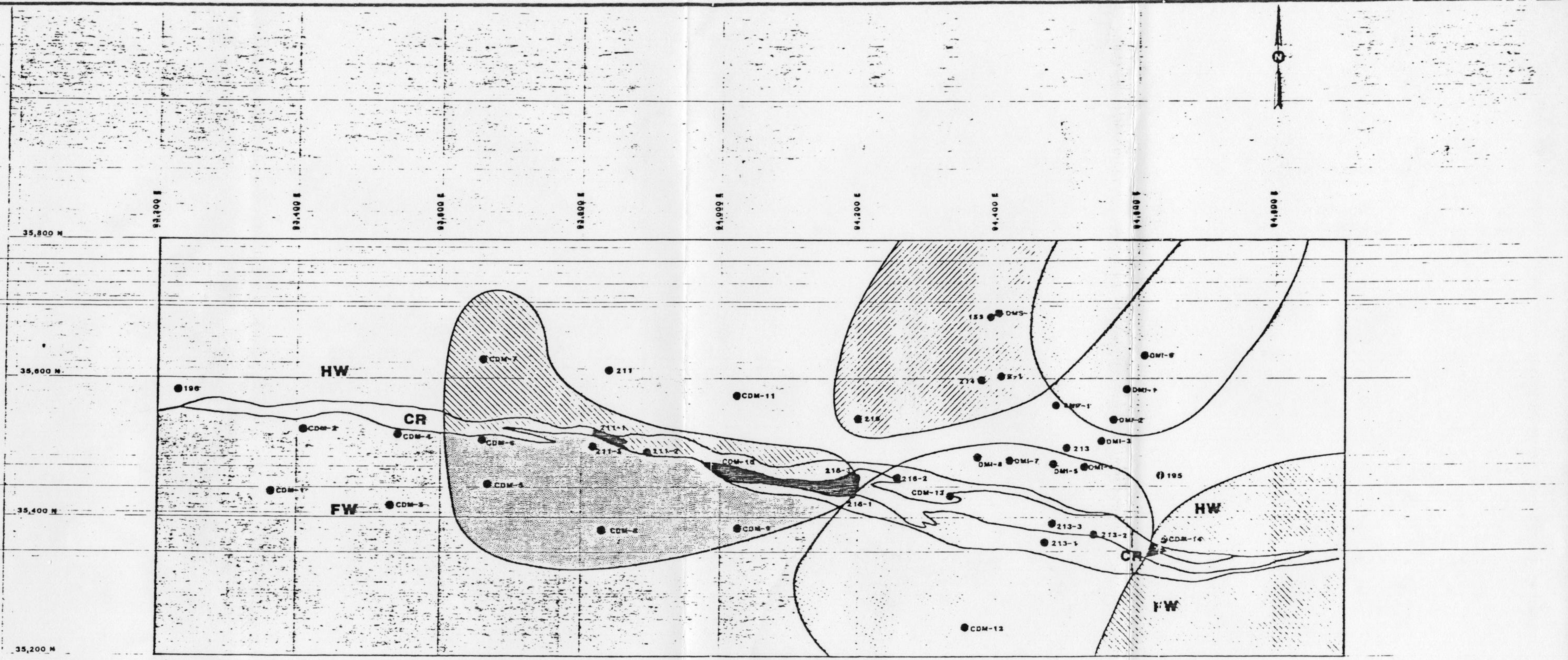
Figure 6.2 is a plan view of bedrock permeability at the subcrop level. Bedrock permeability values were calculated from falling head tests conducted by Exxon Minerals (Reference 30), and are shown in Table 4.2. These values reflect the variation in mineralogy and related weathering mechanisms among the footwall, Crandon formation and hanging wall deposits described in Section 3.2.3. Rocks containing abundant chlorite within the Crandon Unit and hang-



JOB NO. 824-1304	SCALE AS SHOWN	BEDROCK PERMEABILITY	
DRAWN CAB	DATE 9-9-82		
CHECKED	DWG. NO.		
Golder Associates		EXXON MINERALS COMPANY	FIGURE



93,200 E
93,400 E
93,600 E
93,800 E
94,000 E
94,200 E
94,400 E
94,600 E
94,800 E
35,800 N
35,600 N
35,400 N
35,200 N
HW
CR
FW
HW
CR
FW
196
CDM-1
CDM-2
CDM-3
CDM-4
CDM-5
CDM-6
CDM-7
CDM-8
CDM-9
CDM-10
CDM-11
CDM-12
CDM-13
CDM-14
211
213
216
195
155
LEGEND
BEDROCK STRATIGRAPHY
HW HANGING WALL
CR CRANDON FORMATION
FW FOOTWALL
SILICEOUS GOSSAN
GLACIAL STRATIGRAPHY & PERMEABILITY
GLACIAL SANDS IN CONTACT WITH BEDROCK (HIGH PERMEABILITY)
GLACIAL TILL IN CONTACT WITH BEDROCK (LOW PERMEABILITY)
GLACIAL CLAY-RICH TILL IN CONTACT WITH BEDROCK (VERY LOW PERMEABILITY)
JOB NO. 824-1304
SCALE AS SHOWN
DRAWN SKB
DATE 9-24-82
CHECKED
DWG. NO. —
GLACIAL PERMEABILITY
Golder Associates
EXXON MINERALS COMPANY
FIGURE



CHARACTERISTICS

PERMEABILITY RANK	GLACIAL MATERIAL	BEDROCK
	SANDS	SILICEOUS GOSSAN-VERY HIGH
	SANDS	SILICEOUS GOSSAN-HIGH
	SANDS	FW-MODERATE PERMEABILITY
	TILL	SILICEOUS GOSSAN-VERY HIGH
	SANDS	FW/HW LOW PERMEABILITY
	TILL	FW/HW LOW PERMEABILITY
	TILL	FW/HW VERY LOW PERMEABILITY
	CLAY-RICH TILL (VERY LOW PERMEABILITY)	ALL BEDROCK UNITS

INCREASING PERMEABILITY

LEGEND

BEDROCK STRATIGRAPHY

HW HANGING WALL

CR CRANDON FORMATION

FW FOOTWALL

SILICEOUS GOSSAN

GLACIAL STRATIGRAPHY & PERMEABILITY

GLACIAL SANDS IN CONTACT WITH BEDROCK (HIGH PERMEABILITY)

GLACIAL TILL IN CONTACT WITH BEDROCK (LOW PERMEABILITY)

GLACIAL CLAY-RICH TILL IN CONTACT WITH BEDROCK (VERY LOW PERMEABILITY)

SCALE (meters)

JOB NO. 824-1304	SCALE AS SHOWN	RESISTIVE LAYER PERMEABILITY
DRAWN CAB	DATE 9-9-82	
CHECKED DEB	DWG. NO. ———	EXXON MINERALS COMPANY
Golder Associates		FIGURE

ing wall have weathered to clay, producing a low permeability residue. This is in contrast to the siliceous footwall rocks where weathering has resulted in moderate permeability due to leaching and the relative paucity of clay.

In addition to this broad variation in permeability, there are two areas where unusually large or small values of permeability have been recorded.

Within the Crandon formation there is a group of rocks referred to as siliceous massive sulfide (Reference 18). These rocks consist almost entirely of sulfide and quartz, consequently very little clay has been produced by weathering. Leaching and oxidation are the dominant agents of destruction and have resulted in a highly permeable rock. The outline of the oxidized siliceous massive sulfide (gossan) is shown in Figure 6.2.

In contrast, an area of very low permeability has been identified within the hanging wall rocks (Figure 6.2). This is due to the fact that the hanging wall rocks are relatively unweathered in the area outlined, hence the development of secondary permeability is very minor.

Figure 6.3 illustrates the stratigraphy and permeability of the glacial strata overlying the orebody. Two areas of highly permeable coarse drift are present, one crescent-shaped area in the west-central part of the orebody and one area at the east end of the orebody. Two lobes of low permeability clay-rich till cover the east-central portion of the orebody.

Figure 6.4 is a combination of Figures 6.2 and 6.3, and shows those areas with potential to allow groundwater to migrate rapidly from the overburden to the bedrock during mining. The areas of highest permeability are those where coarse drift overlies siliceous gossan. The areas of lowest permeability are those where clay-rich till is found to occur. Gradation between these two extremes is shown on Figure 6.4.

7.0 GROUNDWATER/LAKE INTERACTIONS

7.1 Groundwater Fed Lakes

In general, the lakes and streams in the Project region are groundwater fed. This is primarily the case for surface water bodies which exist in areas of coarse drift and outwash. Figure 4.3 shows the lateral movement of groundwater into the lowlying surface water bodies. The interaction between these surface water bodies and the groundwater system is discussed in detail in Section 5.

7.2 Perched Lakes

In contrast with the lowlying groundwater fed lakes, the highland lakes are primarily in till and are perched above the regional groundwater table. These lakes are underlain by lacustrine deposits of fine silt and clay (Reference 14) which significantly impede seepage losses to the groundwater. The elevations of the groundwater potentiometric contours shown in Figure 4.1 show that Little Sand Lake, Duck Lake, and Deep Hole Lake are perched lakes, i.e. the water level in the lakes is higher than the surrounding saturated groundwater level. Other smaller lakes exist across the Project area but are similar to these three.

Comparison of the lake bottom elevations with the study area groundwater levels show that the bottoms of Duck and Deep Hole Lakes are above the water table. Figures 7.1 and 7.2 are sections parallel and perpendicular to the groundwater flow direction for Duck Lake and Deep Hole Lake, respectively. These figures illustrate their perched nature and show them as discharging into rather than being recharged by the groundwater.

