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ENVIRONMENTAL IMPACT REPORT

CRANDON PROJECT

Prepared For

Wisconsin Department of Natural Resources

EXXON MINERALS COMPANY

CRANDON PROJECT

NR 182.08

REVISED

FEASIBILITY REPORT

MINE WASTE DISPOSAL FACILITY

EXXON MINERALS COMPANY

DECEMBER 1985

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1.0 INTRODUCTION

1.1 Project Background

Exxon Minerals Company (Exxon) has conducted extensive studies on the feasiblity of developing a mine/mill complex (Crandon Project) for the mining and processing of ores and disposal of waste from a zinc, copper, and lead sulfide deposit located in Forest County, Wisconsin. The ore deposit is approximately 5,000 feet long, averages 80 feet wide, and extends to a depth of 2,330 feet beneath the ground surface. The most probable estimate of the tonnage of recoverable reserves of the deposit is 67.4 million tons with average grades of 5.6, 1.0, and 0.5 percent zinc, copper, and lead, respectively. For the most probable estimate of recoverable reserves the ore deposit can sustain a 29 year mine/mill operation. For Crandon Project Mine Waste Disposal Facility (MWDF) design purposes, an approximate 15% contingency is included in the design storage volume. The 15% volume contingency would provide additional storage capacity to accommodate a potential ore reserve of 77.5 million tons with the other volume related design criteria remaining the same.

The Crandon deposit contains two major ore types: stringer and massive. The stringer ore is a combination of copper and zinc mineralization that occurs in stringers or veinlets. The massive ore is a combination of zinc, copper, and lead-bearing minerals. The stringer and massive ore types occur either in contact with or separated from each other by narrow zones of waste rock. The two ore types can generally be mined and handled separately.

An underground mine is planned with ore being hoisted to the surface and then processed in a mill. Zinc, copper, and lead concentrates would be produced at the mill and shipped elsewhere for smelting and refining. Mining, ore processing, and water treatment will generate solid wastes requiring disposal. A large portion of this solid waste will be returned as backfill to the mine. Not all mine waste can be backfilled because of the increase in volume after crushing and milling in the ore processing. Therefore, a surface facility is needed for disposal of portions of the mine waste.

Specific studies were performed for the Project to develop an NR 182 Mine Waste Disposal Facility (MWDF or facility). Residuals Management Technology, Inc. (RMT) was retained to correlate, summarize, and assemble the information with Exxon for the initial NR 182 Feasibility Report which was submitted to the Wisconsin Department of Natural Resources (DNR) in December 1982. A revised NR 182 Feasibility Report prepared by Exxon utilizing additional information prepared by a number of consultants and contractors was resubmitted to the DNR in October 1984. The additional information and other report changes in the October 1984 report specifically responded to questions and concerns raised by the DNR during their review of the initial report.

The revised NR 182 Feasibility Report in this submittal has been prepared by Exxon to reflect a reduced project size. In addition, other MWDF design refinements and information are included to respond to DNR questions, concerns, and suggestions received after the October 1984 Feasibility Report submittal.

1.2 Description of Project Facilities

The Project facilities are located 2 miles east of State Highway 55 on Sand Lake Road (see Plan Sheet 1). The east-west striking deposit occurs in Section 25, Township 35 North, Range 12 East, Nashville Township, and in Section 30, Township 35 North, Range 13 East, Lincoln Township. Physiographically, the deposit lies 0.25 mile north of Little Sand Lake and 1 mile south of Swamp Creek.

The facilities for the Project include an underground mine, a mill to process a nominal total 7,400 tons per day of ore, the waste disposal facility (MWDF or facility) described in this report, and ancillary facilities. The two types of ore in the Crandon deposit (massive, a zinc-copper-lead ore in pyrite gangue, and stringer, a copper-zinc ore in a quartz matrix) will be mined and processed separately and sequentially. The mine/mill design provides for recovery of the massive ore first (Years 1-16) followed by recovery of the stringer ore (Years 17-29). The facilities for the Project are designed based on established technology and consistent with all applicable environmental and regulatory requirements.

Plan Sheet 4 illustrates the relationship of the proposed Project facilities for the mine/mill site, MWDF and reclaim water pond, Mine Refuse Disposal Facility (MRDF), access road and railspur line. Important topographic features such as streams, lakes and roads are also illustrated.

The mine/mill surface facilities will be located in an area surrounding or adjacent to the main mine shaft and headframe. With the exception of the railroad spur and access road, the surface facilities require an area of about 201 acres. A portion of this area will be covered by buildings, roadways, parking lots, and ancillary facilities. The remaining area will either retain its natural state or if disturbed will be landscaped for erosion control and general aesthetics.

The MWDF will be located in an area approximately 1.5 miles southeast of the mine/mill site. This facility, consisting of four tailing ponds, will be designed and constructed for safe surface disposal of waste generated from mining and milling the ores. The tailing ponds will be constructed and reclaimed in stages over the operational life of the mine and will ultimately comprise about 360 acres. The reclaim water pond will be located adjacent to the north side of the MWDF and will encompass approximately 36 acres.

A Mine Refuse Disposal Facility (MRDF) requiring about 10 acres area will be located to the east of the reclaim pond and north of the MWDF. Immediately north of the MRDF a 25 acre construction support area (CSA) will be developed for liner/drain material processing and equipment maintenance for construction of the MWDF and related facilities. In addition, in the same general area and north of the MRDF and CSA a borrow area suitable for borrowing at least 0.5 M yd^3 is located (see Plan Sheet 4).

The mine/mill site and the MWDF will be connected by a 100-foot wide corridor containing the haul road and the tailing slurry and reclaim water pipelines. This corridor will be approximately 0.9 mile in length from the interface point at the eastern side of the mine/mill site to the interface point at the northwest corner of Tailings Pond T1.

The access road will connect the mine/mill site to State Highway 55 at a point about 3 miles northwest of the site. The railroad spur will connect the mine/mill site to the Soo Line Railroad at a point about 2.7 miles northeast of the site.

All facilities will be located, designed, and constructed to minimize undesirable effects on the environment, to achieve the best overall visual aesthetics consistent with the local area, and to provide a healthy and safe working environment for operating personnel.

Additional detailed descriptive information for the Project facilities is presented in Chapter 1.0 of the Crandon Project Environmental Impact Report (EIR) and Volume 1 of the Mining Permit Application.

1.3 Purpose and Scope

This report has been prepared to satisfy the Feasibility Report requirements of NR 182, Regulation of Metallic Mining Wastes, Wisconsin Administrative Code. Table 1.1 indicates where the information required by NR 182.08 can be found in this report. The scope of this report is limited to the described MWDF. Its purpose is to attain approval of the proposed site and facility design and to determine any conditions which must be included in the Plan of Operation and license issued pursuant to NR 182. The Feasibility Report is submitted in accordance with NR 182.06(1) and is consistent with NR 132 of the Wisconsin Administrative Code.

The public, affected municipalities, and the DNR have been provided information and their opinions on the proposed facility have been solicited throughout its preliminary design. This advisory process began with public hearings in Crandon and Rhinelander, Wisconsin on November 2, 1978. In October 1980, Exxon submitted to the DNR, "Volume I, Preliminary Project Description," which described the then planned Crandon Project. A second public hearing was held on January 13, 1981, which allowed the public the opportunity to comment on the preliminary plans presented by Exxon. Following submittal of the original Feasibility Report in December, 1982, Exxon has continually communicated its plans to the DNR, and solicited their opinions, advice, and guidance. The October 1984 NR 182 Feasibility Report was revised to:

1) Incorporate previous applicable material prepared for the DNR responding to MWDF related questions; MWDF Siting letter (July 11, 1983), MWDF letter (July 15, 1983), EIR letter (September 16, 1983), EIR letter (October 3, 1983), Mine Permit letter (November 11, 1983), EIR letter (February 24, 1984), and Mine Permit letter (July 24, 1984).

2) Assure conformity with the revised EIR submitted to the DNR July 24, 1984.

3) Incorporate basic design revisions to the liner and reclamation cap as proposed to the DNR in the letter dated July 11, 1984.

4) Incorporate results of other then current or on-going work responding to specific DNR concerns including:
   a. Field hydrogeological program;
   b. Reclamation cap work;
   c. Documentation work for facilities with similar leachate control systems;
   d. Additional tailings and liner testing work;
   e. Equipment and construction procedures; and
   f. Revised monitoring and contingency plans.

5) Incorporate revised hydrologic impact assessments based on then current ground water modeling work.

This revised NR 182 Feasibility Report (December 1985) has been prepared to:

1) Incorporate a size reduction to the MWDF reflecting the reduced probable ore reserves to 67.4 million tons from a previous estimate of 75.7 million tons.

2) Incorporate a size reduction to the MWDF reflecting a reduced tailings for disposal to ore ratio of 40% versus 43% and an increased tailings density of 108 pcf versus 95 pcf.

3) Incorporate a size reduction to the MWDF reflecting an estimated water treatment plant and reclaim pond sludge volume of 200 acre-feet instead of the previous allowance of 800 acre-feet.

4) Reduce the unused storage capacity of the tailings pond from 15% plus the volume in the freeboard height to an overall 13% further reducing the MWDF size.

5) Provide a 15% contingency volume allowance in final MWDF design versus a previous 12% orebody size contingency.

6) Refine the seepage control system design to reflect recent drain material permeability test results and to incorporate DNR design suggestions and other optimization.

7) Revise the reclamation cap grading plan to reduce earthwork requirements and respond to DNR concerns.

8) Include other changes resulting from the overall Project changes including:
   a. Reduced waste rock disposal quantity;
   b. Removal of benches on MWDF internal slopes;
   c. Other minor elevation adjustments to develop a balanced cut and fill condition for the downsized and reconfigured MWDF.
   d. Plan for a borrow area of 0.5 M yd^3 to provide an allowance for earthwork estimating inaccuracies or for use if required for a future MWDF revision or other Project revision.

A more complete presentation of some of these activities is presented in subsection 1.1.3 of the EIR.

TABLE 1.1

NR 182.08(2) REFERENCE LIST
CRANDON PROJECT MINE WASTE DISPOSAL FACILITY

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
NR 182.08(2)(a)	GENERAL FACILITY INFORMATION	1.4	1-21	1, 5	Exxon, 1985b
	o Project Title o Name, Address, and Phone Contact o Owner o Site Location o Proposed Licensed Acreage o Proposed Facility Life and Disposal Capacity o Estimated Waste Types and Quantities				
NR 182.08(2)(b)	WASTE CHARACTERIZATION AND ANALYSIS				BC Research, 1982; CSMRI, 1981; 1982; Exxon, 1979b; Golder, 1981a; 1981d; Hazleton, 1981; IITRI, 1984
	1. Conduct Waste Characterization and Analysis	3.0	3-1		
	2. Waste Evaluations to be Made o Quantities o Variability o Physical Properties o Radiological Properties o Chemical Properties	3.0	3-1		

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	3. Tests Required on Representative Material	3.2.1, 3.3.1	3-4, 3-13		
	a. Identification of Waste Types o Classification o Generation Rates o Volumes o Ultimate Disposition	2.0, 3.0	2-1, 3-1		
	b. Chemical, Radiological, and Mineralogic Analyses	3.2.1, 3.3.2, 3.5, 3.6	3-4, 3-17 3-33, 3-40		
	c. Particle Size Analyses	3.3.1	3-13		
	d. Chemical and Physical Testing to Address:				
	1. Acid-Producing Characteristics	3.2.3, 3.3.4	3-11, 3-28		
	o Acid-Producing Content o Size and Form of Acid-Producing Material o Distribution of Acid-Producing Particles o Neutralizing Effect of Host Material o Leachate Quality Produced by Similar Wastes				
	2. Leaching Potential and Leachate Composition	3.2.2, 3.3.3	3-9, 3-23		

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	3. Physical, Radiologic, and Chemical Properties as Required to Develop Disposal Plans	3.3.1, 3.5	3-13, 3-35		
	e. Testing Description o Methods o Chain of Custody o Justification and Rationale	See Individual References			BC Research, 1982; CSMRI, 1981; 1982; Exxon, 1979b; Golder, 1981a; 1981d; Hazleton, 1981; IITRI, 1984
	f. Prospecting Samples	Not Applicable			
	g. Discussion of Alternative Waste Management Methods, including Reuse, Sale, Recovery and Processing	4.1	4-2		Davy McKee, 1981a; 1981b
	4. Summary of Waste Characterization Related to Handling, Storage, and Disposal	4.2	4-8		
	5. Use of Characterization, Analyses, and Evaluation Information to Locate, Evaluate, and Design a Disposal Facility	4.2, 8.3, 11.0	4-8, 8-5 11-1		Exxon, 1982b
NR 182.08(2)(c)	REGIONAL INFORMATION (Up to 5 Mile Radius)				
	1. Topography	7.1	7-2	2, 4	Exxon, 1985b
	2. Hydrology	7.6	7-25	2, 4	Exxon, 1985b
	o Surface Water Drainage	7.6.1	7-25		
	o Navigable Waters	7.6.1	7-25		
	o Drainage Divides				Exxon, 1985b
	o Wetlands	7.6.1 7.6.2	7-25 7-26		Exxon, 1985b Normandeau, 1982

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	3. Geology	7.2, 7.3	7-3, 7-5	6-11	Exxon, 1985b Golder, 1981a
	4. Hydrogeology (include discussion of Wells within 1,200 Feet of Facility) o Depth to Ground Water o Flow Directions o Recharge and Discharge Areas o Ground Water Divides o Aquifers	7.5, 8.2	7-20, 8-2	6-12, 14	Exxon, 1985b Golder, 1981b STS, 1984c
	5. Water Quality and Chemistry	7.5.3, 7.6.3,	7-22, 7-27		Exxon, 1985b; DNR, 1980
	6. Climatology	7.4	7-18		Exxon, 1985b
	7. Adjacent Landowners	6.1	6-1	3	
	8. Zoning	6.2	6-2	3	
	9. Land Use o Recreational o Historical o Archaeological o Scientific o Cultural o Scenic Significance	6.3	6-4	2	Exxon, 1985b
	10. Access Roads and Weight Restrictions	NOT APPLICABLE TO MWDF			