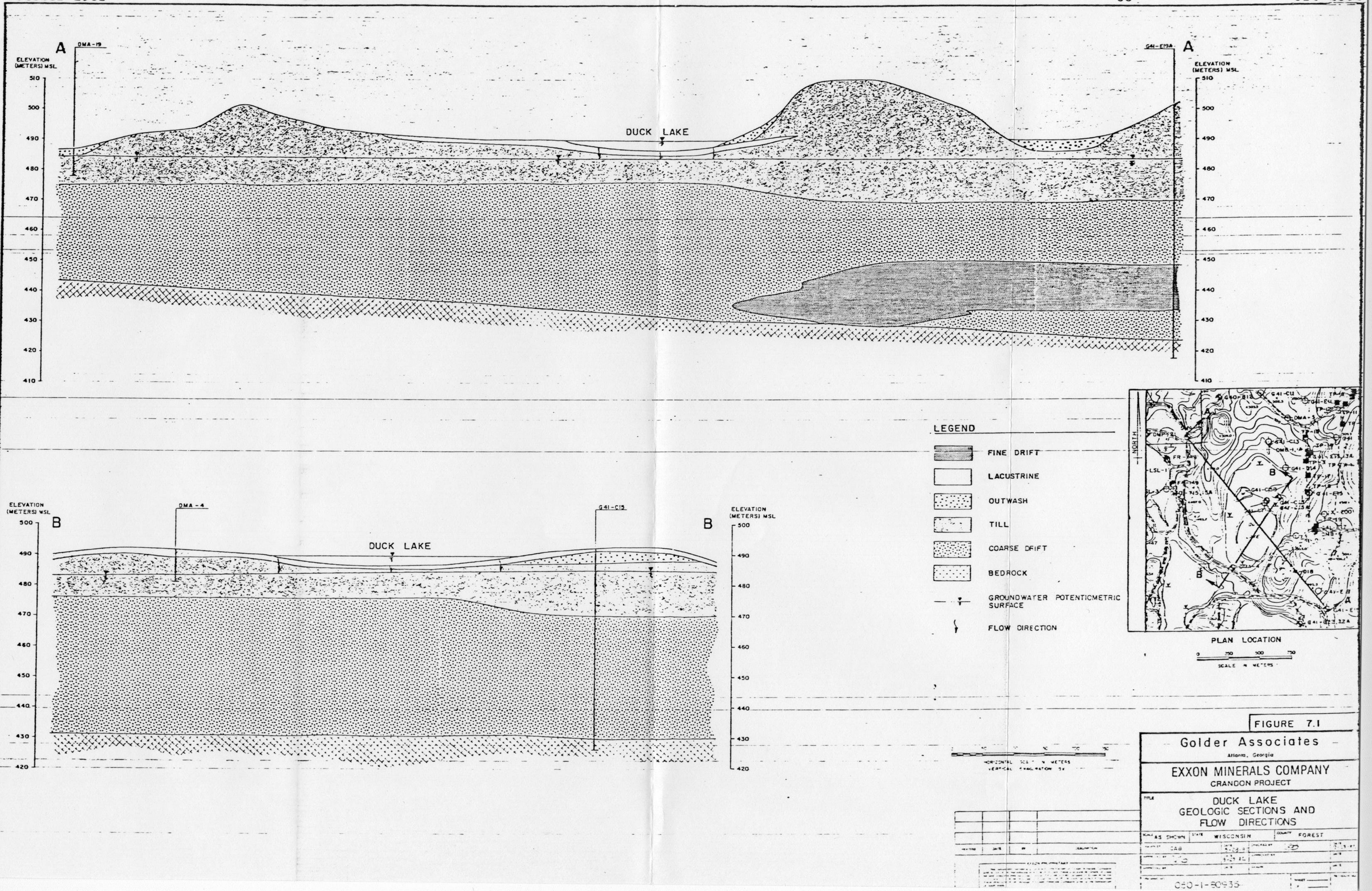


FIGURE 7.1

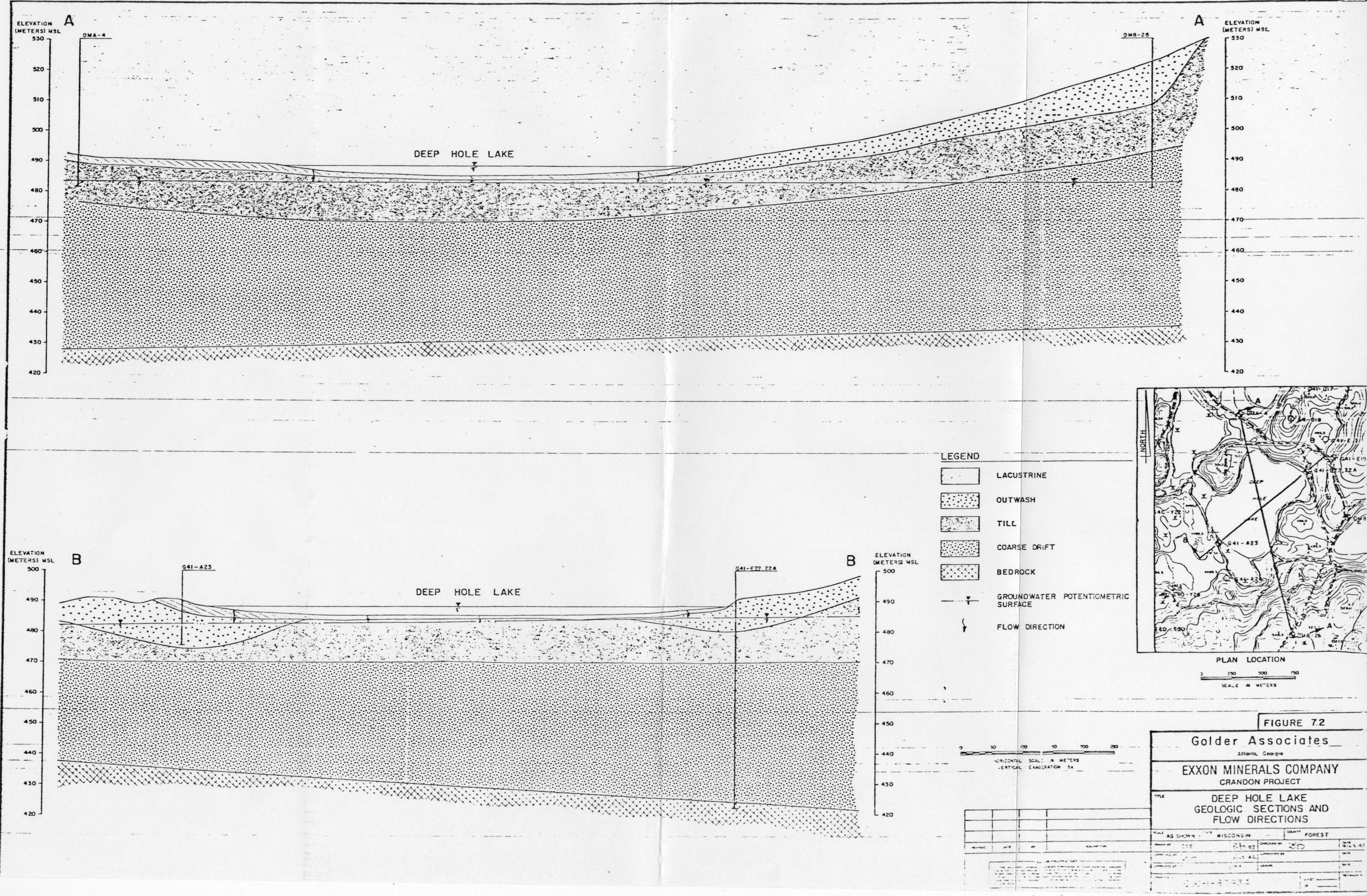
Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

DUCK LAKE
GEOLOGIC SECTIONS AND
FLOW DIRECTIONS

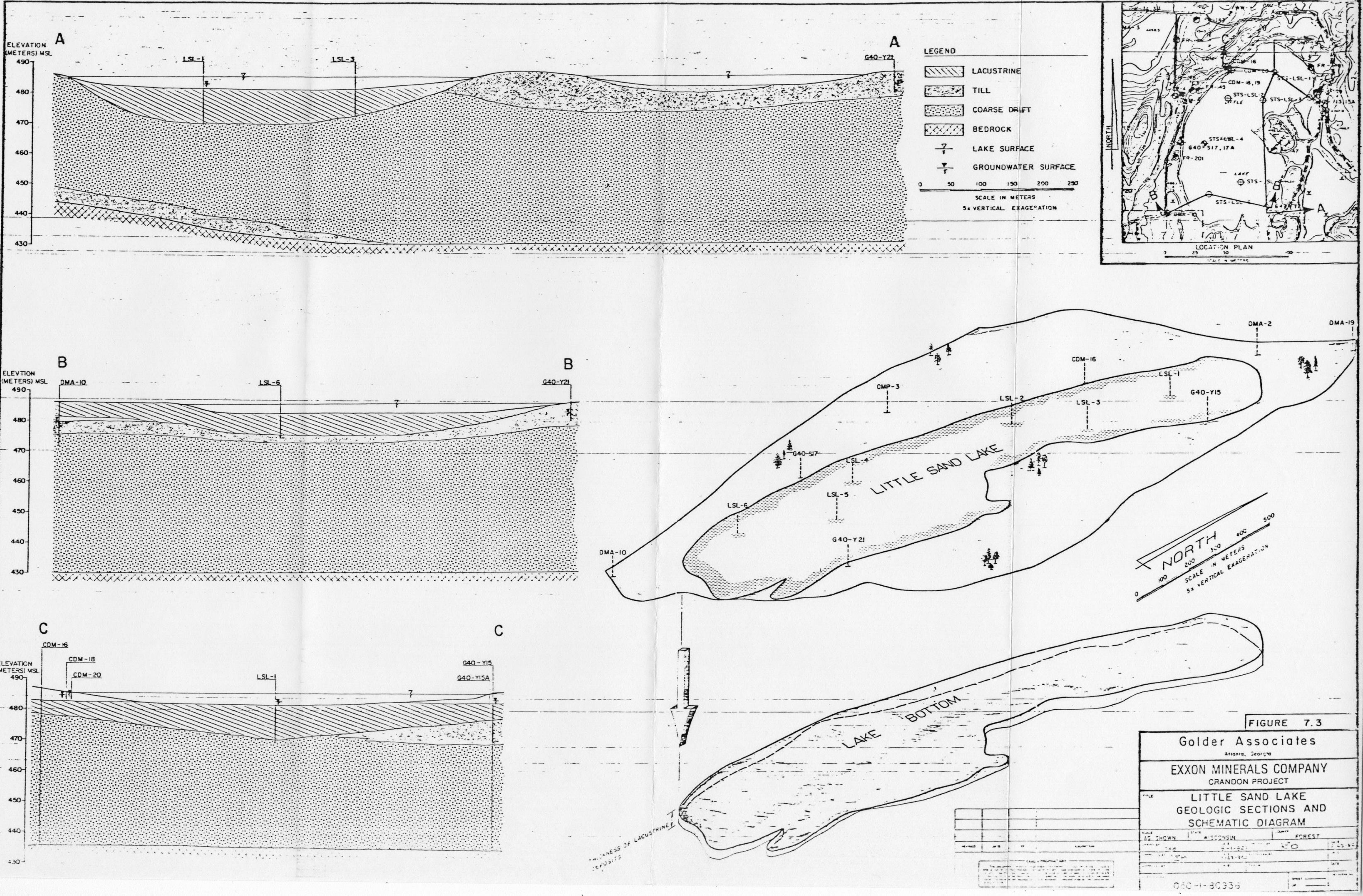
AS SHOWN WISCONSIN FOREST

050-1-60935


A
ELEVATION (METERS) MSL
DMA-4
DMB-26
DEEP HOLE LAKE
B
G41-A23
G41-E22,22A
DEEP HOLE LAKE
LEGEND
LACUSTRINE
OUTWASH
TILL
COARSE DRIFT
BEDROCK
GROUNDWATER POTENTIOMETRIC SURFACE
FLOW DIRECTION
NORTH
PLAN LOCATION
SCALE IN METERS
HORIZONTAL SCALE IN METERS
VERTICAL EXAGGERATION 5x
FIGURE 7.2
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
DEEP HOLE LAKE
GEOLOGIC SECTIONS AND
FLOW DIRECTIONS
AS SHOWN
WISCONSIN
FOREST