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	11. Location Criteria (NR 182.07) o Presence of Endangered and Threatened Species o Within 1,000 Feet of Navigable River or Stream o Within Flood Plain o Within 1,000 Feet of Specified Right-of-Way o Within 1,200 Feet of Public or Private Well o Within Area of Mineable Mineralization less than 1,000 Feet of Surface o Within 200 Feet of Property Line o Within Area Determined by Department that Waste Disposal will have Detrimental Effect on Surface Water per NR 102 to NR 104 o Within Area Determined by Department that Waste Disposal will have Detrimental Effect on Ground Water (NR 182.075) o Minimize Impact on Wetlands (NR 132.06(4))	8.1, 8.2	8-1, 8-2	2	
	12. Aquatic and Terrestrial Ecosystems	5.0	5-1	2	Exxon, 1985b Normandeau, 1982

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
NR 182.08(2)(d)	SITE-SPECIFIC INFORMATION				
	1. Detailed Existing Site Conditions and Topographic Plan Sheet to include:				
	o Property Boundaries			3	
	o Proposed Facility Boundaries			5	
	o Survey Grid and North Arrow			All	
	o Buildings			5	
	o Water Supply Wells	8.2	8-2	(see Figure 7-18)	
	o Utility Lines			–	
	o Man-made Features			4,5	
	o Boring Locations			6, 13	
	o Well Locations			6, 13	
	o Other Pertinent Information			All	
	2. Rationale for Number, Location, and Depth of Soil Borings	7.3	7-5	6, 13	Exxon, 1985b Golder, 1981a; 1981d; 1982c STS, 1984c
	3. Boring Logs			7 - 11	Golder, 1981a; 1982c STS, 1984c
	o Soil and Rock Descriptions				
	o Drilling Methods				
	o Sampling Methods				
	o Sample Depths				
	o Date of Boring				
	o Water Levels and Dates				
	4. Soil Sampling and Testing	7.3	7-5	7 - 11	Exxon, 1985b Golder, 1981a; 1982c STS, 1984c
	a. Soil Classifications per Unified Soil Classification System	7.3.2	7-6		

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	b. Grain Size Distribution and Atterburg Limits	7.3.2	7-6		Exxon, 1985b Golder, 1981a; 1981d; 1982c STS, 1984c
	c. Other Tests - Physical, Chemical, Biological, as appropriate	7.3.2, 7.3.3	7-6, 7-12		
	5. Hydraulic Conductivity of Strata	7.3.2	7-6		Exxon, 1985b Golder, 1981a; 1982c STS, 1984c
	6. Observation Wells and Piezometers				Exxon, 1985b Golder, 1981a; 1982c STS, 1984c
	a. Ground Water Flow Patterns	7.5.1	7-20	12,14	
	b. Well Log Information				
	c. Well Development				
	d. Water Level Readings				
	7. Hydrogeology	7.5	7-20		Exxon, 1985b Golder, 1981a; 1982c STS, 1984c
	a. Geologic Cross-Sections o Existing Topography o Soil Borings o Soil Classifications o Soil Properties o Interpreted Soil Stratigraphy o Bedrock o Boring and Well Locations and Construction o Water Level Readings			6 - 11	

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	b. Water Table Map			14	
	c. Ground Water Flow Nets (horizontal and vertical flow)	7.5.2	7-21		
	8. Site-Specific Environmental Information to include:				
	a. Environmental Characterization	5.0	5-1		Exxon, 1985b Normandeau, 1982; Steigerwaldt, 1982
	b. Baseline Monitoring Program (conducted and data reported consistent with NR 132.05 and NR 132.11)	5.0, 7.0	5-1, 7-1		Exxon, 1985b
	c. Land Use Map			2	Exxon, 1985b Normandeau, 1982
	o Plant Communities	5.1.2	5-5	2	
	o Wildlife Habitat	5.1.2	5-5	2	
	o Rare and Endangered Species Sightings	5.3	5-16	2	
	o Archaeological/Historical Sites	6.3	6-4	2	
	o Buildings	6.3	6-4	2	
	o Areas of Social Importance	6.3	6-4	2	
	d. 12 Months of Monthly Ground Water Monitoring Prior to Operation of MWDF	9.3.5	9-46		
	e. Table of Surface Water Quality	7.6.3	7-27		Exxon, 1985b

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	f. Local Climatology	7.4	7-18		Exxon, 1985b DNR, 1980
	o Seasonal Precipitation o Evaporation o Air Temperature o Wind Velocity and Direction				
NR 182.08(2)(e)	PROPOSED FACILITY DESIGN - This section of the report shall consist of general discussion of proposed operating procedures and a proposed monitoring program, plus:				
	1. Development Map Showing:			4, 5, 15-17, 27-31	
	o Proposed Access				
	o Lateral Extent of Filling				
	o Phases of Facility Development	9.1.1, 9.3.2	9-1, 9-43		
	2. Cross-Sections Showing:			18 - 21	
	o Present Topography				
	o Proposed Base Grades			15	
	o Final Grades	9.1.4	9-20	17	
	3. Earthwork Balance Calculations	9.2.3, 9.2.4	9-27, 9-29	5	
	4. Leachate Control Methods	9.1.3	9-12		Golder, 1982a; 1982b Exxon, 1985a
	5. Operating Procedures Including:	9.3,	9-43		
	o Method of Site Development	9.2.4	9-29		
	o Phasing	9.1.1	9-1		
	o Surface Water Control	9.1.5, 10.1	9-21, 10-1		
	o Screening	8.3	8-5		
	o Access Control			4	Exxon, 1985b
	o Specific Design Features	8.3	8-5		

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
	6. Waste Material Balances to Include:	2.2, 2.4, 9.1.1, 9.1.2	2-2, 2-4, 9-1, 9-8	5, 27-31	
	a. Projected Conditions - End of Typical Year				
	b. Projected Conditions - Before and After Significant Change				
	c. Projected Conditions - End of Operations				
	d. Projected Conditions - End of Reclaiming				
	7. Design Reasoning and Logic for:	4.2, 8.3, 11.0	4-8, 8-5, 11-1		Golder, 1980; 1981c; 1982a
	o Traffic Routing				
	o Base Grades				
	o Waste Characterization Phasing				
	o Liner Design				
	o Monitoring	9.3.5	9-46		
	o Other Design Features				
	8. Monitoring Program	9.3.5	9-46	32-35	Monitoring and Quality Assurance Plan
	9. Prediction of Ground Water Quality Changes Beyond Outer Perimeter of Waste Site (include specific assessment of any adverse environmental impacts expected)	10.2	10-6		D'Appolonia, 1985
	10. Evaluation of Effectiveness of Existing Site Design and Operation (applies to expansions of existing facilities only)	Not Applicable.			

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRAPHY)
NR 182.08(2)(f)	WATER BUDGET - Use Wet, Dry, and Average Precipitation for Following Time Periods: o Before Construction o During Active Operation o After Facility Closure	9.5	9-72		D'Appolonia, 1985; Ayres Associates, 1984, 1985
NR 182.08(2)(g)	AESTHETICS OF SITE o Analysis of Impact o Mitigative Measures	9.3.4	9-45		
NR 182.08(2)(h)	DAM SAFETY 1. Geology of Site Foundation - Type and Homogeneity 2. Embankment Construction - Materials and Methods 3. Engineering Modifications 4. Waste Characterization as Deposited and Through Time 5. Endangerment to Human Safety 6. Potential Area Affected in Case of Failure 7. Compliance with Requirements of MSHA	9.2.2	9-24		Golder, 1982d

Table 1.1 (continued)

NR 182 CODE REFERENCE	SUMMARY OF CODE REQUIREMENTS	SECTION(S)	PAGE(S)	PLAN SHEETS	AUXILIARY REFERENCES (SEE BIBLIOGRPAPHY)
NR 182.08(2)(i)	CONTINGENCY PLAN	9.3.6	9-53		Contingency Plan
NR 182.08(2)(j)	CLOSURE AND LONG-TERM CARE - The section of the report shall include an economic analysis, including engineer's cost esimate for site closure and long-term care (may be provided by reference to reclamation plan submitted pursuant to s. 144.85(3)(b) Stats., and NR 132.08)	9.4	9-62		Ayres Associates, 1984, 1985
NR 182.08(2)(k)	ALTERNATIVE DESIGN, LOCATION, AND OPERATION	11.0	11-1		Dames & Moore, 1979 Exxon, 1985b Golder, 1979; 1980
	1. Design and location alternatives shall be evaluated including economic analysis of each site (that is both environmentally and economically feasible). Operation should be discussed to the extent of its effect on location and design alternatives.				
	2. The site selection process shall allow a legitimate comparison among various sites, all of which may have some imperfections. The best site shall be chosen and must have the least total overall adverse enviromental impact.				Exxon, 1985b
	3. All data on alternative sites and designs studied shall be submitted.				Exxon, 1985b
NR 182.08(2)(1)	APPENDIX				
	1. Boring Logs, Soil Test Data, Well Construction Data, and Water Level Measurements				See Auxiliary References as cited.
	2. Methods and Equations Used				
	3. References				

1.4 General Facility Information

The general facility information required by NR 182.08(2) is presented below:

Project Title - Crandon Project
Feasibility Report
Mine Waste Disposal Facility
NR 182 Regulation of Metallic Mining Wastes
Exxon Minerals Company

Primary Contact - Permitting Manager
Exxon Minerals Company, a division of Exxon Corporation
P. O. Box 813
Rhinelander, WI 54501

Telephone: (715) 369-2800

Owner - Exxon Corporation; c/o Exxon Minerals Company, a division of Exxon Corporation, having an address at: P.O. Box 813, Rhinelander, Wisconsin 54501, with corporate responsibility for the MWDF

Location - Parts of Sections 32 and 33, Township 35N, Range 13E, Town of Lincoln, Forest County

Proposed Licensed Acreage - 360 acres

License Period - 36 years

Disposal Capacity - 21.6 million cubic yards. The facility is being designed for disposal of wastes from a 67.4 million ton ore deposit, representing the probable ore reserves, plus a 15% volume contingency.

Waste Types and Quantities to be Disposed at Facility - A brief description and estimated quantities of the wastes are presented below.

Mine Waste   Waste Rock - rock materials less than 24 inches and 8 inches in diameter during mine development and production, respectively. Where possible, the rock will remain underground for backfill or roads. Otherwise, it will be hauled to the facility and used as embankment slope protection.

Tailing Fines - produced in milling the ore and consist of rock particles smaller than sand, 30 um (0.0012 inch) or less (Note: In this report, um means micrometer; normally the symbol is μ). These tailings will be transported to the MWDF as a slurry. The solids will settle in the MWDF and the water will be decanted to a water reclaim pond for reuse.

Unclassified Tailings - a combination of sands and tailing fines produced when no separation of materials for backfill is performed during operations.

Water Treatment Facilities Waste

Water Treatment Plant Sludge - generated from the various processes used in treating the water at the mill. These solids will be disposed in the MWDF with the tailings.

Reclaim Pond Sludge - fine sediments and precipitates that settle in the reclaim pond from water returned from the MWDF. This sludge will collect in the reclaim pond throughout operation and be disposed in the MWDF when mining ceases.

Water Treatment Plant By-Product Sodium Sulfate - from brine crystallization. Disposal provision will be provided for in each tailings pond. It is expected, however, that this by-product will be marketable to paper companies and no disposal will be necessary on-site.

The types and estimated quantities of waste to be disposed at the MWDF are:

Waste Type	Total Quantities (tons x 10^3)	Total Quantities (cubic yards x 10^3)
Waste Rock[1]	353	235
Tailing Fines[2]	26,970	18,500
Unclassified Tailings[3]	414	284
Water Treatment Plant Sludge and Reclaim Pond Sludge[4]	270	424
By-Product Sodium Sulfate (may be saleable)	120	105
Totals	27,360	19,029

[1]Not included in design volume estimate. Waste rock is utilized in the MWDF as embankment slope protection.
[2]Based on probable ore reserve of 67.4 million tons.
[3]Included in Tailing Fines volume estimate.
[4]Reclaim pond sludge (89 x 10^3 tons or 140 x 10^3 yd^3) is disposed of in the MWDF at Project reclamation.

2.0 CRANDON PROJECT DESCRIPTION

2.1 Location

The ore deposit is located in the Northern Highlands of northeastern Wisconsin. Crandon, the county seat of Forest County, is 5 miles north of the Crandon Project site[1] area. Other communities in the region include Rhinelander, 28 miles west; Antigo, 45 miles south; and Iron Mountain and Iron River, Michigan, 75 miles and 44 miles east and north of Crandon, respectively (Figure 2-1). The Crandon Project site area is 2 miles east of State Highway 55 on Sand Lake Road.

The ore deposit is located in Section 25, Township 35N, Range 12E, Town of Nashville, and in Section 30, Township 35N, Range 13E, Town of Lincoln. The ore deposit lies 0.25 mile north of Little Sand Lake and 1 mile south of Swamp Creek.

In this report, the following terms are used to describe specific geographical areas relative to the Crandon Project:

<u>Site Area</u>	- Area within 2 miles of the ore deposit. The ore deposit and proposed mine/mill site and MWDF are within this area.
<u>Environmental Study Area</u>	- Area within 5 miles of the ore deposit.
<u>Regional Study Area</u>	- Area within 25 miles of the ore deposit.