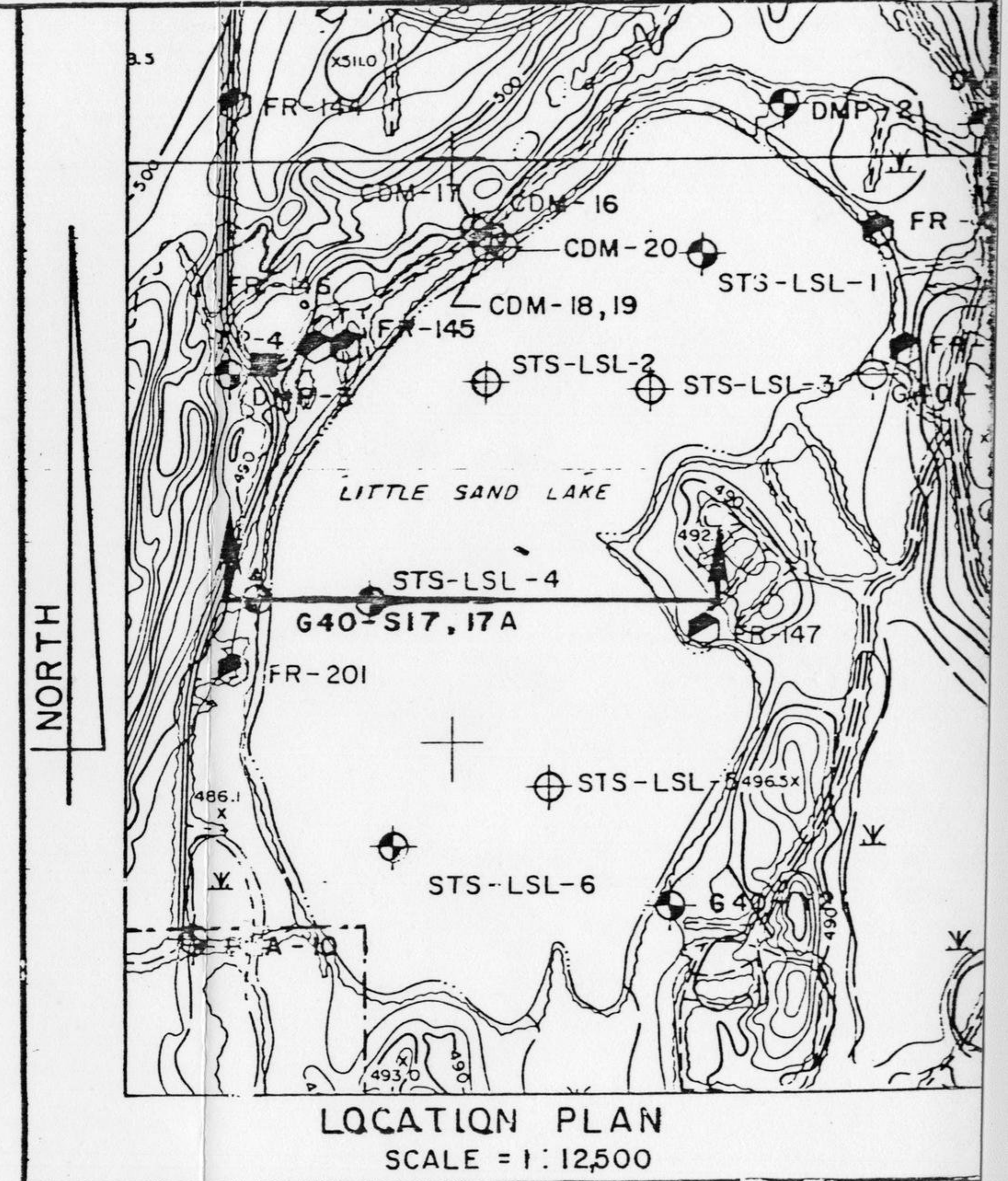
Little Sand Lake differs from Duck and Deep Hole Lakes in that its bottom is beneath the surrounding groundwater level. However, the lake level is about 2.51 m (8.23 ft.) above the surrounding groundwater level. In order to further define the stratigraphy beneath Little Sand Lake, a drilling program was undertaken consisting of six boreholes in the lake bottom, as presented in Reference 14. These data revealed that the lake is underlain by up to 10 m (32 ft.) of lacustrine silt and clay with vertical hydraulic conductivity ranging from 10^{-8} to 10^{-9} m/sec. (Reference 14). Measured groundwater levels in these borings showed them to be below lake level, indicating that Little Sand Lake is a perched lake. Figure 7.3 shows three geologic sections across the lake and a schematic diagram of the underlying lacustrine deposits. Figure 7.4 shows an idealized flow net beneath Little Sand Lake.

By reviewing all the geologic and hydrogeologic data pertaining to Little Sand Lake it can be seen that the lake itself actually impedes the flow of groundwater across the study area. Figure 4.3 shows the groundwater flow directions diverging around the lake. The lower permeability of the lacustrine deposits beneath the lake act as an obstruction to lateral groundwater flow. Similar phenomena have been observed to occur around low permeability landfill sites (Reference 29).

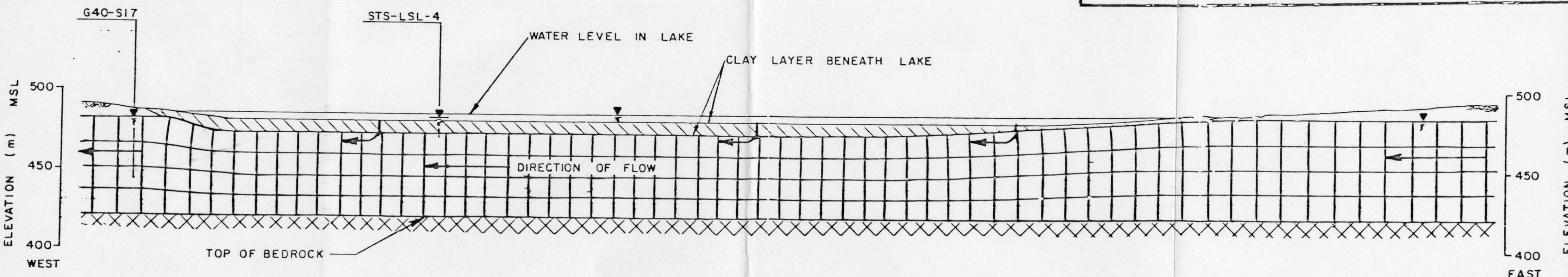

A
A
ELEVATION (METERS) MSL
LSL-1
LSL-3
G40-Y21
LEGEND
LACUSTRINE
TILL
COARSE DRIFT
BEDROCK
LAKE SURFACE
GROUNDWATER SURFACE
0 50 100 150 200 250
SCALE IN METERS
5x VERTICAL EXAGERATION
LOCATION PLAN
NORTH
B
B
ELEVTION (METERS) MSL
DMA-10
LSL-6
G40-Y21
C
C
ELEVATION (METERS) MSL
CDM-16
CDM-18
CDM-20
LSL-1
G40-Y15
G40-Y15A
490
480
470
460
450
440
430
DMA-2
DMA-19
CDM-16
LSL-1
G40-Y15
LSL-2
LSL-3
CMP-3
G40-S17
LSL-4
LSL-5
LSL-6
G40-Y21
DMA-10
LITTLE SAND LAKE
NORTH
0 100 200 300 400 500
SCALE IN METERS
5x VERTICAL EXAGERATION
LAKE BOTTOM
THICKNESS OF LACUSTRINE DEPOSITS
FIGURE 7.3
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
LITTLE SAND LAKE
GEOLOGIC SECTIONS AND
SCHEMATIC DIAGRAM
AS SHOWN
WISCONSIN
FOREST

NOTES:

1. FLOW NET DRAWN ON IDEALIZED SECTION BASED ON GEOLOGIC CROSS SECTION B-B' SHOWN ON FIGURE 3.8
2. SOILS IN IDEALIZED SECTION ARE ASSUMED ISOTROPIC AND HOMOGENEOUS.



LOCATION PLAN
SCALE = 1:12,500



JOB NO. 824 - 1304	SCALE 1:2500	IDEALIZED FLOW NET BENEATH LITTLE SAND LAKE	
DRAWN SKB	DATE 5-24-82		
CHECKED JEB	DWG NO ———		
Golder Associates		EXXON MINERALS COMPANY	FIGURE 7.4

8.0 SUMMARY

The Exxon Minerals Crandon Project may include several aspects which have the potential to affect the existing site hydrogeologic system. As a preamble to evaluation of these effects, the existing hydrologic system has been characterized in detail, including geology, hydrogeology, surface water hydrology, and potential interactions between the groundwater and the orebody and nearby surface water bodies. This review and synthesis effort has lead to several key conclusions which should be considered in the design of various aspects of the Crandon Project.

1. The predominant path of groundwater flow in the Project area is vertically downward through the till and then horizontally through the coarse drift.

2. The water level in the perched lakes south of the orebody (Little Sand, Oak, Duck and Deep Hole Lakes) is higher than the surrounding groundwater levels. This condition precludes migration of groundwater from the underlying aquifers into the lakes.

3. In some areas in the vicinity of the orebody the combination of residual bedrock weathering products and aquifer materials result in the potential for a high degree of hydraulic connection between the orebody and the glacial overburden. These areas should be considered in the design of mine water control strategies.

4. The hydraulic connection between Swamp Creek and the orebody to the south is lessened by the absence of saturated coarse drift material. The hydraulic connection between the perched lakes and the orebody is also minimized by the lacustrine deposits beneath the lakes.

5. Rice Lake has the shortest average residence time of all the lakes studied in the project area. This information should be used in siting any treated water discharge points.

The hydrogeologic characterization presented in this document is the culmination of a great deal of data acquisition, analysis, and study. While Golder Associates has attempted to present the appropriate degree of detail in this report, readers may at times need to refer to the original data and reports. Nonetheless, this report should greatly aid in developing a thorough, comprehensive understanding of the Crandon Project area surface and groundwater hydrology.

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REFERENCES

1. Dames & Moore, Investigation of Feasibility of Dewatering and Other Alternatives for Open Pit Mine Option, Near Crandon, Wisconsin, May 1977.
2. Dames & Moore, Exxon Minerals Company Crandon Project Environmental Baseline Study, Section 2.2, Geology Study and Study Methods, April 1981.
3. Dames & Moore, Exxon Minerals Company Crandon Project Environmental Baseline Study, Section 2.3, Groundwater Study and Study Methods, January 1982.
4. Dames & Moore, Exxon Minerals Company Crandon Project Environmental Baseline Study, Section 2.4, Surface Water Study and Study Methods, February 1982.
5. Golder Associates, Geotechnical Review, Crandon Project, Waste Disposal System, Project Report 2, Vols. 1, 2 and 3, October 1981.
6. Golder Associates, Addendum No. 1 Geotechnical Review, Crandon Project, Waste Disposal System, April 1982.
7. Golder Associates, Pumping Test and Analyses, Crandon Project Waste Disposal System, Project Report 4, September 1981.
8. Golder Associates, Groundwater Potentiometric Contours, Crandon Project, Waste Disposal System, Project Report 7, September 1981.
9. Camp Dresser and McKee, Inc., Mine Hydrology Test Data Analysis (Part One) Crandon Project, November 1981.
10. Camp Dresser and McKee, Inc., Draft Report, Geophysical Logging and Interpretation, Crandon Project, for Exxon Minerals Company (Revision 1), February 1982.
11. Camp Dresser and McKee, Inc., Grain Size Curves (various) for Exxon Minerals Company, 1982.
12. Soil Testing Services, Soils Report, Subsurface Investigation and Laboratory Testing for Two Ventilator Shaft Sites, Crandon Mine Project, Crandon, Wisconsin, April 1978.

13. Soil Testing Services, Soil Report, Surface Facilities and Access Shaft Collars, Prospecting Project, Exxon Mine Development, Crandon, Wisconsin, March 1980.

14. STS Consultants Ltd., Soil Boring and Laboratory Test Results of Little Sand Lake Drilling Project for the Exxon Crandon Project Mine Development, April 1982.

15. Braun Engineering Testing, Soil Borings and Piezometer Installation, Proposed Mine Facility, Crandon, Wisconsin, February 1981.

16. Foth and Van Dyke and Associates, Preliminary Railroad Engineering, Preliminary Soil Investigation, Mine/Mill Railroad Spur, Crandon Project, October 1981.

17. Normandeau Associates, Excerpts from: Wetlands Assessment, Exxon Minerals Company, Crandon Project, Crandon, Wisconsin (Final Draft) 1982.

18. Exxon Minerals Company, Supergene Weathering at the Crandon Deposit, April 1982.

19. U.S. Department of Commerce, Monthly Normals of Temperature, Precipitation, and Heating and Cooling Days 1941-70, August 1973.

20. Simpkins, W.W., M.C. McCartney and D.M. Mickelson, Glacial Geology of Forest County, Wisconsin, Wisconsin Geological and Natural History Survey (unpublished), December 1978.

21. Geoterrex Ltd., Logistic Report on a Refraction Seismic Survey in Crandon, Wisconsin, April 1980.

22. Geoterrex Ltd., An Interpretation Report for a Gravity and Vertical Electrical Sounding Survey, conducted on behalf of Exxon Minerals Company at Swamp Creek, Wisconsin, November 1981.

23. Holmstrom, B.K., Low Flow Characteristics of Streams in the Menominel-Oconto-Peshtigo River basin, Wisconsin, U.S. Geological Survey, Open-File Report 80-749, August 1980.

24. Gebert, W.A. and B.K. Holmstrom, Low-Flow Characteristics at Gaging Stations on the Wisconsin, Fox and Wolf Rivers, Wisconsin, U.S. Geological Survey, Water Resources Investigation 77-27, June 1977.

25. Golder Associates, Groundwater Impact Screening Model, Crandon Project Waste Disposal System, Project Report 9, March 1982.

26. Holland, G.H., Science Progress, July 1964.

27. Oftedahl, C., A Theory of Exhalative-Sedimentary Ores, Geol. Foren. Stockholm Forh. 80:1-19, 1958.

28. Prickett, T.A., and C.G. Lonnquist, Selected Digital Computer Techniques for Groundwater Resource Evaluation, Illinois State Water Survey, Urbana, 1971.

29. Kinsella, J.V., and M. Owen, Groundwater Flow in the Gravels of the Lower Colne Valley, Thames Water Authority, 1981.

30. Chow, V.T., Handbook of Applied Hydrology, McGraw-Hill Book Company, New York, 1964.

APPENDIX A

Crandon Project Boring Data

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET	FEET	FEET	FEET	FEET		FEET
	METERS	METERS	METERS	METERS	METERS		METERS
AR-1	122216.000	2276441.800	1550.00	----	----	-----	----
	37251.887	693867.813	472.45	----	----		----
AR-1A	122224.200	2276451.600	1550.00	----	----	-----	----
	37254.387	693870.812	472.45	----	----		----
AR-2	122134.000	2276484.500	1550.00	----	----	-----	----
	37226.891	693880.813	472.45	----	----		----
AR-2A	122138.900	2276476.300	1550.00	----	----	-----	----
	37228.387	693878.313	472.45	----	----		----
AR-3	117200.000	2276484.000	1655.00	----	----	-----	----
	35722.992	693880.688	504.45	----	----		----
AR-4	117000.000	2276484.000	1640.00	----	----	-----	----
	35662.031	693880.688	499.88	----	----		----
BE-211-1	116170.970	2278391.910	1647.33	1459.33	1578.61	4/82	39
	35409.340	694462.250	502.11	444.81	481.17		12.0
BE-211-2	116451.725	2276560.523	1660.92	1474.42	1580.77	4/82	49
	35494.914	693904.000	506.25	449.41	481.82		15.0
BE-211-3	116476.081	2276300.595	1647.89	1455.89	1580.69	4/82	57
	35502.336	693824.750	502.28	443.76	481.80		17.0
BE-213-1	116025.402	2278436.725	1618.92	1530.92	----	-----	----
	35364.969	694475.875	493.45	466.63	----		----
BE-213-2	116063.997	2278664.481	1616.09	1523.09	----	-----	----
	35376.734	694545.313	492.59	464.24	----		----
BE-213-3	116112.337	2278467.363	1623.74	1534.74	----	-----	----
	35391.465	694485.188	494.92	467.79	----		----
BE-216-1	116252.761	2277530.922	1657.45	1508.45	1578.55	4/82	43
	35434.270	694199.813	505.20	459.78	481.15		13.0
BE-216-2	116327.310	2277555.071	1655.18	1517.18	1576.44	4/82	23
	35456.992	694207.125	504.50	462.44	480.50		7.0
BE-216-3	116338.082	2276188.924	1661.98	1511.98	1591.25	4/82	72
	35460.273	693790.750	506.58	460.86	485.02		22.0
BE-231	116748.300	2276188.900	1646.41	----	----	-----	----
	35585.309	693790.750	501.83	----	----		----
BE-232	116641.900	2278087.900	1653.02	----	----	-----	----
	35552.879	694369.563	503.85	----	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
CDM-01	116262.600 35437.270	2274808.500 693370.000	1657.80 505.30	1497.80 456.53	---- ----	-----	---- ----
CDM-02	116553.300 35525.375	2274955.100 693414.625	1661.50 506.43	1519.50 463.15	---- ----	-----	---- ----
CDM-03	116190.900 35415.414	2275349.500 693534.875	1639.40 499.70	1475.40 449.71	---- ----	-----	---- ----
CDM-04	116533.300 35519.777	2275382.300 693544.875	1641.40 500.30	1475.40 449.71	1576.86 480.63	4/82	43 13.0
CDM-05	116295.400 35447.266	2275803.400 693673.250	1640.00 499.88	1456.00 443.79	---- ----	-----	---- ----
CDM-06	116510.500 35512.828	2275773.800 693664.188	1638.50 499.42	1442.50 439.68	---- ----	-----	---- ----
CDM-07	116887.500 35627.738	2275778.200 693665.563	1648.70 502.53	1457.70 444.31	---- ----	-----	---- ----
CDM-08	116096.200 35386.730	2276342.500 693837.563	1656.90 505.03	1450.90 442.24	---- ----	-----	---- ----
CDM-09	115984.400 35352.473	2276977.700 694031.188	1676.90 511.13	1474.90 449.55	---- ----	-----	---- ----
CDM-10	116367.300 35469.180	2276978.200 694031.313	1683.80 513.23	1490.80 454.40	---- ----	-----	---- ----
CDM-11	116713.800 35574.793	2276976.800 694030.875	1678.70 511.67	1500.70 457.42	---- ----	-----	---- ----
CDM-12	115627.700 35243.750	2278064.000 694362.250	1608.70 490.34	1482.70 451.93	---- ----	-----	---- ----
CDM-13	116241.900 35430.957	2277991.300 694340.125	1648.70 502.53	1532.70 467.17	---- ----	-----	---- ----
CDM-14	116038.900 35369.082	2278989.800 694644.438	1608.40 490.25	1530.40 466.47	---- ----	-----	---- ----
CDM-15	119587.700 36450.770	2276543.200 693898.750	1645.80 501.65	1475.80 449.83	---- ----	-----	---- ----
CDM-16	114360.100 34857.379	2277074.000 694060.500	1595.60 486.34	1426.60 434.83	1579.92 481.57	4/82	141 43.0
CDM-17	114387.900 34865.852	2277034.400 694048.500	1596.70 486.68	---- ----	---- ----	4/82	---- ----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
CDM-13	114345.400 34852.898	2277073.100 694061.750	1595.20 486.22	---- ----	1589.78 484.57	4/82	---- ----
CDM-19	114345.400 34852.898	2277138.100 694080.000	1595.20 486.22	---- ----	---- ----	4/82	---- ----
CDM-20	114320.100 34845.188	2277138.100 694080.000	1594.50 486.01	---- ----	1591.60 485.13	4/82	---- ----
DMA-01N	113664.500 34645.355	2272028.900 692522.813	1638.90 499.54	---- ----	1620.57 493.96	3/82	---- ----
DMA-01S	113661.400 34644.410	2272029.900 692523.063	1638.90 499.54	---- ----	---- ----	3/82	---- ----
DMA-03	115494.400 35203.117	2273938.300 693104.750	1647.51 502.17	---- ----	---- ----	3/82	---- ----
DMA-04	111424.700 33962.660	2280946.900 695210.563	1612.00 491.34	---- ----	1586.67 483.62	3/82	---- ----
DMA-05	115380.000 35168.246	2282390.000 695680.875	1639.80 499.82	---- ----	---- ----	-----	---- ----
DMA-06	115450.000 35189.586	2285290.000 696564.813	1717.00 523.35	---- ----	---- ----	-----	---- ----
DMA-07	112880.000 34406.238	2289900.000 697969.938	1583.80 482.75	---- ----	---- ----	-----	---- ----
DMA-10	110510.000 33683.855	2275400.000 693550.250	1593.60 485.74	---- ----	1574.51 479.92	3/82	---- ----
DMA-12	117887.300 35932.480	2279966.300 694942.062	1621.20 494.15	---- ----	1591.15 484.99	3/82	---- ----
DMA-13	110450.000 33665.566	2265900.000 690624.188	1554.70 473.88	---- ----	1553.52 473.52	3/82	---- ----
DMA-14	128420.000 39142.887	2276320.000 693830.688	1601.90 488.27	---- ----	---- ----	-----	---- ----
DMA-16	123792.900 37732.531	2271254.100 692286.563	1589.90 484.61	---- ----	1553.89 473.63	3/82	---- ----
DMA-17	106565.400 32481.525	2275547.000 693595.063	1564.00 476.71	---- ----	---- ----	-----	---- ----
DMA-18	111757.500 34064.099	2268883.600 691868.813	1619.40 493.60	---- ----	1561.69 476.01	3/82	---- ----