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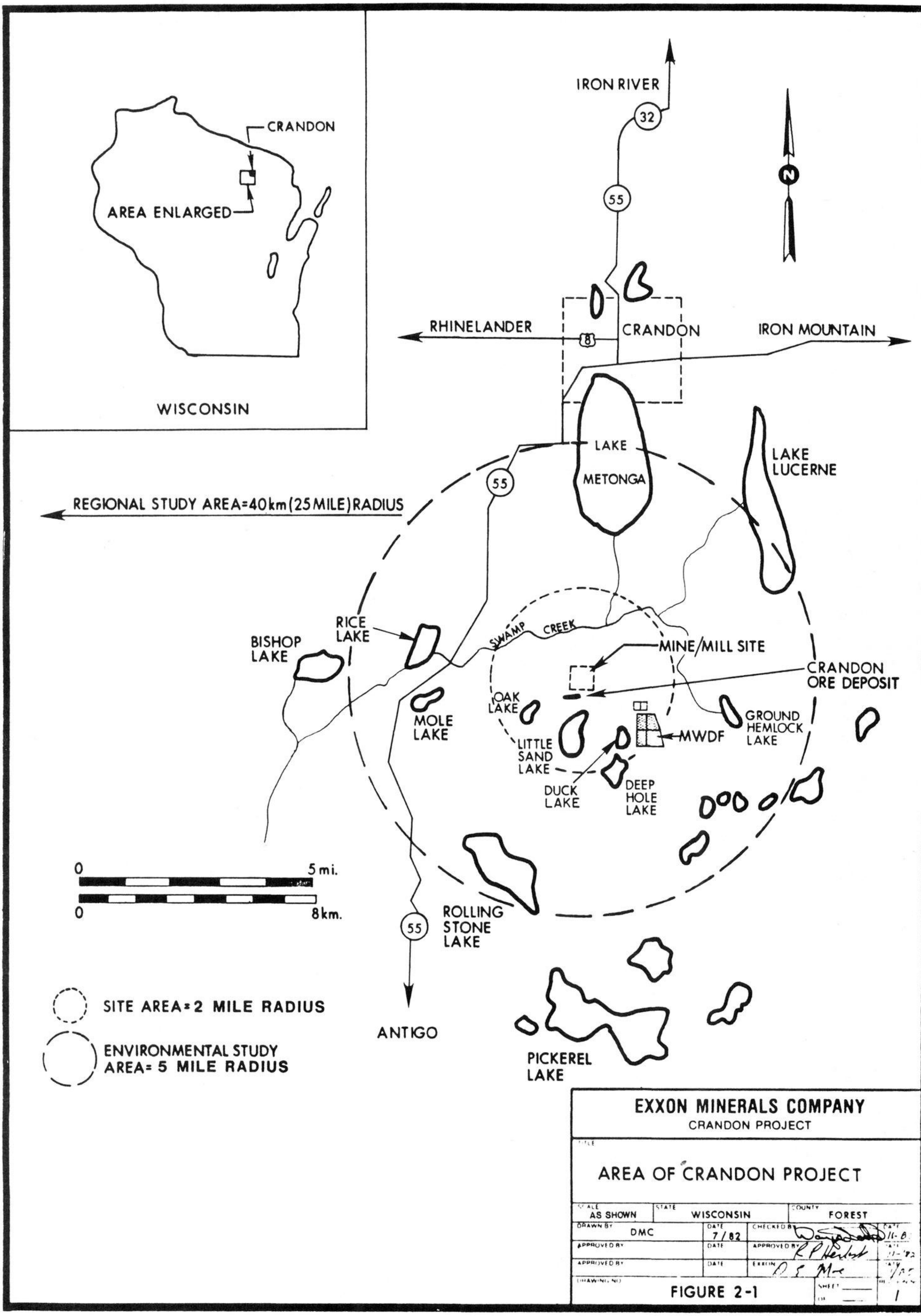
1. Not necessarily mining site as defined in W. S. 144.81.


CRANDON
AREA ENLARGED
WISCONSIN
IRON RIVER
32
55
N
RHINELANDER
8
CRANDON
IRON MOUNTAIN
LAKE
METONGA
LAKE
LUCERNE
55
REGIONAL STUDY AREA=40km (25 MILE) RADIUS
RICE
LAKE
BISHOP
LAKE
SWAMP
CREEK
MINE/MILL SITE
CRANDON
ORE DEPOSIT
OAK
LAKE
MOLE
LAKE
LITTLE
SAND
LAKE
MWDF
GROUND
HEMLOCK
LAKE
DUCK
LAKE
DEEP
HOLE
LAKE
0
5 mi.
0
8 km.
ROLLING
STONE
LAKE
55
ANTIGO
SITE AREA = 2 MILE RADIUS
ENVIRONMENTAL STUDY
AREA = 5 MILE RADIUS
PICKEREL
LAKE
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
AREA OF CRANDON PROJECT
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DMC
DATE 7/82
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APPROVED BY
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DATE
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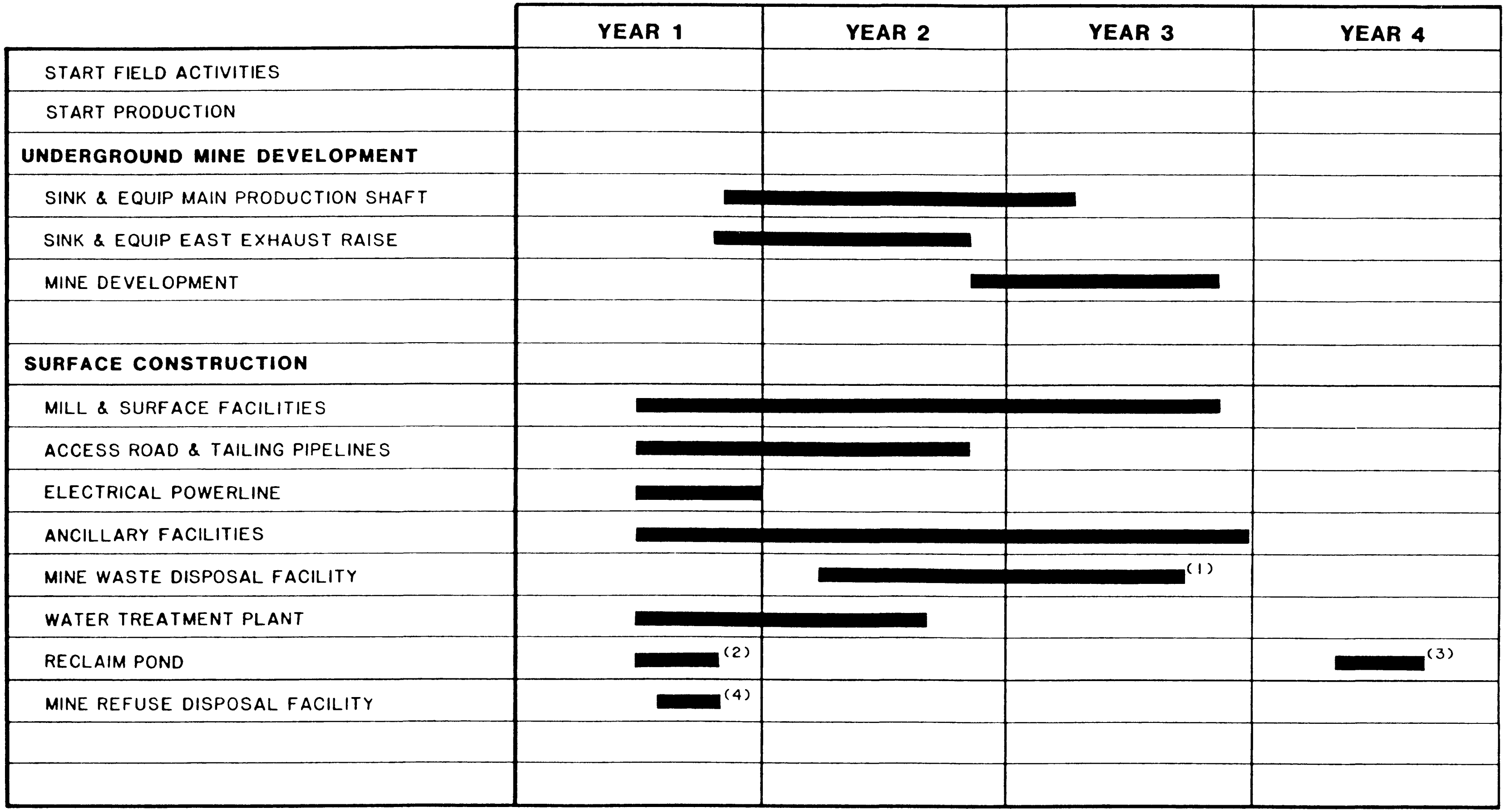
DRAWING NO.
FIGURE 2-1
SHEET
OF
1

2.2 Production Rates and Schedule

Allowing for full production of the design orebody reserve of 67.4 million tons, an approximate 29 year mine operation is estimated from an annual production rate between 2.1-2.6 million tons. Ore will be mined underground and hoisted to the surface at a rate of approximately 6,100-7,800 tons per day, on a 3 shift per day, 7 days per week basis. The ore will be processed in the mill at an average rate of 5,700-7,400 tons per day and operate on a 3 shift per day, 7 days per week basis. Zinc, copper, and lead concentrates will be produced at the mill and shipped elsewhere for smelting and refining. The range of rates for mine and mill operations reflect the different operating rates for the two ore types. The massive ore mined in Years 1-16 will be processed at the higher operating rate and the stringer ore at the lower rate in Years 17-29.

The Project will require approximately 3 years for development and initial production of concentrates. A condensed construction schedule for this time period of the proposed Project is presented in Figure 2-2.



1. TAILINGS POND T I
2. CELL A
3. CELL B
4. CELL I

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PROPOSED CONSTRUCTION SCHEDULE

SCALE NONE	STATE WISCONSIN	COUNTY FOREST

DRAWN BY DR SPRINGBORN	DATE 12-85	CHECKED BY R P Herbst	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C C Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON	DATE

DRAWING NO FIGURE 2-2	SHEET ____ OF ____	REVISION NO 3

2.3 Concentrating

The first stage of crushing the mined rock to minus 8 inches will be completed underground. The ore will be hoisted to the surface and stored temporarily in the coarse ore storage building. The ore will then be transferred to the mill for grinding and recovery of zinc, copper, and lead minerals in the concentrator. Zinc, copper and lead sulfide mineral particles will be separated from waste minerals in the ore slurry using a process known as selective flotation.

2.4 Waste Generation

Wastes generated during the mining, milling, and concentrating, and water treatment processes are the following:

1) Waste rock;
2) Backfill sands;
3) Tailing fines;
4) Unclassified tailings;
5) Water treatment plant sludge and by-product sodium sulfate; and
6) Reclaim pond sludge.

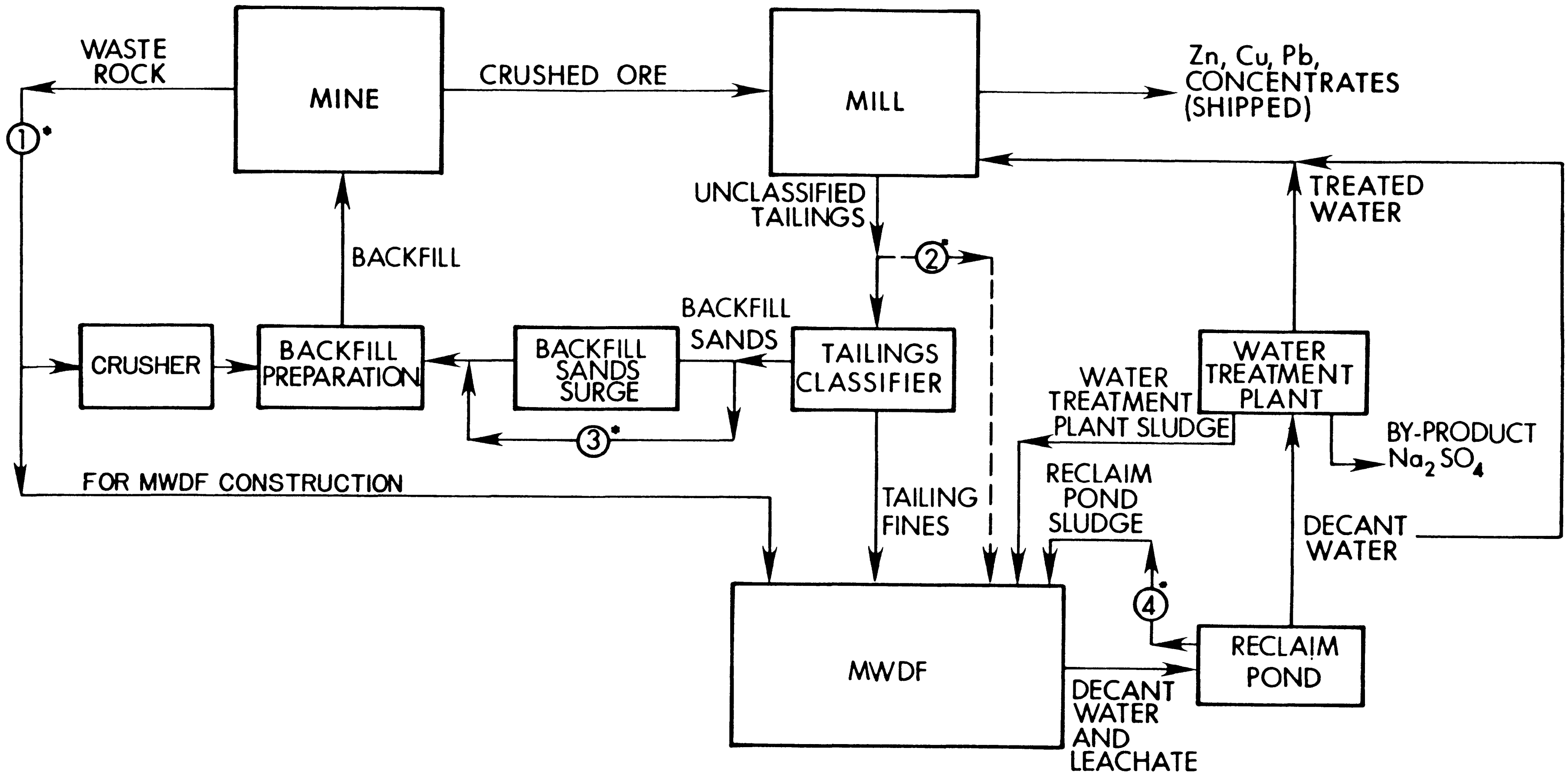
A generalized block diagram showing waste generation is presented in Figure 2-3, and a description of the waste materials is provided in the following subsections.

2.4.1 Waste Rock

Ore and waste rock excavated in the mine during mine development will be approximately 24 inches in diameter. Once the underground crusher is operational, all rock hoisted to the surface (ore and waste rock) will be crushed to 8 inches. Some waste rock will remain underground to fill previously mined areas and for use in road building; otherwise, it will be hoisted to the surface for use as slope protection at the MWDF or crushed and reintroduced into the mine for backfill.

2.4.2 Backfill Sands

After the zinc, copper, and lead concentrates are recovered in the concentrator, a cyclone classification, or a similar process, will be used to separate the tailings generated in the concentrator into coarse and fine fractions. The separation will be in the 20-30 um particle size range. The coarser material (backfill sands) will be pumped to the backfill preparation



NOTES*

1. Waste rock will be used in the mine as much as possible for backfilling or underground road construction. Otherwise it will be hoisted to the surface and used for slope protection in construction of the MWDF.

2. Minor amounts of unclassified tailings may be disposed in the MWDF in initial production years.

3. Temporary sand storage area in the backfill preparation facility. No outside storage will be required.

4. At pond reclamation.

Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
SIMPLIFIED DIAGRAM OF WASTE AND PRODUCT GENERATION

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY LCG	DATE 07/26/82	CHECKED BY	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON	DATE
DRAWING NO FIGURE 2-3		SHEET ___ OF ___	REVISION NO. 2

plant. The backfill sands will be pumped underground for deposition in mined areas (stopes). Limited surge storage of cycloned sands will be provided in Marconaflo storage tanks with sufficient capacity for the storage of approximately 18,000 tons of cycloned tailing sands.

2.4.3 Tailing Fines

Tailing fines will consist of the finer fraction particles after the backfill sands have been separated from the total concentrator tailings. The tailing fines will be pumped to the MWDF in a slurry of approximately 55 percent solids by weight. At the facility, the solids will settle and the pooled water on the surface will be decanted to the reclaim pond.

During normal operation of the mill, tailings will be separated into backfill and fines; the tailing fines will be disposed at the MWDF, and the backfill sands will be returned to the mine.

2.4.4 Unclassified Tailings

The current mining plan requires the use of backfill sands when mill production starts. If, for some reason, backfill cannot be accepted underground, and surface storage is full, the entire concentrator tailings (unclassified tailings) would be pumped to the MWDF. The unclassified tailings will be composed of fines and sand size particles.

2.4.5 Water Treatment Sludges and By-Product Sodium Sulfate

Two sludges will be produced from the operation of the Project water treatment plant.

One sludge will be largely composed of calcium carbonate and minor amounts of fine particle precipitates (i.e., hydroxides and sulfides). The other will be a sodium sulfate by-product. It may be marketable to Kraft paper mills and possibly to other users of sodium sulfate. Any unmarketable sodium sulfate will be impounded in an isolated area in each tailings pond.

Sludge that accumulates in the reclaim pond will consist of fine sediments and precipitates that settle from the water. They will ultimately be disposed in the MWDF at the completion of Project operations. The reclaim ponds will be drained and the sludge transported to the MWDF by pumping or in trucks.

3.0 WASTE CHARACTERIZATION AND ANALYSIS

This section presents the results of characterization studies performed on the Project wastes to be disposed at the MWDF. Extensive study has been completed on the wastes to fulfill the requirements of NR 182 and to provide estimates of the physical, chemical, and mineralogical characteristics of the wastes, the quantities of waste that will be generated, and the potential environmental effect of disposing of the wastes, either as mine backfill or in the MWDF.

In addition to meeting DNR regulatory submittal requirements, data on physical and chemical characteristics of the waste were used to establish design and operational requirements for the MWDF. Items assessed also included leaching and radiological properties and potential air emissions.

Leaching potential of the waste was evaluated from laboratory tests. Laboratory permeability tests were conducted on tailing samples to quantitatively assess leachate generation rate potential. Tailings permeability and leaching characteristics, soil permeability and attenuation characteristics, and hydrogeological information were considered in establishing design and operational concepts for the MWDF.

All testing was conducted on samples considered to be representative of the wastes to be disposed in the MWDF, however, actual characteristics may vary some from those measured.

This chapter provides a summary of the pertinent data and major conclusions. Sources are referenced where applicable. For additional information on data gathered, methodology, procedures, quality control, and chain of custody records, refer directly to these sources.

3.1 Waste Quantities

The present estimate of mine recoverable reserves for the Crandon ore deposit is 67.4 million tons. The MWDF design capacity includes a 15 percent contingency to this ore deposit size estimate. The design estimated total quantities of ore and waste generated annually will vary. Total wastes for the Project are provided in Table 3.1.

TABLE 3.1

ESTIMATED TOTAL WASTE QUANTITIES REQUIRING DISPOSAL AT THE PROJECT SITE

Waste Type	Approximate Total Quantities
Waste Rock[1]	4,690,000 cubic yards
Backfill Sands[2]	31,200,000 tons
Tailing Fines	27,000,000 tons
Water Treatment Plant Sludge[3]	284,000 cubic yards
Reclaim Pond Sludge[4]	140,000 cubic yards

[1] 235,000 cubic yards are used for slope protection in the MWDF. Remaining volume is reused in the mine directly or crushed and used as backfill.

[2] For disposal in the mine.

[3] Provision for disposal of 105,000 cubic yards of by-product sodium sulfate is also provided in the MWDF design.

[4] Disposed of in the MWDF at Project reclamation.

3.2 Waste Rock Characteristics

3.2.1 Chemical/Mineralogical Properties

Chemical and mineralogical analyses of samples from drill core borings were conducted on waste rock samples ranging in sulfur content from less than 1 to 4.3 percent. A complete description of the sample preparation is provided in Appendix 14 of BC Research (1982). These samples were typical of the waste rock that will be generated during mining. These samples included the following:

Sample Number	Description
100	Composite drill core sample, east end footwall rock above 1,155 foot level.
101	Composite drill core sample, east end footwall rock below 1,155 foot level.
102	Composite drill core sample, west end footwall rock above 1,155 foot level.
103	Composite drill core sample, west end hanging wall rock above and below 1,155 foot level blended to <0.5% S.
104	Composite drill core sample, west end hanging wall rock above and below 1,155 foot level blended to >1% S.

The chemical analyses for samples 100-104 are presented in Table 3.2 (see BC Research, 1982 Appendix 3 for parameter analysis methodology). A summary of the data indicating mineralogical composition of the fragments from these samples is presented in Table 3.3. The fragments were separated on their mineralogical composition and were distinguished by assigning a suffix

TABLE 3.2

ASSAYS OF COMPOSITE SAMPLES COLLECTED FROM DRILL CORES OF THE CRANDON ORE DEPOSIT[a]
(All Values as Percent Unless Otherwise Indicated)

ELEMENT	SAMPLE NUMBER 100	101	102	103	104
Ag	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Al (as Al_2O_3)	14.06	11.15	8.90	12.70	12.76
As	< 0.005	< 0.005	0.032	< 0.005	< 0.005
Ba	0.031	0.037	0.011	0.032	0.045
CO_3	0.25	0.55	0.15	< 0.01	0.05
Ca (as CaO)	0.22	0.14	0.058	0.16	0.057
Cd	< 0.002	0.003	0.003	< 0.002	< 0.002
Cl	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Cr	0.018	0.02	0.02	0.01	0.01
Cu	0.051	0.15	0.25	0.036	0.02
F	0.11	0.10	0.12	0.09	0.07
Fe (as Fe_2O_3)	11.46	11.54	12.35	10.66	10.22
Hg (ug/g)[b]	0.63	0.71	0.21	0.02	0.33
K (as K_2O)	2.06	1.93	0.92	1.99	2.08
Mg (as MgO)	4.08	3.98	5.43	5.15	4.08
Mn	0.107	0.087	0.058	0.10	0.037
Na (as Na_2O)	0.75	0.32	0.29	0.37	0.62
Pb	0.060	0.076	0.065	0.054	0.066
S	4.29	3.68	2.62	0.35	2.98
Se (ug/g)[b]	21.7	18.3	21.5	4.0	6.8
Si (as SiO_2)	59.6	63.97	65.07	61.42	62.45
Ti (as TiO_2)	0.907	0.67	0.59	0.92	0.81
V	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Zn	0.10	0.14	0.36	0.052	0.025
H_2O (180°C)	0.113	0.074	0.136	0.097	0.126
*U (ug/g)[b]	1.40	5.00	1.33	1.17	3.64
*Th (ug/g)[b]	4	4	4	3	5
*Ra (pCi/g)[c]	5	2	1	1	1
TOTAL (%)	98.19	98.44	97.39	94.52	96.83

[a]BC Research, 1982

[b]microgram/gram

[c]picocurie/gram

*See Table 3.16 for a more typical analysis of uranium, radium and thorium in the waste rock, massive ore, and stringer ore from composited Crandon orebody samples and granite outcrop and soil.

TABLE 3.3

MINERALOGICAL ANALYSIS (VOLUME PERCENT) OF COMPOSITE SAMPLES OBTAINED FROM DRILL CORES IN THE CRANDON DEPOSIT*

SUBSAMPLE	MINERALOGICAL COMPOSITION (%) Sulfide		Non-sulfide	
100A	Pyrite	3-4	Quartz	55-62
			Sericite	25-30
			Dacite Flow	1-2
			Ti-oxide	0.5-1
			Chlorite	0.3
100B	Pyrite	20-25	Chlorite	50-55
			Quartz	20-25
			Sericite	0.5
			Calcite	0.3
			Ti-oxide	minor
100C	Pyrite	3-5	Sericite	40-45
			Dacite Flow	25-30
			Quartz	17-23
			Carbonate	5-7
			Apatite	0.5-1
			Chlorite	0.3
			Ti-oxide	0.5
101A	Pyrite	0.3	Quartz	35-43
	Chalcopyrite	trace	Plagioclase	30-37
	Sphalerite	trace	Sericite	12-15
			Chlorite	4-5
			Ti-oxide	minor
			Calcite	1.5-2
101B	Pyrite	12-15	Calcite	40-45
	Sphalerite	2-3	Sericite	20-25
	Galena	0.2	Chlorite	10-12
	Tetrahedrite	trace	Quartz	4-5
101C	Pyrite	minor	Plagioclase	70-75
	Sphalerite	trace	Sericite	12-15
			Quartz	5-7
			Calcite	6-8
			Ti-oxide	0.3

TABLE 3.3
(continued)

SUBSAMPLE	MINERALOGICAL COMPOSITION (%)			
	Sulfide		Non-sulfide	
102A	Pyrite	3-4	Plagioclase-Quartz	65-70
	Galena	trace	Chlorite	19-25
			Quartz	3-4
			Apatite	minor
			Ti-oxide	0.3
			Plagioclase	1.5-2
102B	Pyrite	10-12	Plagioclase	35-40
	Sphalerite	2-3	Quartz	25-32
	Chalcopyrite	3-4	Chlorite	11-13
	Pyrrhotite	trace	Sericite	3-5
			Tri-oxide	minor
			Hematite	0.2
			Apatite	trace
102C	Pyrite	1-1.5	Plagioclase	65-70
	Sphalerite	trace	Chlorite	10-12
			Quartz	10-14
			Sericite	5-7
			Ti-oxide	1-1.5
			Calcite	minor
			Chlorite	minor
103A	Pyrite	3-4	Quartz-Plagioclase	35-40
	Chaclopyrite-Bornite	0.5-1	Sericite	25-30
			Quartz	15-17
			Chlorite	6-8
			Dacite	5-7
			Ti-oxide	1-2
			Cherty Quartz	1-1.5
			Apatite	minor
103B	Pyrite	trace	Plagioclase	50-55
	Chalcopyrite	trace	Chlorite	22-30
	Bornite	trace	Quartz	8-12
			Sericite	5-7
			Cherty Quartz	3-5
			Ti-oxide	1-1.5

TABLE 3.3
(continued)

SUBSAMPLE	MINERALOGICAL COMPOSITION (%)			
	Sulfide		Non-sulfide	
104A			Sericite	45-50
			Quartz	37-43
			Hematite	7-10
			Ti-oxide	1-1.5
104B	Pyrite	1-2	Plagioclase	60-65
	Chalcopyrite	trace	Quartz	12-15
			Sericite	17-20
			Ti-oxide	0.5-1
			apatite	0.5-1
			Chlorite	0.5
104C	Rock similar to 104B			
104D	Pyrite	0.3	Sericite	58-64
			Quartz	20-26
			Chlorite	5-7
			Ti-oxide	2-3

*BC Research, 1982

letter (i.e. 101A, 101B). Results of the detailed mineralogical examination of each of the five samples are presented in Appendix 5 of BC Research (1982).

The results show that individual rock fragments within the samples vary considerably in their mineralogy, with respect both to their sulfide and non-sulfide contents. For example, subsample 100A is predominantly quartz-sericite, with only minor sulfide content (3 to 4 percent). In comparison, subsample 100B contained 20 to 25 percent pyrite in a predominantly chlorite-quartz assemblage. Similar variations are apparent from analysis of rock fragments within the other sample groups. These samples also indicate the total absence of the highly reactive mineral, pyrrhotite.

Preliminary studies were done on some waste rock samples with sulfur contents ranging from less than 1 to 16 percent; chemical analyses of these samples are reported in Table 5 of the report by BC Research (1982).

3.2.2 Leaching Properties

Leaching tests were also completed on the waste rock from the five drill core composite samples. These leaching tests were conducted as specified by the United States Environmental Protection Agency (U.S. EPA) for characterizing wastes under the Resource Conservation and Recovery Act (40 CFR 261.24). Before leaching, composite samples were pulverized to -1/4 inch. The results of the leaching tests are summarized in Table 3.4. These results show no measurable concentration of the eight metals analyzed after extraction (BC Research, 1982).

TABLE 3.4

RESULTS OF THE U.S. EPA EXTRACTION PROCEDURE TESTS CONDUCTED ON WASTE ROCK SAMPLES[a]

ELEMENT	SAMPLE NUMBER[b]					U.S. EPA HAZARDOUS WASTE LIMIT
	100	101	102	103	104	
Arsenic (As)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	5.0
Barium (Ba)	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	100.0
Cadmium (Cd)	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	1.0
Chromium (Cr)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	5.0
Lead (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	5.0
Mercury (Hg)	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.2
Selenium (Se)	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	1.0
Silver (Ag)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	5.0

[a]BC Research, 1982

[b]NOTE: 3000 ml (0.793 gallons) solution obtained from leaching 150 g (5.29 ounces) of sample. All results expressed in milligrams per liter (ppm).

3.2.3 Acid Generation Potential

Acid generation potential tests were conducted on waste rock samples from the five drill core collections. Titration tests and biological confirmation tests were also performed. Details of the methodology and results are presented in BC Research (1982). The results of the chemical titration phase showed that all samples except Sample 103 had acid generation potential. However, in column tests on minus 1.5 inch sample material, only Sample 104 was a confirmed acid producer.

All samples were submitted to the biological Thiobacillus ferrooxidans (bacterial innoculation) confirmation tests which had positive results for the acid-producing potential of Samples 100, 101, 102, and 104; Sample 103 was non-acid producing. The pH values (1.6 - 1.9) at the end of the leaching tests for Samples 100, 101, 102, and 104 indicate that waste rock could potentially produce acidic effluents.

After completion of the confirmation tests, the contents of each duplicate shake flask were filtered and distilled water was added until sample volume was 0.026 gallons. The solutions were analyzed for the same parameters as in U.S. EPA leaching tests. The results of these analyses are shown in Table 3.5.

The data in Table 3.5 show that when waste rock samples are subjected to microbiological activity, metal concentrations in the resulting test leachates are higher, except for barium (see Table 3.4), than the sample solutions produced from the U.S. EPA leaching test alone. This may be a result of the lower pH conditions in the biological confirmation tests or the dissolution of metals from sulfide minerals oxidation by the organisms, or both.