BORING NAME	COORDINATE NORTH FEET / METERS	COORDINATE EAST FEET / METERS	ELEVATION(MSL) GROUND FEET / METERS	ELEVATION(MSL) BEDROCK FEET / METERS	GROUNDWATER ELEV.(MSL) FEET / METERS	GROUNDWATER DATE	AQUIFER THICKNESS FEET / METERS
DMA-19	115003.800 35053.578	2279719.900 694867.063	1597.20 486.83	---- ----	1588.54 484.19	3/82	---- ----
DMA-20	119200.200 36332.660	2272622.100 692703.563	1592.00 485.25	---- ----	1561.37 475.91	3/82	---- ----
DMA-22	113800.000 34686.656	2297350.000 700240.750	1628.63 496.41	---- ----	---- ----	-----	---- ----
DMA-22B	113800.000 34686.656	2297350.000 700240.750	1629.20 496.59	---- ----	1602.85 488.55	3/82	---- ----
DMA-27	105150.000 32050.105	2254020.000 687033.562	1540.10 469.43	---- ----	---- ----	-----	---- ----
DMA-27A	104430.000 31830.648	2254790.000 687268.250	1547.10 471.56	---- ----	---- ----	-----	---- ----
DMA-29	101230.000 30855.275	2251380.000 686228.875	1537.10 468.51	---- ----	1534.58 467.75	3/82	---- ----
DMA-29A	101250.000 30861.371	2251380.000 686228.875	1536.70 468.39	---- ----	1534.68 467.78	3/82	---- ----
DMA-30	122680.000 37393.316	2281010.000 695260.250	1577.60 480.86	---- ----	---- ----	-----	---- ----
DMA-31	120160.000 36625.211	2281570.000 695430.938	1592.10 485.28	---- ----	1584.70 483.02	3/82	---- ----
DMA-32A	112050.000 34153.250	2290580.000 698177.188	1592.10 485.28	---- ----	1583.54 482.67	3/82	---- ----
DMA-33	109525.000 33383.621	2251770.000 686347.750	1537.90 468.76	---- ----	---- ----	-----	---- ----
DMA-34	114000.000 34747.617	2248050.000 685213.875	1535.90 468.15	---- ----	1533.82 467.51	3/82	---- ----
DMA-35	111180.000 33888.074	2245820.000 684534.188	1570.40 478.66	---- ----	---- ----	-----	---- ----
DMA-36	129500.000 39472.074	2250180.000 685863.125	1675.50 510.70	---- ----	---- ----	-----	---- ----
DMA-37	125340.000 38204.094	2247430.000 685024.938	1684.10 513.32	---- ----	---- ----	-----	---- ----
DMA-38	141150.000 43023.039	2249880.000 685771.688	1772.00 540.11	---- ----	---- ----	3/82	---- ----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
DMA-39	143560.000 43757.617	2250980.000 686107.000	1772.30 540.20	---- ----	---- ----	-----	---- ----
DMA-42	133040.000 40551.082	2271020.000 692215.250	1615.90 492.53	---- ----	---- ----	-----	---- ----
DMA-43	137000.000 41758.102	2272720.000 692733.438	1624.70 495.21	---- ----	1625.65 495.50	3/82	---- ----
DMA-44	88280.000 26908.068	2259180.000 688606.375	1590.80 484.88	---- ----	---- ----	-----	---- ----
DMA-45	100630.000 30672.395	2310200.000 704157.438	1640.60 500.06	---- ----	---- ----	-----	---- ----
DMA-46	117420.000 35790.047	2319400.000 706961.625	1714.50 522.59	---- ----	---- ----	-----	---- ----
DMA-47	121392.600 37000.910	2276057.900 693750.813	1573.60 479.64	---- ----	1554.68 473.87	3/82	---- ----
DMA-48	118981.500 36266.000	2268708.500 691510.688	1547.40 471.65	---- ----	1537.39 468.60	3/82	---- ----
DMB-01	114405.000 34871.063	2282890.000 695833.250	1627.30 496.01	---- ----	---- ----	-----	---- ----
DMB-01A	114405.000 34871.063	2282900.000 695836.313	1627.90 496.19	---- ----	1592.76 485.48	3/82	---- ----
DMB-02	114995.000 35050.898	2285800.000 696720.250	1706.30 520.09	---- ----	---- ----	-----	---- ----
DMB-03	116895.000 35630.027	2287465.000 697227.750	1587.90 484.00	---- ----	1579.45 481.42	3/82	---- ----
DMB-04	118405.000 36090.277	2283785.000 696106.063	1644.50 501.25	---- ----	1592.48 485.39	10/80	---- ----
DMB-05	112135.000 34179.160	2285540.000 696641.000	1688.80 514.75	---- ----	---- ----	3/82	---- ----
DMB-05A	112130.000 34177.637	2285545.000 696642.500	1689.30 514.90	---- ----	1592.51 485.40	3/82	---- ----
DMB-06	112385.000 34255.359	2283015.000 695871.375	1666.50 507.96	---- ----	1592.28 485.33	3/82	---- ----
DMB-07	106150.000 32354.910	2287845.000 697343.563	1653.70 504.05	---- ----	1589.07 484.35	3/82	---- ----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
DMB-08	114595.000	2287840.000	1622.70	----	1586.97	3/82	----
	34928.977	697342.063	494.60	----	483.71		----
DMB-09A	110555.000	2287235.000	1661.60	1422.60	1590.48	3/82	167
	33697.570	697157.625	506.46	433.61	484.78		50.9
DMB-09B	110555.000	2287235.000	1661.60	----	1590.31	3/82	----
	33697.570	697157.625	506.46	----	484.73		----
DMB-09C	110555.000	2287235.000	1661.60	----	1590.47	3/82	----
	33697.570	697157.625	506.46	----	484.78		----
DMB-10	117720.000	2271170.000	1619.10	----	1559.89	3/82	----
	35881.488	692260.938	493.51	----	475.46		----
DMB-11	109960.000	2273820.000	1656.90	----	1569.34	3/82	----
	33516.211	693068.688	505.03	----	478.34		----
DMB-12	107390.000	2275205.000	1586.10	----	1565.15	3/82	----
	32732.867	693490.875	483.45	----	477.06		----
DMB-13	107110.000	2269980.000	1609.40	----	1553.02	3/82	----
	32647.521	691898.250	490.55	----	473.37		----
DMB-14	110075.000	2270985.000	1638.70	----	----	-----	----
	33551.266	692204.563	499.48	----	----		----
DMB-15	113660.000	2272025.000	1637.50	----	----	-----	----
	34643.984	692521.563	499.12	----	----		----
DMB-16	111980.000	2273470.000	1674.60	----	----	3/82	----
	34101.434	692962.000	510.42	----	----		----
DMB-17	108960.000	2268755.000	1649.00	----	----	3/82	----
	33211.410	691524.875	502.62	----	----		----
DMB-18	110560.000	2268060.000	1601.00	----	1556.32	3/82	----
	33699.094	691313.000	487.99	----	474.37		----
DMB-19	110450.000	2265815.000	1554.60	1418.60	----	-----	----
	33665.566	690628.750	473.85	432.39	----		----
DMB-20	115725.000	2270530.000	1605.80	----	1578.55	3/82	----
	35273.406	692065.975	489.45	----	481.15		----
DMB-20A	115720.000	2270545.000	1606.20	----	1561.93	3/82	----
	35271.883	692070.438	489.58	----	476.08		----
DMB-21	112820.000	2265775.000	1559.30	----	1554.58	3/82	----
	34387.949	690616.563	475.28	----	473.84		----

BORING NAME	COORDINATE NORTH FEET / METERS	COORDINATE EAST FEET / METERS	ELEVATION(MSL) GROUND FEET / METERS	ELEVATION(MSL) BEDROCK FEET / METERS	GROUNDWATER ELEV.(MSL) FEET / METERS	GROUNDWATER DATE	AQUIFER THICKNESS FEET / METERS
DMB-22	113240.000	2269090.000	1616.50	----	1559.62	3/82	----
	34515.969	691627.000	492.72	----	475.38		----
DMB-23	115900.000	2268205.000	1563.30	----	1553.90	3/82	----
	35326.746	691357.188	476.50	----	473.63		----
DMB-24	102060.000	2271375.000	1565.40	----	1539.79	10/80	----
	31108.264	692323.438	477.14	----	469.33		----
DMB-25	105725.000	2268525.000	1644.70	----	1548.17	3/82	----
	32225.369	691454.750	501.31	----	471.89		----
DMB-26	105520.000	2282250.000	1713.00	----	1584.09	3/82	----
	32162.883	695638.187	522.13	----	482.84		----
DMB-27	108675.000	2283695.000	1649.00	----	1587.03	3/82	----
	33124.539	696078.625	502.62	----	483.73		----
DMB-28	106840.000	2285425.000	1642.13	----	1587.88	3/82	----
	32565.225	696605.938	500.53	----	483.99		----
DMB-29	104385.000	2288110.000	1629.98	----	1587.56	3/82	----
	31816.932	697424.313	496.82	----	483.89		----
DMC-01	115120.000	2292330.000	1614.30	----	1585.98	10/80	----
	35089.000	698710.625	492.04	----	483.41		----
DMC-02	126510.000	2288740.000	1588.60	----	1579.13	3/82	----
	38560.711	697616.375	484.21	----	481.32		----
DMC-03	106940.000	2291715.000	1610.00	----	1589.96	3/82	----
	32595.705	698523.125	490.73	----	484.63		----
DMI-01	116746.700	2278815.300	1636.70	1575.50	1589.44	3/82	3
	35584.824	694591.250	498.87	480.22	484.47		1.0
DMI-02	116608.900	2278750.100	1629.40	1574.50	1588.64	3/82	14
	35542.820	694571.375	496.65	479.91	484.22		4.3
DMI-03	116504.400	2278692.200	1626.30	1573.50	----	-----	----
	35510.969	694553.750	495.70	479.61	----		----
DMI-04	116374.700	2278621.700	1637.10	1561.00	----	-----	----
	35471.437	694532.313	498.99	475.80	----		----
DMI-05	116392.000	2278473.600	1641.20	1557.50	----	-----	----
	35476.711	694487.125	500.24	474.73	----		----
DMI-07	116412.900	2278275.300	1647.70	1557.00	----	-----	----
	35483.078	694426.688	502.23	474.58	----		----

BORING NAME	COORDINATE NORTH FEET / METERS	COORDINATE EAST FEET / METERS	ELEVATION(MSL) GROUND FEET / METERS	ELEVATION(MSL) BEDROCK FEET / METERS	GROUNDWATER ELEV.(MSL) FEET / METERS	GROUNDWATER DATE	AQUIFER THICKNESS FEET / METERS
DMI-08	116430.200	2278125.200	1647.30	1550.00	----	-----	----
	35488.355	694380.938	502.10	472.45	----		----
DMI-09	116908.900	2278902.900	1633.80	1579.00	----	-----	----
	35634.262	694618.000	497.99	481.29	----		----
DMI-11	116544.000	2278599.500	1634.80	----	----	-----	----
	35523.039	694525.500	498.29	----	----		----
DMP-01	116675.000	2278490.000	1647.60	----	1587.81	3/82	----
	35562.969	694489.063	502.19	----	483.97		----
DMP-02	115135.000	2278685.000	1595.60	----	1584.52	3/82	----
	35093.570	694551.563	486.34	----	482.97		----
DMP-03	113665.000	2275625.000	1623.60	----	1577.34	3/82	----
	34645.508	693618.875	494.88	----	480.78		----
DMS-01	117104.100	2278219.900	1661.70	1554.00	1593.96	3/82	0
	35693.762	694409.813	506.49	473.66	485.84		0.0
DMS-02	117926.700	2277889.700	1641.20	1484.00	1590.48	3/82	0
	35944.492	694309.188	500.24	452.33	484.78		0.0
DW-01A	116334.900	2276266.400	1648.50	----	1581.32	3/82	----
	35459.305	693814.375	502.47	----	481.99		----
DW-01U	116320.900	2276261.000	1648.30	----	1581.01	3/82	----
	35455.039	693812.688	502.41	----	481.90		----
DW-02L	116776.800	2279794.400	1600.70	----	1591.52	3/82	----
	35593.996	694889.750	487.90	----	485.10		----
DW-02U	116776.800	2279794.400	1600.70	----	1596.06	3/82	----
	35593.996	694889.750	487.90	----	486.48		----
DW-03L	116254.600	2274840.100	1657.10	----	1575.98	3/82	----
	35434.828	693379.563	505.09	----	480.36		----
DW-03U	116254.600	2274840.100	1657.10	----	1576.21	3/82	----
	35434.828	693379.563	505.09	----	480.43		----
G40-D24	108060.000	2266940.000	1629.93	1446.43	1553.23	3/82	105
	32937.086	690971.625	496.81	440.88	473.43		32.0
G40-E16	113255.000	2267520.000	1574.40	----	----	-----	----
	34520.539	691148.438	479.88	----	----		----
G40-E22	109650.000	2267465.000	1594.10	----	----	-----	----
	33421.723	691131.688	485.89	----	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G40-G07	118955.000	2268700.000	1548.35	1431.35	----	-----	----
	36257.922	691508.125	471.94	436.28	----		----
G40-G19	111340.000	2269350.000	1649.90	----	----	-----	----
	33936.840	691706.250	502.90	----	----		----
G40-G24	107830.000	2268850.000	1658.70	----	----	-----	----
	32866.980	691553.313	505.58	----	----		----
G40-G26	106690.000	2268660.000	1678.70	----	----	-----	----
	32519.504	691495.875	511.67	----	----		----
G40-H13	115275.000	2269330.000	1762.20	----	----	-----	----
	35136.242	691700.125	537.13	----	----		----
G40-H16	113260.000	2269110.000	1617.10	1355.10	1559.50	3/82	68
	34522.063	691633.063	492.90	413.04	475.34		20.7
G40-H27	105930.000	2269650.000	1602.10	1370.10	1549.10	3/82	62
	32287.854	691797.688	488.33	417.61	472.17		18.9
G40-J15	113810.000	2270150.000	1603.60	----	1562.13	3/82	----
	34689.707	691950.063	488.78	----	476.14		----
G40-J20	111140.000	2269905.000	1629.70	----	----	-----	----
	33875.879	691875.375	496.74	----	----		----
G40-K13	115130.000	2270885.000	1600.90	----	1564.60	3/82	----
	35092.047	692174.063	487.96	----	476.90		----
G40-L09	117745.000	2271185.000	1621.00	1415.00	----	-----	----
	35888.109	692265.563	494.09	431.30	----		----
G40-L19	111060.000	2271025.000	1671.30	----	----	-----	----
	33851.496	692216.750	509.42	----	----		----
G40-L23	108920.000	2271065.000	1639.30	----	1561.32	-----	----
	33198.215	692228.938	499.66	----	475.90		----
G40-M14	114595.000	2271820.000	1649.60	----	----	-----	----
	34928.977	692459.063	502.80	----	----		----
G40-M15	113660.000	2271735.000	1637.60	1352.60	1568.20	3/82	128
	34643.984	692433.188	499.15	412.28	477.99		39.0
G40-P10	117145.000	2273040.000	1634.00	----	----	-----	----
	35706.227	692830.938	498.05	----	----		----
G40-P10A	116745.000	2272895.000	1651.35	1497.35	1569.36	3/82	33
	35584.305	692786.750	503.34	456.40	478.35		10.1

BORING NAME	COORDINATE NORTH FEET / METERS	COORDINATE EAST FEET / METERS	ELEVATION(MSL) GROUND FEET / METERS	ELEVATION(MSL) BEDROCK FEET / METERS	GROUNDWATER ELEV.(MSL) FEET / METERS	GROUNDWATER DATE	AQUIFER THICKNESS FEET / METERS
G40-P17	112710.000 34354.422	2273490.000 692968.125	1707.90 520.57	---- ----	---- ----	-----	---- ----
G40-P20	111070.000 33854.543	2273515.000 692975.750	1641.10 500.21	---- ----	1570.22 478.61	3/82	---- ----
G40-Q07	119050.000 36286.879	2274350.000 693230.250	1608.10 490.15	---- ----	1564.24 476.79	3/82	---- ----
G40-R23	108770.000 33153.496	2274805.000 693368.938	1620.30 493.87	---- ----	1568.63 478.12	3/82	---- ----
G40-S11	116240.000 35430.379	2275365.000 693539.625	1639.90 499.85	---- ----	---- ----	-----	---- ----
G40-S17	112295.000 34227.930	2275770.000 693663.063	1595.65 486.36	---- ----	1576.10 480.40	3/82	---- ----
G40-S17A	112335.000 34240.121	2275790.000 693669.125	1595.90 486.44	---- ----	1577.00 480.68	3/82	---- ----
G40-T30	105765.000 32237.561	2278410.000 694467.750	1590.40 484.76	1434.40 437.21	1578.02 480.99	3/82	104 31.7
G40-X01	121515.000 37038.219	2277990.000 694339.750	1616.55 492.73	1485.05 452.65	1583.27 482.59	3/82	34 10.4
G40-X01A	121930.000 37164.711	2277830.000 694290.938	1578.90 481.25	1509.90 460.22	1573.68 479.66	3/82	0 0.0
G40-V15	113655.000 34642.461	2279180.000 694702.438	1593.40 485.67	1425.40 434.47	1585.60 483.30	3/82	113 34.4
G40-V15A	113665.000 34645.508	2279170.000 694699.375	1593.70 485.77	---- ----	---- ----	3/82	---- ----
G40-V21	110730.000 33750.910	2278040.000 694354.938	1592.80 485.49	---- ----	1582.26 482.28	3/82	---- ----
G40-V22	108880.000 33187.023	2278310.000 694437.250	1609.10 490.46	1419.00 432.52	1575.93 480.35	3/82	157 47.9
G40-V26	106680.000 32516.455	2278800.000 694586.625	1590.70 484.85	1465.70 446.75	1580.56 481.76	3/82	107 32.6
G41-A23	108070.000 32940.133	2280288.000 695040.188	1608.00 490.12	---- ----	1583.32 482.60	3/82	---- ----
G41-A24	107060.000 32632.281	2280500.000 695104.750	1614.10 491.98	1440.80 439.16	---- ----	-----	---- ----

BORING NAME	COORDINATE NORTH	EAST	ELEVATION(MSL) GROUND	BEDROCK	GROUNDWATER ELEV.(MSL)	DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G41-B12	116120.000 35393.801	2280610.000 695138.313	1610.65 490.93	1497.65 456.49	1591.46 485.08	3/82	24 7.3
G41-C11	116095.000 35386.194	2281690.000 695467.500	1634.40 498.17	---- ----	---- ----	----	---- ----
G41-C13	114775.000 34983.840	2281895.000 695530.000	1617.20 492.93	---- ----	---- ----	----	---- ----
G41-C15	113350.000 34549.496	2282075.000 695584.875	1615.60 492.44	1410.60 429.96	1591.40 485.06	3/82	118 36.0
G41-C15A	113365.000 34554.070	2282080.000 695586.375	1615.60 492.44	---- ----	---- ----	----	---- ----
G41-C15B	113265.000 34523.590	2281850.000 695516.250	1611.60 491.22	---- ----	1592.61 485.43	3/82	---- ----
G41-C15C	113160.000 34491.582	2281790.000 695498.000	1611.35 491.15	---- ----	1606.61 489.70	3/82	---- ----
G41-C32	102500.000 31242.377	2282115.000 695597.063	1739.90 530.30	1498.80 456.84	1584.93 483.09	3/82	73 22.3
G41-D14	114075.000 34770.480	2282300.000 695653.438	1615.10 492.29	---- ----	---- ----	----	---- ----
G41-D17	112220.000 34205.070	2282525.000 695722.000	1649.20 502.68	---- ----	---- ----	----	---- ----
G41-D19	111300.000 33924.648	2282140.000 695604.687	1680.40 512.19	---- ----	---- ----	----	---- ----
G41-E11	115865.000 35316.070	2282875.000 695828.688	1651.60 503.41	---- ----	---- ----	----	---- ----
G41-E13	114395.000 34868.016	2282890.000 695833.250	1627.30 496.01	1386.80 422.70	1592.98 485.55	3/82	116 35.4
G41-E13A	114385.000 34864.969	2282895.000 695834.813	1626.70 495.82	---- ----	---- ----	----	---- ----
G41-E15	113380.000 34558.641	2282935.000 695847.000	1647.30 502.10	---- ----	---- ----	----	---- ----
G41-E17	112385.000 34255.359	2283005.000 695868.313	1666.40 507.92	1418.90 432.49	1591.05 484.96	3/82	75 22.9
G41-E19	110750.000 33757.003	2283085.000 695892.688	1620.90 494.06	---- ----	---- ----	----	---- ----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION (MSL) GROUND	ELEVATION (MSL) BEDROCK	GROUNDWATER ELEV. (MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G41-E19A	110260.000 33607.652	2283290.000 695955.188	1645.60 501.58	1391.60 424.16	1588.95 484.32	3/82	90 27.4
G41-E22	109970.000 33519.262	2282570.000 695735.750	1609.75 490.66	1391.75 424.21	1588.58 484.21	3/82	146 44.5
G41-E22A	109955.000 33514.688	2282590.000 695741.812	1609.50 490.58	---- ----	1590.24 484.71	3/82	---- ----
G41-F13	114845.000 35005.130	2283660.000 696067.938	1670.70 509.24	---- ----	---- ----	----	---- ----
G41-F24	107255.000 32691.719	2283465.000 696008.500	1653.50 503.99	1428.80 435.50	1586.38 483.53	3/82	128 39.0
G41-G11	116095.000 35386.194	2284345.000 696276.750	1687.10 514.23	---- ----	---- ----	----	---- ----
G41-G12	115825.000 35303.887	2284430.000 696302.688	1675.70 510.76	---- ----	---- ----	----	---- ----
G41-G13	115260.000 35131.672	2284725.000 696392.563	1709.60 521.09	1393.60 424.77	1591.69 485.15	3/82	41 12.5
G41-G14	113930.000 34726.281	2284315.000 696267.625	1705.10 519.72	---- ----	---- ----	----	---- ----
G41-G14A	114080.000 34772.004	2284315.000 696267.625	1706.90 520.27	---- ----	1591.94 485.23	3/82	---- ----
G41-G14B	114055.000 34764.383	2284315.000 696267.625	1706.80 520.24	1391.80 424.23	1592.03 485.26	3/82	36 11.0
G41-G14C	114030.000 34756.762	2284315.000 696267.625	1706.30 520.09	---- ----	1592.78 485.49	3/82	---- ----
G41-G14D	113855.000 34703.422	2284315.000 696267.625	1705.60 519.87	---- ----	1592.02 485.25	3/82	---- ----
G41-G14E	113830.000 34695.801	2284315.000 696267.625	1705.60 519.87	---- ----	1592.14 485.29	3/82	---- ----
G41-G14F	113805.000 34688.184	2284315.000 696267.625	1703.50 519.23	---- ----	1592.28 485.33	3/82	---- ----
G41-G15	113415.000 34569.309	2284420.000 696299.625	1691.50 515.58	1366.50 416.51	1592.37 485.36	3/82	70 21.3
G41-G15A	113480.000 34589.121	2284390.000 696290.438	1692.80 515.97	---- ----	1592.01 485.25	3/82	---- ----