TABLE 3.5

ANALYSES OF BIOLOGICAL CONFIRMATION
TEST LEACHATES CONDUCTED ON WASTE ROCK SAMPLES
FROM THE DRILL CORES IN THE DEPOSIT[a]

ELEMENT	SAMPLE NUMBER 100	101	102	103	104
As (mg/l)[b]	5.6	5.2	20.2	0.02	3.2
Ba	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cd	1.34	1.88	4.40	0.21	0.21
Cr (total)	8.2	10.3	10.0	< 0.1	9.9
Pb	1.00	0.87	1.02	0.37	0.81
Hg (ug/l)[c]	0.63	2.6	< 0.5	< 0.5	1.33
Se	0.8	0.4	0.6	0.1	< 0.1
Ag	0.1	< 0.1	< 0.1	< 0.1	< 0.1

[a]BC Research, 1982

[b]Milligrams per liter (ppm)

[c]Micrograms per liter (ppb)

3.3 Tailings Characteristics

3.3.1 Physical Properties

Grain Size and Specific Gravity - Three tailing samples (i.e., tailing fines - massive ore; tailings fines - massive/stringer ore; and unclassified tailings - massive ore) produced in the pilot-scale metallurgical testing at Lakefield Research of Canada Ltd., Lakefield, Ontario, Canada were tested for their physical and chemical properties by the Colorado School of Mines Research Institute (CSMRI, 1982). The massive ore tailing fines sample is typical of the waste material that will be generated when processing massive Crandon ores alone. Also, since the mine plan involves mining massive ore followed by stringer ore, some of the tailings ponds may contain a mixture of massive and stringer ore tailings.

Size analyses data of the tailing samples are shown in Table 3.6. These data indicate that approximately 90 and 85 percent of the tailing fines and unclassified tailings, respectively, disposed in the facility will be minus 0.0012 inch in size (CSMRI, 1982).

Grain size distribution analyses of a sample of tailing fines are shown on Figure 3-1 (Golder, 1981a). The grain size distribution curve shows the particles are 82 percent silt size with the remaining 18 percent clay size. No sand-size particles were present.

Because the tailing fines are ground rock and not weathered materials, the clay size particles are mostly angular pieces and not typically plate-shaped clay particles. Atterburg limit tests show these materials to be nonplastic.

Specific gravity test results by Golder Associates (1981a) are presented in Table 3.7. These data showed that the specific gravity of the tailing fines was about 3.2 for massive/stringer mixtures. Table 3.9 indicates that the specific gravity of tailings fines from massive ore only will be about 3.8.

TABLE 3.6

GRAIN SIZE ANALYSES OF TAILING SAMPLES[a]

Tailings Fines (Massive Ore)

Mesh Size in um[b]	Wt % Retained Each Size	Cumulative Percent Passing
34.5	10.4	89.6
26.8	9.0	80.6
18.7	16.3	64.3
12.8	15.7	48.6
9.9	10.0	38.6
- 9.9	38.6	--
	100.0	

Tailings Fines (Massive/Stringer Ore)

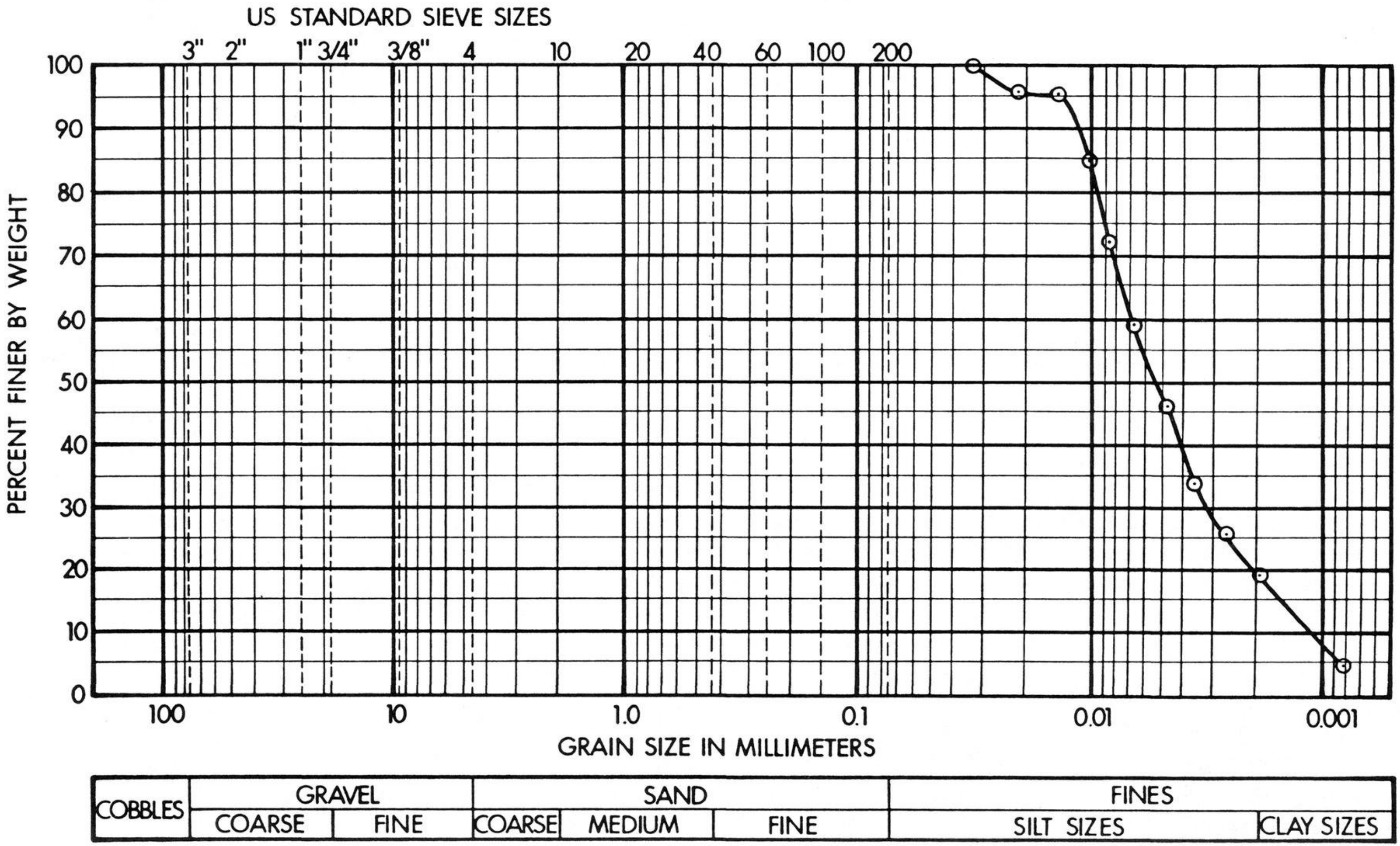
Mesh Size in um[b]	Wt % Retained Each Size	Cumulative Percent Passing
37.2	3.5	96.5
28.9	5.7	90.8
20.1	15.2	75.6
13.8	17.4	58.2
10.7	11.2	47.0
-10.7	47.0	--
	100.0	

Unclassified Tailings (Massive Ore)

Mesh Size in um[b]	Wt % Retained Each Size	Cumulative Percent Passing
150 mesh	1.2	98.8
200	5.4	93.4
270	5.9	87.5
36.6 um	0.1	87.4
28.4	2.1	85.3
19.8	9.0	76.3
13.6	11.1	65.2
10.5	8.6	56.6
-10.5	56.6	--
	100.0	

[a]CSMRI, 1982

[b]micrometer = .0000394 inch



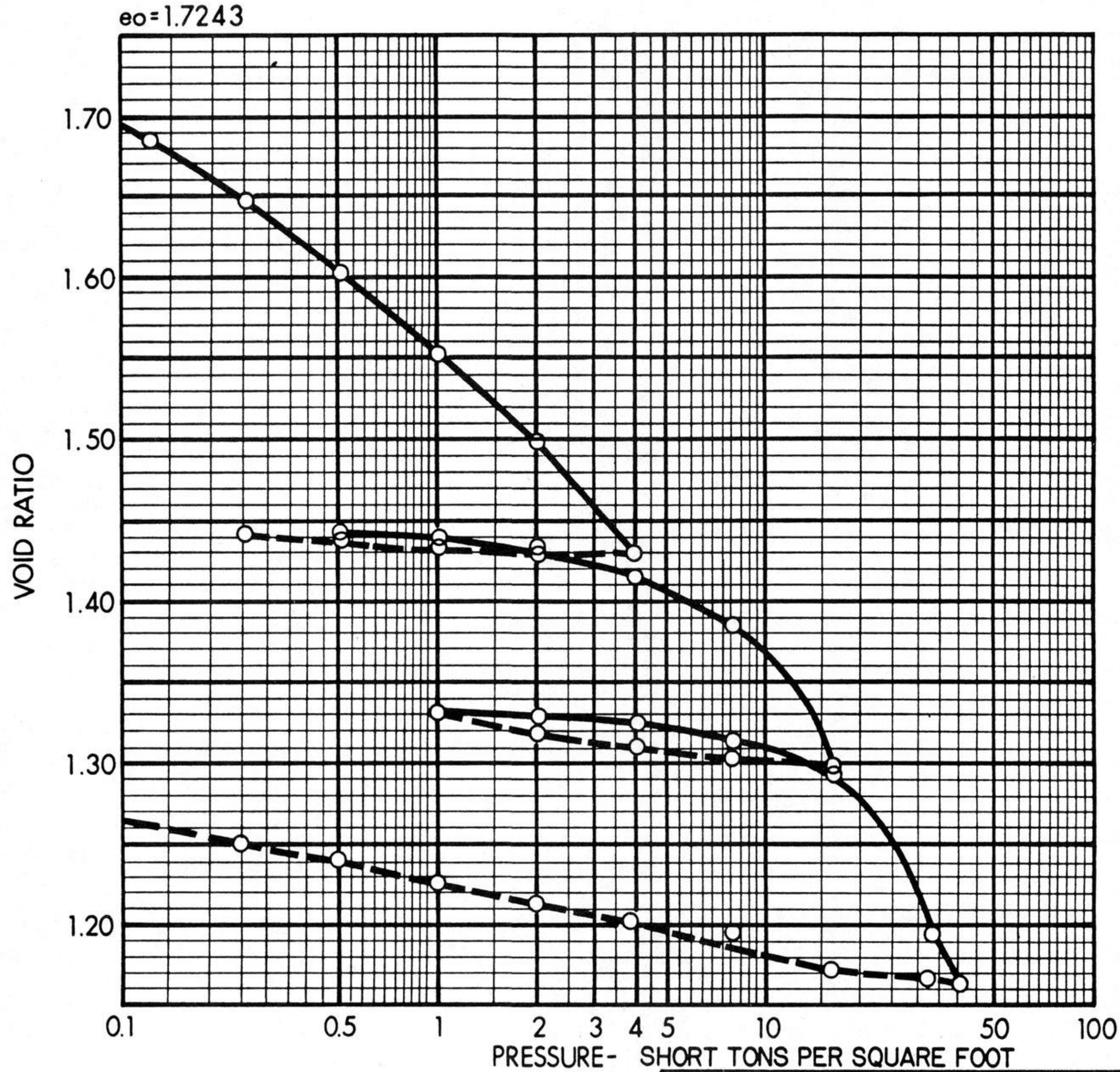
SPECIFIC GRAVITY = 3.2

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
TAILING FINES SIZE CHARACTERIZATION

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/23/82	CHECKED BY [illegible]	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON [illegible]	DATE [illegible]
DRAWING NO. FIGURE 3-1		SHEET ___ OF ___	REVISION NO. 0

INITIAL SAMPLE HEIGHT 0.7500 IN. (19.05mm) SAMPLE AREA 4.9087 SQ.IN. (3166.9mm^2)
SPECIFIC GRAVITY 3.16 INITIAL MOISTURE CONTENT * % INITIAL BULK DENSITY * PCF
INITIAL DRY DENSITY 72.4 PCF (1160 kg/m^3) INITIAL VOID RATIO 1.7243 INITIAL SATURATION * %
FINAL SATURATION ** % ATTERBERG LIMITS: L_w - % I_w - % P_w NON-PLASTIC %



REMARKS: * NOT DETERMINED BECAUSE OF SAMPLE PREPARATION METHOD
** NOT DETERMINED

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE TAILING FINES DENSITY			
SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/23/82	CHECKED BY R.P. Habel	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON D.F. [illegible]	DATE [illegible]
DRAWING NO FIGURE 3-2		SHEET OF	REVISION

TABLE 3.7

PERMEABILITY DATA SUMMARY
ON - 20 MICRON (0.000792 INCH) TAILING FINES

SAMPLE DATA POINT[b]	TEST METHOD[c]	SPECIFIC GRAVITY	VOID RATIO	DRY DENSITY kg/m^3	DRY DENSITY pcf[d]	PERMEABILITY m/s	PERMEABILITY ft/s[e]
1	CHT, SL	3.16	1.41	1311	81.8	3.8×10^{-8}	1.2×10^{-7}
2			2.25	973	60.7	9.5×10^{-8}	3.1×10^{-7}
3	CHT, ML	3.16	1.24	1411	88.0	7.2×10^{-8}	2.4×10^{-7}
4			1.18	1452	90.6	5.0×10^{-8}	1.6×10^{-7}
5			1.08	1532	95.6	4.9×10^{-8}	1.6×10^{-7}
6			0.94	1627	101.5	5.1×10^{-8}	1.7×10^{-7}
7			0.82	1733	108.1	6.0×10^{-8}	2.0×10^{-7}
8			0.66	1898	118.4	5.3×10^{-8}	1.7×10^{-7}
9			0.47	2148	134.0	3.3×10^{-8}	1.1×10^{-7}
10	BF	3.16	2.11	1016	63.4	6.9×10^{-8}	2.3×10^{-7}
11			1.83	1114	69.5	8.0×10^{-8}	2.6×10^{-7}
12			1.73	1159	72.3	1.3×10^{-8}	4.3×10^{-7}
13			1.36	1340	83.6	6.1×10^{-8}	2.0×10^{-7}
14			1.16	1460	91.1	4.4×10^{-8}	1.4×10^{-7}
15			1.14	1480	92.3	4.8×10^{-8}	1.6×10^{-7}
16			1.12	1488	92.8	4.8×10^{-8}	1.6×10^{-7}
17	C(0.25-0.5)	3.16	1.62	1205	75.2	1.1×10^{-7}	3.6×10^{-7}
18	C(0.5-1.0)		1.57	1228	76.6	5.8×10^{-8}	1.9×10^{-7}