BORING NAME	COORDINATE NORTH	EAST	ELEVATION(MSL) GROUND	BEDROCK	GROUNDWATER ELEV.(MSL)	DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G41-G15B	113440.000	2284385.000	1692.10	----	1591.86	3/82	----
	34576.930	696288.938	515.76	----	485.20		----
G41-G15C	113440.000	2284405.000	1692.00	----	----	3/82	----
	34576.930	696295.063	515.73	----	----		----
G41-G16	112790.000	2284390.000	1685.70	----	----	----	----
	34378.805	696290.438	513.81	----	----		----
G41-G19	110880.000	2284280.000	1696.60	----	----	----	----
	33796.633	696256.938	517.13	----	----		----
G41-G21	109495.000	2284265.000	1664.80	----	1589.49	3/82	----
	33374.477	696252.375	507.44	----	484.48		----
G41-H09	117300.000	2285000.000	1702.00	1391.50	1591.82	3/82	60
	35753.473	696476.375	518.78	424.13	485.19		18.3
G41-H13	114700.000	2284975.000	1715.20	----	----	----	----
	34960.980	696468.750	522.80	----	----		----
G41-H17	112145.000	2284960.000	1684.50	----	----	3/82	----
	34182.207	696464.188	513.44	----	----		----
G41-H18	111470.000	2285125.000	1684.30	----	----	3/82	----
	33964.273	696514.500	513.38	----	----		----
G41-H19A	111590.000	2285065.000	1680.40	----	1679.06	3/82	----
	34013.043	696496.188	512.19	----	511.78		----
G41-H19B	111455.000	2285099.000	1683.80	1403.80	1587.73	3/82	60
	33971.895	696506.563	513.23	427.88	483.95		18.3
G41-J11	116010.000	2285580.000	1709.00	----	----	----	----
	35360.273	696653.188	520.91	----	----		----
G41-J14	114110.000	2285890.000	1689.20	----	----	----	----
	34781.148	696747.688	514.87	----	----		----
G41-J17	112090.000	2285520.000	1689.20	----	----	----	----
	34165.445	696634.875	514.87	----	----		----
G41-J17A	112110.000	2285530.000	1688.90	----	----	----	----
	34171.539	696637.938	514.78	----	----		----
G41-J18	111215.000	2285495.000	1679.70	----	1650.17	3/82	----
	33898.742	696627.250	511.98	----	502.98		----
G41-J19	110780.000	2285680.000	1686.50	----	----	----	----
	33766.152	696683.688	514.05	----	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G41-K13	114755.000 34977.746	2285965.000 696770.563	1699.70 518.07	1427.70 435.17	1591.72 485.16	3/82	41 12.5
G41-K13A	114770.000 34982.316	2295955.000 696767.500	1699.90 518.14	---- ----	1592.29 485.34	3/82	---- ----
G41-K13B	114850.000 35006.703	2286070.000 696802.563	1696.80 517.19	---- ----	---- ----	3/82	---- ----
G41-K17	112155.000 34185.258	2286325.000 696880.250	1688.70 514.72	---- ----	---- ----	----	---- ----
G41-K21	109385.000 33340.949	2286215.000 696846.750	1673.70 510.15	---- ----	---- ----	----	---- ----
G41-K21A	109730.000 33446.105	2285890.000 696747.688	1680.40 512.19	1392.40 424.41	---- ----	----	---- ----
G41-K26	106260.000 32388.433	2286445.000 696916.813	1686.10 513.93	1367.10 416.70	1588.24 484.10	3/82	153 46.6
G41-L11	115895.000 35325.223	2286690.000 696991.500	1708.50 520.76	---- ----	---- ----	----	---- ----
G41-L13	114665.000 34950.313	2286795.000 697023.500	1711.50 521.67	---- ----	---- ----	----	---- ----
G41-L15	113575.000 34618.078	2286755.000 697011.313	1705.30 519.78	---- ----	---- ----	----	---- ----
G41-L19	111060.000 33851.496	2286820.000 697031.125	1686.40 514.02	---- ----	---- ----	----	---- ----
G41-L23	108275.000 33002.617	2286580.000 696958.000	1677.60 511.34	---- ----	---- ----	----	---- ----
G41-L25	106640.000 32504.264	2286975.000 697078.375	1693.70 516.25	---- ----	---- ----	----	---- ----
G41-M11	116270.000 35439.523	2287725.000 697307.000	1582.80 482.44	1426.30 434.74	1579.47 481.43	3/82	75 22.9
G41-M15	113115.000 34477.867	2287645.000 697282.625	1653.00 503.84	1416.00 431.60	---- ----	----	---- ----
G41-M24	107900.000 32888.316	2287176.000 697139.625	1653.10 503.87	---- ----	---- ----	----	---- ----
G41-N21	109170.000 33275.418	2288410.000 697515.750	1727.40 526.52	---- ----	1588.97 484.32	3/82	---- ----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
G41-P16	113755.000 34672.941	2288760.000 697622.438	1588.70 484.24	1423.70 433.95	1582.40 482.32	3/82	40 12.2
G41-P18	111645.000 34029.805	2288825.000 697642.250	1588.90 484.30	---- ----	1586.43 483.55	3/82	---- ----
G41-P18B	111390.000 33952.082	2288820.000 697640.750	1589.10 484.36	---- ----	1588.54 484.19	3/82	---- ----
G41-P24	107550.000 32781.637	2288660.000 697592.000	1682.00 512.68	1365.00 416.06	1589.16 484.38	3/82	187 57.0
G41-022	108460.000 33059.008	2289190.000 697753.500	1612.30 491.43	1303.80 397.40	1589.32 484.43	3/82	216 65.8
RR-1	124445.600 37931.477	2282308.700 695656.063	1575.00 480.07	---- ----	---- ----	----	---- ----
RR-2	124368.500 37907.977	2282299.500 695653.250	1575.00 480.07	---- ----	---- ----	----	---- ----
STS-B01	116792.100 35598.660	2278140.800 694385.687	1655.70 504.66	---- ----	---- ----	----	---- ----
STS-B02	116641.400 35552.727	2278142.900 694386.375	1652.90 503.81	---- ----	---- ----	----	---- ----
STS-B03	116580.800 35534.254	2277998.600 694342.313	1654.30 504.39	---- ----	---- ----	----	---- ----
STS-B04	116777.400 35594.180	2278021.300 694349.250	1661.20 506.34	---- ----	---- ----	----	---- ----
STS-B05	116298.300 35448.148	2277936.000 694323.250	1655.60 504.63	---- ----	---- ----	----	---- ----
STS-B06	116252.400 35434.160	2278096.700 694372.250	1649.70 502.83	---- ----	---- ----	----	---- ----
STS-B07	116252.400 35434.160	2278287.000 694430.250	1642.10 500.52	---- ----	---- ----	----	---- ----
STS-B08	116436.100 35490.152	2278096.700 694372.250	1653.00 503.84	---- ----	---- ----	----	---- ----
STS-B09	116554.200 35526.148	2278191.900 694401.312	1652.00 503.54	---- ----	---- ----	----	---- ----
STS-B10	116498.500 35509.172	2278303.400 694435.250	1647.70 502.23	---- ----	---- ----	----	---- ----

BORING NAME	COORDINATE NORTH FEET / METERS	COORDINATE EAST FEET / METERS	ELEVATION(MSL) GROUND FEET / METERS	ELEVATION(MSL) BEDROCK FEET / METERS	GROUNDWATER ELEV.(MSL) FEET / METERS	GROUNDWATER DATE	AQUIFER THICKNESS FEET / METERS
STS-B11	116514.900	2278385.500	1651.00	----	----	-----	----
	35514.168	694460.250	503.23	----	----		----
STS-LSL-1	114280.000	2278245.000	1591.91	----	1583.31	4/82	----
	34832.965	694417.438	485.22	----	482.60		----
STS-LSL-2	113575.000	2277080.000	1591.91	----	----	4/82	----
	34618.078	694062.375	485.22	----	----		----
STS-LSL-3	113510.000	2277990.000	1591.91	----	----	4/82	----
	34598.266	694339.750	485.22	----	----		----
STS-LSL-4	112345.000	2276430.000	1591.91	----	1583.69	4/82	----
	34243.168	693864.250	485.22	----	482.71		----
STS-LSL-5	111310.000	2277390.000	1591.91	----	----	4/82	----
	33927.695	694156.813	485.22	----	----		----
STS-LSL-6	110950.000	2276590.000	1591.91	----	1580.68	4/82	----
	33817.969	693913.000	485.22	----	481.80		----
TP-01	110900.000	2285500.000	1680.00	----	----	-----	----
	33802.727	696628.813	512.07	----	----		----
TP-02	116000.000	2285600.000	1715.00	----	----	-----	----
	35357.227	696659.250	522.74	----	----		----
TP-03	114200.000	2282900.000	1620.00	----	----	-----	----
	34808.578	695836.313	493.78	----	----		----
TP-04	113700.000	2275800.000	1620.00	----	----	-----	----
	34656.180	693672.188	493.78	----	----		----
TP-05	112600.000	2273700.000	1705.00	----	----	-----	----
	34320.895	693032.125	519.69	----	----		----
TP-06	111100.000	2270100.000	1625.00	----	----	-----	----
	33863.688	691934.813	495.31	----	----		----
TP-07	115980.000	2285270.000	1710.00	----	----	-----	----
	35351.129	696558.688	521.21	----	----		----
TP-08	116100.000	2285570.000	1709.00	----	----	-----	----
	35387.707	696650.125	520.91	----	----		----
TP-09	115960.000	2284920.000	1707.00	----	----	-----	----
	35345.035	696452.000	520.30	----	----		----
TP-10	116080.000	2284160.000	1695.00	----	----	-----	----
	35381.609	696220.375	516.64	----	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION (MSL) GROUND	ELEVATION (MSL) BEDROCK	GROUNDWATER ELEV. (MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
TP-11	115720.000	2283900.000	1680.00	----	----	----	----
	35271.883	696141.125	512.07	----	----		----
TP-12	115820.000	2283800.000	1695.00	----	----	----	----
	35302.363	696110.625	516.64	----	----		----
TP-13	115320.000	2283920.000	1674.00	----	----	----	----
	35149.961	696147.187	510.24	----	----		----
TP-14	114480.000	2283040.000	1635.00	----	----	----	----
	34893.925	695879.000	498.35	----	----		----
TP-15	114860.000	2282840.000	1643.00	----	----	----	----
	35009.750	695818.000	500.79	----	----		----
TP-16	115920.000	2284090.000	1681.00	----	----	----	----
	35332.844	696199.000	512.38	----	----		----
TP-17	113860.000	2282880.000	1632.00	----	----	----	----
	34704.945	695830.188	497.44	----	----		----
TP-18	113400.000	2282860.000	1647.00	----	----	----	----
	34564.738	695824.125	502.01	----	----		----
TP-19	112460.000	2283060.000	1666.00	----	----	----	----
	34278.223	695885.063	507.80	----	----		----
TP-20	112290.000	2285500.000	1704.00	----	----	----	----
	34198.973	696628.813	519.39	----	----		----
TP-21	109240.000	2288320.000	1727.00	----	----	----	----
	33296.754	697488.375	526.40	----	----		----
TP-22	107600.000	2288700.000	1682.00	----	----	----	----
	32796.875	697604.188	512.68	----	----		----
TP-41	114150.000	2284250.000	1705.00	----	----	----	----
	34793.340	696247.813	519.69	----	----		----
TW-01	116883.900	2279723.300	1601.20	----	1589.56	3/82	----
	35626.641	694868.000	488.05	----	484.50		----
TW-02	116282.500	2274923.300	1654.40	----	----	----	----
	35443.332	693404.938	504.27	----	----		----
TW-41	114130.000	2284315.000	1707.20	----	----	----	----
	34787.242	696267.625	520.36	----	----		----
WW-01	116903.200	2277828.600	1671.20	----	----	----	----
	35632.527	694290.500	509.39	----	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET	FEET	FEET	FEET	FEET		FEET
	METERS	METERS	METERS	METERS	METERS		METERS
WW-02	116442.000	2276157.400	1645.40	----	----	----	----
	35491.949	693781.188	501.52	----	----		----
WW-04	116170.970	2278391.910	1623.67	----	1584.55	4/82	----
	35409.340	694462.250	494.90	----	482.98		----
X-134	119143.700	2273092.600	1582.70	1472.00	----	----	----
	36315.438	692846.938	482.41	448.67	----		----
X-135	112800.000	2270400.000	1590.00	1498.00	----	----	----
	34381.855	692025.250	484.64	456.60	----		----
X-136	116664.100	2270059.900	1615.60	1391.00	----	----	----
	35559.648	691922.625	492.44	423.98	----		----
X-155	117093.800	2278198.100	1661.70	1552.70	----	----	----
	35690.621	694403.125	506.49	473.27	----		----
X-195/EVS	116342.000	2278974.100	1614.10	1544.10	----	----	----
	35461.469	694639.625	491.98	470.65	----		----
X-196/WVS	116743.900	2274372.100	1683.00	1523.00	----	----	----
	35583.969	693236.938	512.98	464.22	----		----
X-199	113411.500	2286407.400	1717.50	1415.00	----	----	----
	34568.242	696905.438	523.50	431.30	----		----
X-200	112752.900	2283365.300	1676.20	1402.00	----	----	----
	34367.496	695978.125	510.91	427.33	----		----
X-201	115395.500	2270437.900	1606.80	1377.00	----	----	----
	35172.973	692037.875	489.76	419.71	----		----
X-202	114083.300	2270000.300	1607.00	1345.00	----	----	----
	34773.008	691904.438	489.82	409.96	----		----
X-203	110489.200	2287173.200	1664.40	1426.00	----	----	----
	33677.516	697138.813	507.32	434.65	----		----
X-204	112717.300	2286263.600	1703.50	1434.00	----	----	----
	34356.645	696861.500	519.23	437.09	----		----
X-205	111575.200	2286710.500	1693.60	1422.00	----	----	----
	34008.531	696997.750	516.22	433.43	----		----
X-206	113751.100	2285903.900	1698.00	1393.00	----	----	----
	34671.754	696751.938	517.56	424.59	----		----
X-207	113742.100	2290047.800	1596.30	1328.00	----	----	----
	34669.012	698015.000	486.56	404.78	----		----

BORING NAME	COORDINATE NORTH	COORDINATE EAST	ELEVATION(MSL) GROUND	ELEVATION(MSL) BEDROCK	GROUNDWATER ELEV.(MSL)	GROUNDWATER DATE	AQUIFER THICKNESS
	FEET METERS	FEET METERS	FEET METERS	FEET METERS	FEET METERS		FEET METERS
X-208	114124.500	2270008.400	1607.60	1339.00	----	-----	----
	34785.598	691906.938	490.00	408.13	----		----
X-211	116837.100	2276372.800	1652.30	1474.80	----	-----	----
	35612.379	693846.750	503.63	449.52	----		----
X-213	116471.300	2278537.500	1638.40	1528.30	----	-----	----
	35500.879	694506.525	499.39	465.83	----		----
X-214	116807.600	2278244.200	1652.00	1565.00	----	-----	----
	35603.387	694417.250	503.54	477.02	----		----
X-215	116609.800	2277553.700	1677.20	1543.10	----	-----	----
	35543.094	694206.750	511.22	470.34	----		----

APPENDIX B

U.S.G.S. Well Data

APPENDIX B

U.S.G.S. WELL DATA

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-36	Unknown	1534 (467.6)	3
FR-96	Unknown	1534 (467.6)	3
FR-97	1977	1531 (466.6)	4
FR-98	"	1537 (468.5)	4
FR-99	"	1534 (467.6)	4 Next to Swamp Creek
FR-100	"	1536 (468.2)	4 Between Mole Lake and Rice Lake
FR-103	"	1534 (467.6)	4
FR-104	"	1534 (467.6)	4
FR-105	"	1535 (467.9)	4
FR-106	"	1534 (467.6)	4 Between Mole Lake and Rice Lake
FR-107	"	1536 (468.2)	4 Between Mole Lake and Rice Lake
FR-108	Unknown	1535 (467.9)	3 Between Mole Lake and Rice Lake
FR-109	1977	1535 (467.9)	4 Between Mole Lake and Rice Lake
FR-110	Unknown	1536 (468.2)	3 Between Mole Lake and Rice Lake

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-111	1977	1537 (468.5)	4 Between Mole Lake and Rice Lake
FR-112	"	1534 (467.6)	4 Next to Swamp Creek
FR-113	"	1535 (468.9)	4 Between Mole Lake and Rice Lake
FR-114	"	1534 (467.6)	4 Between Mole Lake and Rice Lake
FR-115	"	1535 (467.9)	4 Between Mole Lake and Rice Lake
FR-116	Unknown	1534 (467.6)	3 Between Mole Lake and Rice Lake
FR-117	1977	1538 (468.8)	4 Between Mole Lake and Rice Lake
FR-118	"	1538 (468.8)	4 Between Mole Lake and Rice Lake
FR-119	"	1520 (463.3)	4 Next to Swamp Creek
FR-120	"	1534 (467.6)	4 Next to Swamp Creek
FR-121	"	1538 (468.8)	4
FR-122	"	1536 (468.2)	4
FR-123	"	1537 (468.5)	4 Between Mole Lake and Rice Lake
FR-124	"	1534 (467.6)	4 Between Mole Lake and Rice Lake
FR-125	"	1537 (468.5)	4
FR-126	"	1533 (467.3)	4
FR-127	"	1537 (468.5)	4 Next to Swamp Creek

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-128	1977	1536 (468.2)	4
FR-131	"	1536 (468.2)	4 Next to Swamp Creek
FR-132	"	1542 (470.0)	4
FR-133	"	1543 (470.3)	4 Next to Mole Lake
FR-134	"	1534 (467.6)	4
FR-135	Unknown	1541 (469.7)	3 Next to Mole Lake wetland
FR-136	1977	1540 (469.4)	4
FR-138	Unknown	1551 (472.7)	3 Next to Mole Lake
FR-139	"	1552 (473.0)	3 Next to Mole Lake wetland
FR-140	"	1535 (467.9)	3
FR-142	"	1565 (473.0)	3 About 700 ft. (213 m) north of Oak Lake
FR-143	"	1575 (480.1)	3
FR-144	1977	1577 (480.7)	4
FR-145	Unknown	1580 (481.6)	3 Next to Little Sand Lake
FR-146	"	1575 (480.1)	3 Next to Little Sand Lake
FR-147	"	1577 (480.7)	3 Next to Little Sand Lake

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-148	Unknown	1583 (482.5)	3 Next to Little Sand Lake
FR-149	"	1569 (478.2)	3 Next to Little Sand Lake
FR-150	1977	1535 (467.9)	4 Next to Bishop Lake
FR-151	"	1534 (467.6)	4 Near Bishop Lake
FR-152	"	1538 (468.8)	4 Next to Bishop Lake
FR-153	"	1538 (468.8)	4 Next to Bishop Lake
FR-154	"	1542 (470.0)	4 Next to Bishop Lake
FR-156	Unknown	1549 (472.1)	3
FR-157	"	1539 (469.1)	3 Next to Bishop Lake
FR-157	1977	1554 (473.7)	4 Northeast of Rice Lake
FR-158	"	1556 (474.3)	4
FR-159	"	1594 (485.9)	4
FR-160	"	1591 (484.9)	4
FR-161	"	1599 (487.4)	4
FR-162	"	1604 (488.9)	4
FR-163	"	1603 (488.6)	4

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments	
FR-164	Unknown	1611 (491.0)	3	
FR-165	1977	1618 (493.2)	4	
FR-166	Unknown	1580 (481.6)	3	
FR-167	"	1602 (488.3)	3	
FR-168	"	1592 (485.2)	3	
FR-169	"	1640 (499.9)	3	
FR-170	"	1660 (506.0)	3	
FR-171	"	1649 (502.6)	3	
FR-172	"	1536 (468.2)	3	
FR-173	"	1575 (480.1)	3	
FR-174	"	1592 (485.2)	3	
FR-175	"	1575 (480.1)	3	
FR-176	1977	1534 (467.6)	4	Between Mole Lake and Rice Lake
FR-179	"	1545 (470.9)	4	Next to Rice Lake wetland
FR-180	"	1545 (470.9)	4	Next to Rice Lake wetland
FR-181	"	1537 (468.5)	4	

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-182	1977	1536 (468.2)	4
FR-183	"	1543 (470.3)	4
FR-185	"	1558 (474.9)	4
FR-186	Unknown	1572 (479.1)	1
FR-187	1977	1539 (469.1)	4 Next to Hoffman Pond
FR-188	"	1549 (472.1)	4
FR-189	"	1545 (470.9)	4 Next to Bishop Lake wetland
FR-190	Unknown	1548 (471.8)	3 Next to Bishop Lake wetland
FR-191	1977	1541 (469.7)	4 Next to Bishop Lake wetland
FR-194	Unknown	1541 (469.7)	3 Next to Bishop Lake
FR-195	"	1534 (467.6)	3
FR-197	"	1533 (467.3)	3
FR-198	"	1536 (468.2)	3
FR-199	"	1538 (468.8)	3
FR-200	"	1538 (468.8)	3
FR-201	"	1575 (480.1)	3

Observation Well	Meas. Date	Water Elevation Ft. (m)	Comments
FR-202	Unknown	1539 (469.1)	3
FR-203	"	1534 (467.6)	3
FR-205	"	1535 (467.9)	3 Next to Swamp Creek
FR-207	"	1534 (467.6)	3 Next to Bishop Lake
LN-478	1977-78	1538 (468.8)	2

NOTE: Data sources as listed by the U.S.G.S. are as follows:
1 - Unknown
2 - data from Dames & Moore
3 - data from Wisconsin Logs
4 - data from JRE

APPENDIX C

Miscellaneous Data Sources

EXXON MINERALS COMPANY

POST OFFICE BOX 4508 • HOUSTON, TEXAS 77210

June 22, 1982

Crandon Project - Table of
Permeabilities for the Ore Zone

Mr. Gary H. Collison, P. E.
Golder Associates
5125 Peachtree Road
Atlanta, GA 30341

Dear Gary:

Enclosed is a copy of the Summary of Slug Test Analyses from the testing work done earlier this year.

Sincerely,

Charles R. Glore, P. E. G.

CRG:jmn

Enclosure

c: J. D. Grenia
G. D. Mittelstadt
C. C. Schroeder, Crandon Project

Test Analyses

The following table summarizes the results of the tests for each type of weathering that was tested:

TABLE 1 SUMMARY OF SLUG TEST ANALYSES

Well Number	DEGREE OF WEATHERING		
	LOW	MILD	STRONG
253	4 8 $0.04/1.7 \times 10^{-8}$ (258 - 375)	13 $0.14/6.4 \times 10^{-8}$ (167 - 258)	
254	14 $0.15/7.0 \times 10^{-8}$ (315 - 435)	7.8 $0.07/3.4 \times 10^{-8}$ (217 - 315)	
255*		13 $0.35/1.7 \times 10^{-7}$ (252 - 300)	1867 $18.96/8.9 \times 10^{-6}$ (300 - 426)
256		139 $2.1/9.8 \times 10^{-7}$ (282 - 394)	290 $5.3/2.5 \times 10^{-6}$ (167 - 282)
257 (Averaged)	8.1 $0.16/7.6 \times 10^{-8}$		

* Note: Both tests in Well 255 were in strongly weathered rock. The lower zone was a strongly leached, gossain.

LEGEND

Transmissivity (gpd/ft)
Permeability gpd/ft^2/meters/sec
(Test Interval, feet)

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

April 14, 1982

786085/MA/407
F/N 402.7

Dames & Moore
1550 Northwest Highway
Park Ridge, Illinois 60068

Attention: Mr. Kenneth P. Stimpfl
Project Manager

RE: STREAM FLOWS
EXXON CRANDON PROJECT
CRANDON, WISCONSIN

Gentlemen:

The following flow values were transmitted in a phone conversation between Mr. Stimpfl and Mr. Clerici on April 13, 1982:

	Flows (cfs) for Water Year 1978		
Gage	Total	Runoff	Baseflow
SG1	70.79	26.60	44.19
SG2	38.24	13.99	24.25
SG3	33.04	7.25	25.79
SG4	11.61	4.33	7.28
SG5B	4.24	1.68	2.56
SG6	4.79	1.41	3.38
SG19	4.54	0.85	3.69
SG22	17.10	9.25	7.85
SG23	4.63	1.96	2.67
UGSG @ M	45.29	16.47	28.82
USGS @ 55	31.22	12.62	18.60

These values were obtained by Dames & Moore by integrating the hydrographs used in the Surface Water Report, and were used in the water balances presented in Table 2.4-12.

GOLDER ASSOCIATES INC • 3125 PEACHTREE ROAD ATLANTA GEORGIA 30341 U.S.A. • TELEPHONE 404/458-3686 • TELEX 700523
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Please contact us if this recap of the conversation is not correct since this data will be used in additional studies being performed.

Very truly yours,

GOLDER ASSOCIATES

Gary H. Collison

Gary H. Collison, P.E.
Associate

GHC:JFC:dap

cc: Mr. Curtis E. Fowler