[a]Golder, 1982a

[b]Data Point - This number corresponds to the data point numbers on Figure 3.3

[c]Test Method Legend:

CHT, SL - Constant head, triaxial, single layer
CHT, ML - Constant head, triaxial, multiple layer
BF - Buchner Funnel
C - Consolidation test (load range in tons per square feet)

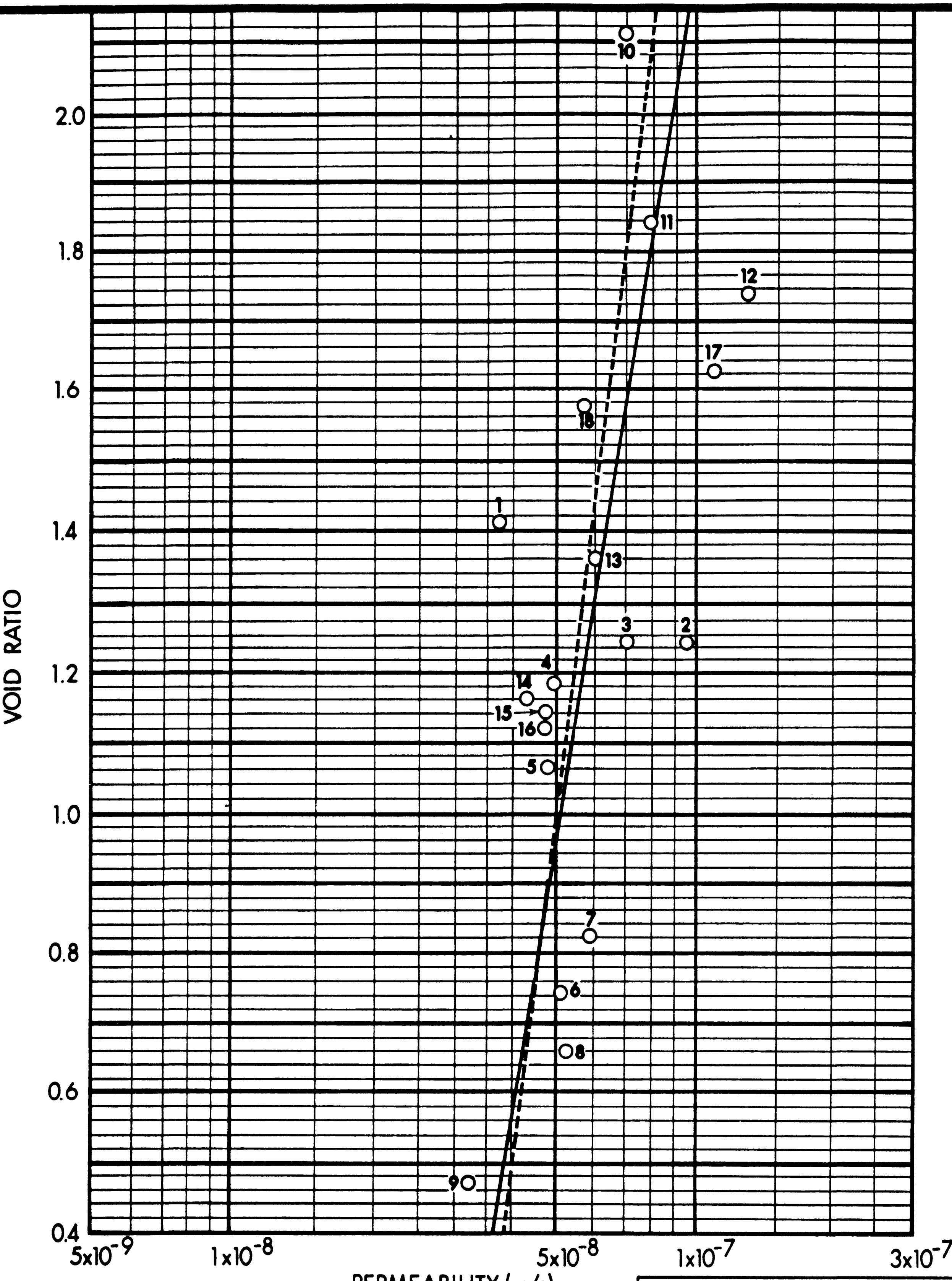
[d]pcf = Pounds per cubic foot

[e]ft/s = Feet per second

Consolidation Testing - Consolidation testing was conducted on a tailing fines sample. These tests indicate little clay structure in the samples. During the testing, the time for primary consolidation at a specific load increment was extremely short, usually less than 30 seconds and often less than 3 seconds. The relationship between pressure and void ratio for this testing is shown on Figure 3-2.

Density - Densities of tailing fines were estimated from specific gravity and estimated void ratios. The void ratio, which represents the air or pore space available among adjoining particles, for the samples tested ranged from 0.47 to 2.25 (Table 3.7). Void ratio values for the grain sizes indicated for tailing fines in the literature usually range from 0.8 to 1.2 (Golder, 1981a). For preliminary design purposes, estimates of dry density for the tailing fines are based on a void ratio of 0.85. This value, used in conjunction with a specific gravity of 3.2, results in a dry unit weight of 108 pounds per cubic foot.

Permeability Tests - Constant head - single layer, constant head - multi-layer, and Buchner funnel - single layer tests were used to measure permeability of the tailing fines (Golder, 1982a). Results of the permeability determinations by each of the methods employed are summarized in Table 3.7 and are plotted on Figure 3-3 along with linear regression calculations. The linear regression curve represented by a dashed line shows additional testing conducted on pyrite and non-pyrite fractions of the tailing fines. The linear regression curves indicate good correlation with most of



LEGEND

○ TAILING FINES (SAMPLE NUMBERS CORRESPOND TO THOSE ON TABLE 3 - 7)

- - - LINEAR REGRESSION FOR ALL SAMPLES

——— LINEAR REGRESSION FOR TAILING FINES SAMPLES ONLY

REGRESSION ANALYSIS PERFORMED WITH VOID RATIO AS INDEPENDENT VARIABLE.

EXXON MINERALS COMPANY CRANDON PROJECT				
TITLE: TAILING FINES PERMEABILITY				
SCALE	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY BWM	DATE 07/22/82	CHECKED BY RP Hubel	DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82	
APPROVED BY	DATE	EXXON D E M	DATE	
DRAWING NO FIGURE 3-3		SHEET ___ OF ___	REVISION NO 0	

the tests completed by the various methods. Of the tests performed, the Buchner funnel method showed the widest scatter of results. The permeability of the materials tends to be lower at high densities (lower void ratios), but the differences are small over the range of void ratios tested. Based on these data, an average permeability for the tailing fines of 1.6×10^{-7} feet per second was used in preliminary design of the MWDF.

An additional series of permeability and consolidation tests conducted by STS Consultants, Ltd. (STS 1983) generally confirmed the value established for permeability.

3.3.2 Chemical/Mineralogical Properties

The chemical and mineralogical properties of the tailing fines and unclassified tailings were also studied. Chemical analysis of the samples was conducted in steps. First, semi-quantitative emission spectrographic analyses were performed. After review of the semi-quantitative data, quantitative analyses were performed on the samples. The quantitative analytical methods used were cited in the U.S. EPA publication "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 1980." Additional data on specific gravity were obtained with air pycnometer techniques (CSMRI, 1982).

Semi-quantitative emission spectrographic analysis data on samples of tailing fines and unclassified tailings are given in Table 3.8. Quantitative chemical analysis data and specific gravity data are presented in Table 3.9.

These results indicate that the tailing samples are composed primarily of iron sulfide (FeS_2), silica (SiO_2), and silicates ($R \cdot SiO_2$;

TABLE 3.8

SEMI-QUANTITATIVE EMISSION SPECTROGRAPHIC ANALYSIS DATA[a,b] ON TAILING SAMPLES[c,d]

ELEMENT	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/STRINGER TAILING FINES	UNCLASSIFIED TAILINGS
Aluminum (Al)	0.6	3.0	1.0
Antimony (Sb)	< 0.003	< 0.003	< 0.003
Arsenic (As)	0.3	0.2	0.2
Barium (Ba)	0.002	0.004	0.004
Beryllium (Be)	< 0.001	< 0.001	< 0.001
Bismuth (Bi)	< 0.005	< 0.005	< 0.005
Boron (B)	< 0.003	< 0.003	< 0.003
Cadmium (Cd)	< 0.05	< 0.05	< 0.05
Calcium (Ca)	0.1	0.15	0.1
Cesium (Cs)	< 0.001	< 0.001	< 0.001
Chromium (Cr)	< 0.003	< 0.003	< 0.003
Cobalt (Co)	< 0.01	< 0.01	< 0.01
Copper (Cu)	0.1	0.2	0.08
Gallium (Ga)	< 0.005	< 0.005	< 0.005
Germanium (Ge)	< 0.005	< 0.005	< 0.005
Gold (Au)	< 0.001	< 0.001	< 0.001
Hafnium (Hf)	< 0.01	< 0.01	< 0.01
Indium (In)	< 0.005	< 0.005	< 0.005
Iridium (Ir)	< 0.01	< 0.01	< 0.01
Iron (Fe)	>10.0	>10.0	>10.0
Lead (Pb)	0.05	0.05	0.07
Lithium (Li)	< 0.001	< 0.001	< 0.001
Magnesium (Mg)	0.6	0.7	0.6
Manganese (Mn)	0.02	0.02	0.02
Molybdenum (Mo)	< 0.01	< 0.01	< 0.01

(TABLE CONTINUED ON NEXT PAGE)

TABLE 3.8
(continued)

ELEMENT	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/ STRINGER TAILINGS FINES	UNCLASSIFIED TAILINGS
Nickel (Ni)	< 0.01	< 0.01	< 0.01
Niobium (Nb)	< 0.01	< 0.01	< 0.01
Osmium (Os)	< 0.01	< 0.01	< 0.01
Palladium (Pd)	< 0.005	< 0.005	< 0.005
Platinum (Pt)	< 0.005	< 0.005	< 0.005
Potassium (K)	0.4	0.4	0.4
Rhenium (Re)	< 0.005	< 0.005	< 0.005
Rhodium (Rh)	< 0.005	< 0.005	< 0.005
Rubidium (Rb)	< 0.001	< 0.001	< 0.001
Ruthenium (Ru)	< 0.005	< 0.005	< 0.005
Silicon (Si)	>10.0	>10.0	>10.0
Silver (Ag)	< 0.001	< 0.001	< 0.001
Sodium (Na)	0.02	0.05	0.02
Strontium (Sr)	<0.001	< 0.001	< 0.001
Tellurium (Te)	<0.05	< 0.05	< 0.05
Thallium (Tl)	<0.05	< 0.05	< 0.05
Thorium (Th)	<0.05	< 0.05	< 0.05
Tin (Sn)	<0.003	< 0.003	< 0.003
Titanium (Ti)	0.006	0.01	0.006
Tungsten (W)	<0.05	< 0.05	< 0.05
Vanadium (V)	<0.005	< 0.005	< 0.005
Zinc (Zn)	0.6	0.4	0.6
Zirconium (Zr)	< 0.01	< 0.01	< 0.01

[a]All values in weight percent (%)

[b]Limits of accuracy reported as ± 50%

[c]Samples washed with 5 displacements of deionized water, vacuum dried, and pulverized as necessary prior to analysis

[d]CSMRI, 1982

TABLE 3.9

QUANTITATIVE CHEMICAL ANALYSIS DATA[a,b,c] ON TAILING SAMPLES[d]

CONSTITUENT	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/STRINGER TAILINGS FINES	UNCLASSIFIED TAILINGS
Aluminum (as Al_2O_3)	29,000	45,000	23,000
Antimony (Sb)	< 100	< 100	< 100
Arsenic (As)	1,600	900	1,400
Barium (Ba)	< 40	< 40	< 40
Cadmium (Cd)	17	16	15
Calcium (as CaO)	4,400	5,260	4,260
Carbonate (CO_3)	6,500	7,000	6,000
Chloride (Cl)	120	< 100	< 100
Chromium (Cr)	26	18	27
Copper (Cu)	1,260	1,690	1,190
Cyanide (CN)	5	4.5	4.0
Fluoride (F)	730	720	450
Gold (Au)	0.9	0.5	0.9
Iron (Fe)	291,000	231,000	294,000
Lead (Pb)	1,540	1,000	1,330
Magnesium (as MgO)	11,100	19,700	10,400
Manganese (Mn)	450	490	440
Mercury (Hg)	3.4	2.2	3.4
Nickel (Ni)	11	12	46
Phosphorus (P)	120	100	90
Potassium (as K_2O)	3,860	4,290	3,370
Selenium (Se)	< 40	110	< 40
Silica (SiO_2)	279,000	380,000	274,000
Silver (Ag)	58	43	57
Sodium (as Na_2O)	320	580	300
Sulfur (Total S)	299,000	220,000	312,000
Thallium (Tl)	< 40	< 40	< 40
Thorium (Th)	< 10	< 10	< 10
Titanium (Ti)	360	660	410
Uranium (U)	< 10	< 10	< 10
Zinc (Zn)	6,210	5,410	6,770
Specific Gravity	3.84	3.48	3.85

[a]Samples washed with 5 displacements of deionized water, vacuum dried, and pulverized as necessary prior to analysis.

[b]All values in parts per million (ppm) except Specific Gravity

[c]Analytical methods as cited in Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, U.S. EPA, SW-846, 1980

[d]CSMRI, 1982

R = Al_2O_3, MgO, K_2O, Na_2O); minor amounts of copper, lead, and zinc sulfides (CuS, PbS, ZnS), calcium/magnesium carbonate ($CaCO_3$, $MgCO_3$), and arsenic-iron sulfide (AsFeS); and trace amounts of chloride (<100 ppm), chromium (18-27 ppm), fluoride (450-720 ppm), gold (0.5-0.9 ppm), manganese (440-490 ppm), mercury (2.2-3.4 ppm), nickel (12-46 ppm), phosphorus (90-100 ppm), selenium (<40-100 ppm), silver (43-57 ppm), and titanium (410-660 ppm) occurring either in compounds or in the crystal lattices of silicates and sulfides. The data also show cyanide in trace amounts (4.0-5.0 ppm) adhering to tailing particles after an intensive 5-cycle displacement washing procedure with deionized water (CSMRI, 1982). The sulfur content of the samples ranged from 22 to 31 percent.

X-ray diffraction was conducted on each of the two tailing samples for semi-quantitative estimation of mineralogies. With this procedure, minerals present in amounts greater than a few percent by weight can generally be identified. Minerals less abundant than this may well be below detection limits. In addition, optical microscopy was used to better determine details of sulfide mineralogy, in particular the presence of sulfides other than pyrite, especially sphalerite (ZnS) (CSMRI, 1982).

Results of the mineralogical examination are given in Table 3.10. Both samples show similar mineralogies in terms of the chemical species present and the approximate amount of each. In approximate order of decreasing abundance, the minerals generally found in the samples are pyrite, quartz, chlorite, mica, sphalerite, dolomite, chalcopyrite, siderite, and galena (CSMRI, 1982).

Pyrite is by far the most abundant sulfide mineral in the samples. It generally comprises over 45 percent by volume of the tailing fines and unclassified tailing (Table 3.10). Minute amounts of other sulfides (sphalerite, chalcopyrite, galena) can only be observed microscopically --

TABLE 3.10

MINERAL COMPOSITION AND ESTIMATED VOLUME PERCENTAGES OF TAILINGS*

MINERAL	FORMULA	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/STRINGER TAILINGS FINES	UNCLASSIFIED TAILING
Pyrite	FeS_2	51	45	55
Quartz	SiO_2	35	41	34
Chlorite	$Mg, Fe, Al(Si_4O_{10})(OH)_8$	7	10	6
Mica	$K\ Al_2(AlSi_3O_{10})(OH)_2$	6	4	4
Sphalerite	ZnS	< 1	< 1	< 1
Dolomite	$CaMg(CO_3)_2$	1	Trace	< 1
Chalcopyrite	$CuFeS_2$	Trace	Trace	Trace
Galena	PbS	Trace	Trace	Trace
Siderite	$FeCO_3$	--	--	Trace

*CSMRI, 1982

they were not identifiable on the X-ray diffraction patterns (CSMRI, 1982). No pyrrhotite was identified.

Microscopic examination shows that sulfides other than pyrite to be very minor. Sphalerite is the most abundant nonpyrite sulfide, but is not more than 1 percent of any of the samples. No other zinc minerals appeared. The only other identifiable sulfides observed were traces of chalcopyrite ($CuFeS_2$) and galena (PbS) (CSMRI, 1982).

3.3.3 Leaching Properties

The Colorado School of Mines Research Institute also conducted a study of leaching characteristics of the tailing fines and unclassified tailings. Leaching tests were conducted using both U.S. EPA (40 CFR 261.24) and a modified ASTM procedure ("Proposed Methods for Leaching of Waste Materials, Method A - Water Extraction Procedure," published 1978) (CSMRI, 1982).

U.S. EPA leaching test results are presented in Table 3.11. These results show that, for all samples, none of the eight criteria inorganic parameters (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) were present in the leachate in concentrations above the threshold values for classification as hazardous waste. Cadmium and lead concentrations in the leachates were generally within one order of magnitude of the threshold values, while the concentrations of the other parameters were generally two orders of magnitude less than the threshold values (CSMRI, 1982).

Additional leaching tests were conducted through three, 48-hour cycles. Procedures for these tests were developed from a proposed ASTM leaching test (CSMRI, 1982). For each cycle, four parts of deionized water were used to leach one part of sample. At the end of each cycle, the sample slurries were pressure-filtered through a .0000187 inch filter, and the

TABLE 3.11

U.S. EPA EXTRACTION PROCEDURE LEACHING TEST RESULTS ON TAILING SAMPLES[a,b,c]

PARAMETER	UNCLASSIFIED TAILINGS	TAILING FINES Sample No. (1)	(2)	(2)	(2)	U.S. EPA HAZARDOUS WASTE LIMIT
Arsenic (As)	0.050	0.057	0.039	0.024	0.024	5.0
Barium (Ba)	< 0.2	< 0.2	< 0.2	< 0.1	< 0.1	100.0
Cadmium (Cd)	0.20	0.27	0.23	0.11	0.09	1.0
Chromium (Cr) (total)	< 0.02	< 0.02	< 0.02	< 0.01	< 0.01	5.0
Lead (Pb)	0.90	1.40	0.67	0.66	0.67	5.0
Mercury (Hg)	< 0.0005	<0.0005	< 0.0005	< 0.0005	< 0.0005	0.2
Selenium (Se)	0.012	0.011	0.016	< 0.005	< 0.005	1.0
Silver (Ag)	< 0.05	< 0.05	< 0.05	< 0.01	< 0.01	5.0

[a]CSMRI, 1982

[b]All values mg/l (ppm).

[c]U.S. EPA Extraction Procedure for hazardous waste identification, Federal Register, v. 45, no. 98, May 19, 1980, pp. 33127-28.

(1) Sample Number 1 - Zinc Tailings Fines (Massive Ore)
(2) Sample Number 2 - Zinc Tailings Fines (Mixture massive/stringer ore). Sample No. 2 was tested three times.

filtered leachates were analyzed. Also, portions of the filtered leachates from each cycle were combined into composite samples and analyzed for additional parameters. The results of these tests are presented in Tables 3.12 and 3.13, respectively (CSMRI, 1982).

The data from the three-cycle leaching tests given in Table 3.12 indicate that most of the leaching occurred in the first cycle. However, these data also indicate that some combination of entrained liquid release, dissolution, and/or diffusion of ions from the tailings occurred during the second and third leach cycles (CSMRI, 1982).

The data given in Table 3.13 on the composite leaching results indicate that manganese, sulfate, and zinc were the primary ions leached. Minor amounts of iron were leached from the tailing fines, but only trace amounts of iron were leached from the unclassified tailings. Trace amounts of cadmium, lead, and selenium were present in the leachates of both samples. Barium, chromium (total), copper, mercury, and silver concentrations in the composite leachates were below the analytical detection limits. Chloride concentrations in the composite leachates were below the analytical detection limit for unclassified tailings but were detected in the leachate from massive/stringer tailing fines. Fluoride and nitrate were detected at trace levels in the composite leachates from two of the three samples (CSMRI, 1982).

Leaching tests were also conducted on a sample of tailing fines using the modified ASTM procedures with an initial alkaline (pH 10) condition. These tests were done primarily to determine thiosulfate generation rates as

TABLE 3.12

LEACHATE ANALYSIS RESULTS FOR
MULTI-CYCLE AGITATED WATER-LEACHING
OF TAILING SAMPLES[a]

PARAMETER	CYCLE[b]	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/ STRINGER TAILINGS FINES	UNCLASSIFIED TAILINGS
pH	1	5.80	6.35	5.9
	2	5.65	6	5.85
	3	6.00	6.2	6
Specific Conductance (mmhos/cm)	1	2.20	1.97	2.03
	2	1.14	0.58	0.98
	3	0.43	0.29	0.41
Cu (mg/l)	1	0.2	0.05	0.02
	2	< 0.1	< 0.03	< 0.03
	3	< 0.1	< 0.02	< 0.02
Fe (mg/l)	1	0.5	0.19	0.56
	2	< 0.1	1.59	< 0.02
	3	< 0.1	10.5	< 0.02
Pb (mg/l)	1	0.7	0.1	0.23
	2	0.1	0.03	0.03
	3	< 0.1	< 0.03	< 0.05
Zn (mg/l)	1	1190	85	258
	2	60	8.9	20
	3	20	0.44	5.2
SO_4 (mg/l)	1	9680	1603	
	2	2840	209	573
	3	680	91	159

[a]CSMRI, 1982

[b]48 hours for each cycle

TABLE 3.13

ANALYSIS RESULTS FOR
LEACHATE COMPOSITES FROM THREE CYCLES OF
WATER LEACHING OF TAILING SAMPLES[a]

PARAMETER[b]	MASSIVE TAILINGS FINES	MIXTURE MASSIVE/ STRINGER TAILINGS FINES	UNCLASSIFIED TAILINGS
As	0.14	< 0.01	0.17
Ba	< 0.1	< 0.1	< 0.1
Cd	0.26	0.04	0.22
Cr, total	< 0.02	< 0.02	< 0.02
Cu[c]	< 0.02	< 0.02	< 0.02
Fe[c]	0.04	4.09	0.19
Pb[c]	0.10	0.04	0.08
Mn	11.7	4.4	10.4
Hg	< 0.0005	< 0.0005	< 0.0005
Se	0.17	0.09	0.21
Ag	< 0.01	< 0.01	< 0.01
Zn[c]	101	31	94
Cl	< 0.5	1.6	< 0.5
F	0.18	0.30	0.17
NO_3	< 0.05	0.18	0.09
SO_4[c]	1030	630	960
pH[c]	5.8	6.3	5.9
Specific Conductance[c] mmhos/cm	1.3	0.9	1.1
Color, units	1	1	3

[a]CSMRI, 1982

[b]All values mg/l except pH, specific conductance, and color

[c]Values calculated from analysis results on three cycle leachates

the tailing fines become exposed to high pH. These results are presented in Table 3.14.

3.3.4 Acid Generation Potential

The acid generation potential of tailing fines and unclassified tailings was determined with a procedure specified by Exxon Minerals Company. For detailed testing methodology, refer to Colorado School of Mines Research Institute, 1982. The procedure was essentially the same as that used by B. C. Research except that no further grinding of the tailings samples was done. The results of this acid production testing indicate that all of the tailing samples have a definite potential for acid generation (CSMRI, 1982). However, column leaching tests conducted for 31 weeks on tailing fines samples have indicated no acid generation (CSMRI, 1982). The column tests are more typical of MWDF conditions because of the lack of agitation.

TABLE 3.14

LEACHATE ANALYSIS RESULTS FROM AGITATED
LEACHING OF TAILING FINES UNDER ALKALINE CONDITIONS*

PARAMETER	TAILING FINES
Initial pH	10.01
Final pH	6.48
Cu	0.07 mg/l
Fe	< 0.02 mg/l
Pb	< 0.05 mg/l
Zn	89 mg/l
SO_4	2640 mg/l
S_2O_3	9 mg/l

*CSMRI, 1982.

3.4 Reclaim Pond and Water Treatment Plant Sludges

3.4.1 Reclaim Pond Sludge

The water entering the reclaim pond from the tailing and copper concentrate thickeners and the operating disposal pond will contain small quantities of fine suspended particles. The concentration of suspended solids in waters flowing to the reclaim pond will generally range from 10 to 500 mg/l. This fine particulate material will settle to the bottom of the reclaim pond. Lime will be added to the reclaim ponds as necessary and will form metal hydroxides which will also settle in the reclaim ponds. The mineralogical and chemical composition of this settled fine material is expected to be similar to that reported for the tailing fines. This sludge will be removed if necessary from the reclaim ponds and transported to the operating disposal pond. This will also occur at the completion of operations.

The reagent types proposed for use in the mill concentrating processes are presented in Table 3.15. Also indicated are the estimated quantities of the reagents for use in the mill. Studies conducted on operating facilities processing similar ore types using organic reagents have shown that these types of chemicals (i.e., organic) are basically below detectable concentration limits in the environment (Gale and Wixson, 1977). This is expected because of the small quantities used in the concentrating processes and the oxidation and degradation of these substances in the tailing and reclaim ponds. Therefore, it is not expected that these substances will be found in detectable concentrations in the sludge.

TABLE 3.15

REAGENT TYPES AND ESTIMATED QUANTITIES FOR USE IN PRODUCTION OF CONCENTRATE

	FORMULA	Estimated Consumption[3] Rate of Consumption lbs/t	Estimated Consumption[3] Monthly Consumption Tons
PRIMARY PROCESS REAGENTS			
Calcium Oxide (lime)	CaO	4.0	441
Sulfur Dioxide	SO_2	0.45	50
Copper Sulfate	$CuSO_4 \cdot 5H_2O$	0.72	80
Zinc Sulfate	$ZnSO_4 \cdot 7H_2O$	0.22	24
Sodium Cyanide	$NaCN$	0.06	7.2
Activated Carbon	C	0.23	25
Sodium Dichromate	$Na_2Cr_2O_7 \cdot 2H_2O$	0.14	16
Sodium Silicate	Na_2SiO_3	0.41	46
Xanthate[1]	(1)	0.16	18
Methyl Isobutyl Carbinol	$C_6H_{14}O$	0.07	8
Carboxy Methyl Cellulose	$(C_6H_{10}O_5)\ COCH_3$	0.10	11
Sodium Sulfide	$Na_2S \cdot 9H_2O$	0.02	2.5
Polypropylene Glycol Methyl Ether	$C_4H_{10}O_2$	0.02	2
Sodium Carbonate	Na_2CO_3	0.02	3
Sodium Hydroxide	$NaOH$	0.003	.3
Flocculant[2]	-		

(1)Xanthates include sodium ethyl xanthate, potassium amyl xanthate, and sodium isopropyl xanthate.

(2)A particular flocculant has not yet been selected; it will likely be a polyacrylamide; typical dosage rate, if necessary, would be 4.5 to 17 tons per month.

(3)Estimated consumptions based on pilot scale tests. Actual consumptions may vary.

3.4.2 Water Treatment Plant Sludge and By-Product Sodium Sulfate

Two sludges will be produced in the water treatment processes. One sludge will be the combined waste from lime/sulfide precipitation of the contaminated mine water and intercepted ground water and lime/soda ash softening of process recycle water. The other waste product will be the ultimate result of the reverse osmosis, vapor compression, and crystallization processes.

The sludge from the lime/sulfide precipitation and lime-soda softening processes will be primarily calcium carbonate and silt (from suspended solids in the mine water) and contain less than 10 percent zinc and iron combined. These precipitates will be hydroxides and sulfides of the heavy metals. The other sludge constituents will be minor and amount to less than 0.2 percent of the total quantity. These projections are based on sludge quality data generated from the Water Use Computer Model (CH2M Hill, 1982). This carbonate sludge will be pumped to the MWDF with the tailing slurry.

The other sludge will result from evaporative treatment of the brine from the reverse osmosis process. This sludge will consist of anhydrous sodium sulfate, sodium sulfate decahydrate, and, possibly, some sodium thiosulfate. Small quantities of other constituents such as calcium, magnesium, silica and chloride may also be present. A potential market exists for this by-product in paper mill processes. Until the marketability of this material can be definitely determined, it will be stored in an isolated area in tailing pond T1 and if necessary in the remaining tailings ponds as they are developed and operated.

3.5 Radiological Properties of Ore, Waste Rock, and Soils

Hazleton Environmental Sciences evaluated the radiological properties of ore, waste rock, and soils under the direction of their Nuclear Sciences Department with input from Exxon Minerals Company and Camp Dresser and McKee, Denver, Colorado. Exxon Minerals Company was responsible for collecting and compositing all samples according to the method outlined in the technical work plan reviewed by the Wisconsin Department of Health and Social Services, Radiation Protection Section; the Wisconsin Geological and Natural History Survey; and Wisconsin Department of Natural Resources personnel (Hazleton, 1981).

Composite samples were prepared from massive and stringer ores and waste rock. Also, soil composites from areas considered for the mine/mill site and MWDF (Areas 40 and 41), plus a local granite outcrop, were analyzed for comparison. The principal parameters measured were gross alpha, gross beta, radium-226, total uranium, total thorium, and gamma radiation. Gamma radiation provided data on radioactivity resulting from the decay of uranium-238 and thorium-232. Gamma spectroscopic analysis provided data on thorium-228, radium-226, potassium-40, cesium-137, and ruthenium-106. The results are summarized in Table 3.16.

The data indicate that the local granite outcrop had higher concentrations of uranium, thorium, and radium than the Crandon ore, waste rock, or site area soils. The average total uranium content of waste rock and massive ore samples was 1.46 and 1.33 ppm, respectively. Stringer ore samples contained the lowest average level of uranium (<0.83 ppm) of all sample types, including site area soils.

TABLE 3.16

RADIOLOGICAL TEST RESULTS FOR WASTE ROCK
MASSIVE ORE, STRINGER ORE, GRANITE OUTCROP AND SOIL[a]

	pCi/g dry wt.								Total Uranium		Total Thorium	
	Gross Alpha	Gross Beta	Ra-226 by Rn-222	Gamma Emitters: Ra-226	Gamma Emitters: Th-228	Gamma Emitters: K-40	Gamma Emitters: Cs-137	Gamma Emitters: Ru-106	pCi/g dry wt.	ppm	pCi/g dry*	ppm
Waste Rock												
Mean ± s.d.	6.5±1.9	16.2±2.5	0.66±0.20	0.63±0.19	0.66±0.18	17.2±3.7	< 0.04	<LLD[b]	0.99±0.39	1.46±0.55	1.66±0.29	7.61±1.33
Range	(3.2-8.6)	(13.2-19.9)	(0.40-0.96)	(0.34-0.85)	(<0.21-0.83)	(13.1-22.4)			(<0.56-1.58)	(<0.83-1.67)	(0.7-1.0)	(6.0-8.7)
Massive Ore												
Mean ± s.d.	4.7±1.1	4.9±1.7	0.74±0.22	0.45±0.17	0.25±0.07	1.8±0.6	< 0.06	<LLD	0.90±0.31	1.33±0.46	0.85±0.12	3.90±0.55
Range	(3.7-7.2)	(2.5-8.1)	(0.48-1.30)	(0.12-0.79)	(<0.09-0.31)	(<1.0-2.5)			(0.56-1.13)	(0.83-1.67)	(0.7-1.0)	(3.2-4.6)
Stringer Ore												
Mean ± s.d.	3.2±1.0	6.3±1.5	0.27±0.06	0.22±0.04	< 0.18	3.5±0.4	< 0.06	<LLD	< 0.56	<0.83	0.65±0.05	2.98±0.23
Range	(2.0-3.9)	(<3.7-9.0)	(0.20-0.40)	(<0.11-0.27)		(2.8-3.7)					(0.6-0.7)	(2.8-3.2)
Granite Outcrop[c]	20.7±6.3	43.0±4.5	1.54±0.05	2.01±0.12	3.02±0.18	46.8±1.5	< 0.029	<LLD	2.94	4.34	4.9±0.5	22.5±2.3
Soil												
Mean ± s.d.	9.4±1.6	23.8±1.4	0.77±0.06	0.72±0.22	0.84±0.26	20.9±0.7	0.39±0.08	0.68±0.06	0.56±0.00	0.83±0.00	2.2±0.4	10.1±1.8
Range	(7.1-11.6)	(22.1-24.7)	(0.70-0.86)	(0.26-0.88)	(0.28-0.99)	(19.8-21.8)	(<0.22-0.46)	(<0.22-0.74)	(<0.56-0.56)	(<0.83-0.83)	(1.7-2.7)	(7.8-12.4)

a. Hazleton, 1981.

b. LLD - Lower limit of detection.

c. The error given for the granite outcrop samples results in the probably counting error at the 95 percent confidence level. All others are one standard deviation.

The uranium content of the granite outcrop samples was approximately three times that found in the massive ore and waste rock. Overall, uranium and thorium concentrations in the Crandon ore and waste rock are similar to values reported for other basaltic and andesitic igneous rocks. In descending order, the relative ranking of the sample types based on radioactivity was generally: granite outcrop > soil > Crandon ore and waste rock.

A beta-gamma survey also was conducted on 2,160 feet of core used for the ore composites in the radiological analyses. Survey results indicated uniform levels of radiation indistinguishable from background levels.

The analyses also showed that the composition and levels of radioactivity in soil, waste rock, ore, and granite outcrop were at the background concentration. No unusual levels of radioactivity were detected in any of the samples analyzed. Trace amounts of cesium-137 and ruthenium-106 detected in most of the soil samples were attributed to the fallout of radiactive debris from nuclear tests conducted in the atmosphere (Hazleton, 1981).

The Hazleton Environmental Sciences report presents additional quantitative data on the radioactivity of massive and stringer ore composites. These analyses, performed by Exxon during 1977-1978, indicated uranium and thorium concentrations less than detection limits (Table 3.17). Of the seven stringer and seven massive ore samples analyzed, uranium was always below the 2 ppm detection limit for the inductively coupled argon plasma emission spectroscopy (ICP). Thorium content only exceeded the 5 ppm detection limit in 3 massive ore composite samples from drill holes and ranged from 7 to 10 ppm (Exxon, 1978).

TABLE 3.17

URANIUM (U) AND THORIUM (Th) CONTENT[a] IN COMPOSITE ORE SAMPLES FROM THE CRANDON PROJECT[b]

DIAMOND DRILL HOLE COMPOSITE SAMPLE	ppm[c] U	ppm[c] Th
Massive Ore		
3	< 2	8
5 (high grade)	< 2	7
5 (low grade)	< 2	< 5
18	< 2	< 5
23	< 2	< 5
28	< 2	< 5
22	< 2	10
Stringer Ore		
3	< 2	< 5
5	< 2	< 5
8	< 2	< 5
12	< 2	< 5
16	< 2	< 5
18	< 2	< 5
122	< 2	< 5

[a]Analyses performed using inductively coupled argon plasma emission spectrospcopy (ICP) on single hole composites (Exxon, 1978).

[b]Hazleton, 1981.

[c]ppm = mg/kg.

These results indicated that the ore is within the reported range of uranium and thorium content for quartz and feldspar, both common igneous minerals (0.1-10 and 0.5-10 ppm, respectively) (Rogers and Adams, 1969a,b). The Crandon ore is also within the range of uranium content, 0.5-10 ppm, reported for intermediate rocks such as andesites, dacites, rhyodacites, diorites, quartz diorites, and granodiorites (Rogers and Adams, 1969b). In addition, during September 1980, the Wisconsin Geological and Natural History Survey detected no major gamma activity above background in the Crandon upper ore zone (Hazleton, 1981).

The Colorado School of Mines Research Institute studied the radiological properties of tailing fines and unclassified tailings (CSMRI, 1982). Samples were analyzed for radium-226, radium-228, and thorium-230 using standard counting techniques. Thorium-232 was estimated from the chemical analysis for total thorium. The samples were washed with five displacements of deionized water and vacuum dried before analysis.

Radiological analysis data on the tailing samples are presented in Table 3.18. The data obtained on the tailing samples indicate that their radioactivity is similar to that reported for soils. A comparison of data in the literature on radium-226 and thorium-232 levels in soils and the tailing samples is presented in Table 3.19. These results indicate that radioactivity will be similar to that of the current surrounding soils of the site area.

TABLE 3.18

RADIOLOGICAL ANALYSIS RESULTS ON TAILING SAMPLES*

DESCRIPTION	Radium-226 pCi/g	Radium-228 pCi/g	Thorium-230 pCi/g	Thorium-232 pCi/g
Tailings Fines (Massive)	0.2 ± 0.8	0.2 ± 2.5	0.6 ± 2.21	< 1
Tailing Fines (Massive/Stringer)	0.2 ± 0.7	1.5 ± 3.1	1.3 ± 2.5	< 1
Unclassified Tailings	0.2 ± 0.8	0.1 ± 2.5	0.6 ± 2.2	< 1

*CSMRI, 1982.

TABLE 3.19

RADIOLOGICAL PARAMETER LEVELS IN TAILING SAMPLES COMPARED TO SOIL CONCENTRATIONS[a]

ISOTOPE	ANALYSIS RESULTS ON TAILING SAMPLES, pCi/g	LEVELS REPORTED IN THE LITERATURE FOR SOILS, pCi/g[b]
Radium-226	0.2 ± 0.7 to 0.2 ± 0.8	0.3 to 2
Thorium-232	< 1	0.01 to 1.4

[a]CSMRI, 1982.

[b]Bowen, 1966.

3.6 Results of Asbestiform Mineralogical Analysis of the Crandon Ore Deposit

Geologists from Exxon Minerals Company and the Wisconsin Geological Survey inspected thin sections from diamond drill cores which intersect the major ore zones of the Crandon mineral deposit. The samples were judged by two survey geologists to be representative of the ore zone and surrounding host rocks (Exxon, 1979b). None of the sections examined contained any asbestiform minerals.

A sample of tailing fines was studied by Illinois Institute of Technology Research Institute (IITRI) for asbestiform mineral content. Transmission electron microscopy (TEM) was used employing a procedure that was an updated version of EPA-600/2-77-178 (revised June 1978), entitled "Electron Microscope Measurement of Airborne Asbestos Concentrations - A Provisional Methodology Manual". The studies were performed on the very finest fractions of tailing particles obtained by suspension and sedimentation in water. This was done to study those particles that potentially could be airborne if dusting were to occur. The results of the study showed a presence of non-asbestos mineral fibers and the absence of asbestiform minerals (IITRI, 1984).

4.0 RELATIONSHIP OF WASTE CHARACTERIZATION TO WASTE MANAGEMENT

As described in Chapter 3, extensive investigations have been conducted on the various waste types which will be generated from the Project mining and milling operations. This chapter provides an analysis of how the waste characteristics were used to evaluate the potential for reuse, recovery or sale of various waste streams and how waste characteristics relate to the design, construction, operation, maintenance, and long-term care of the MWDF.

4.1 Discussion of Alternative Waste Reuse or Recovery Methods

Six wastes will be generated during the mining and milling operations. They are waste rock, unclassified tailings, backfill sands, tailing fines, reclaim pond sludge, and water treatment plant sludges. Backfill sands will be produced for placement in the mine when mill operations start and will not normally be placed in the MWDF. During the waste characterization studies, data were evaluated for the purpose of reviewing the reuse, recovery or sale potential of each of the wastes. The coarse fraction of the tailings, termed backfill sands, will be used to backfill mined out stopes; this effectively reduces the area required in the MWDF for tailings disposal. The following paragraphs indicate some of the reuse or recovery considerations for each waste type.

Waste Rock - During initial stages of mining and prior to installation of underground crushing equipment, waste rock will be less than 24 inches in diameter. Approximately 0.44 million cubic yards of waste rock will be generated during mine construction. After underground crushing starts, waste rock will be a maximum of 8 inches in diameter. Approximately 4.2 million cubic yards will be generated during actual mine operations. About 5% of the waste rock will be used for construction of the MWDF as rip-rap for inside pond areas. Most waste rock will be reused within the mine directly or it will be crushed and reintroduced into the mine for backfill.

Backfill Sands - The construction needs (timing and materials) for structural stability in the mine were examined as a beneficial use of the mill tailings. A tailings classification circuit will be used during operations to separate the flotation tailings into backfill sands and tailing fines for disposal. Use of the backfill sands to fill mined stopes substantially reduces the required size of the MWDF for the disposal of the tailing.

Tailing Fines - A pyrite processing study was conducted to evaluate alternative reuse and recovery methods for the tailing fines (Davy McKee, 1981b). The study focused on separating the tailing fines into a pyrite concentrate and a non-pyrite tailing and the marketing of pyrite concentrates either for direct use or for use in production of other commodities. The study emphasized the technical and economic feasibility of producing those products with commercially proven processes. It also examined processing locations and potential environmental effects of the recovery and processing of pyrite concentrates.

A pyrite processing center at Crandon was not considered because the environmental effects of either sulfur dioxide emissions and/or volume of waste generated would have far outweighed any benefit of reducing the volume of tailings for disposal.

Alternative uses for the pyrite concentrate that were studied included sulfuric acid production, production of iron oxide pellets and nonferrous metals recovery, production of diammonium phosphate, and elemental sulfur recovery. Other alternatives, including direct marketing of the pyrite and secondary products such as liquid sulfur dioxide, by-product gypsum, pigments, and iron powder, were also considered (Davy McKee, 1981b).

The conclusions of the pyrite study were:

1) Because of commodity prices, freight rates, moisture content, and particle size, no market exists for pyrite concentrates.

2) Production of liquid sulfur dioxide, by-product gypsum, pigments, and iron power did not warrant economic evaluation;

3) Production of sulferic acid from pyrite cannot economically compete with the production of sulfuric acid from elemental sulfur or recovery from smelters;

4) Reclaiming iron pellets and nonferrous metals along with production of sulfuric acid does not warrant capital expenditures;

5) Using sulfuric acid to produce diammonium phosphate fertilizer along with reclaiming iron pelltets and nonferrous metals shows a positive, but marginal return on investment; and

6) Production of elemental sulfur from pyrite cannot economically compete with other sulfur sources.

In summary, the use of tailing fines for manufacturing commercial by-products is apparently not economically justifiable in the current marketplace (Davy McKee, 1981a). A reexamination of the Davy McKee study economics, consistent with the revised Project plan, did not produce justification to change any of the original conclusions (Thomas L. Coefield Associates, 1985). Therefore, it was recommended that the tailings not be separated into pyritic and nonpyritic materials.

Reclaim Pond Sludge - Reclaim pond sludge was not evaluated for reuse or reclamation potential as its actual physical-chemical characteristics, as well as the absolute quantities which may be generated, are unknown. Estimated volume, compared to the total waste generated, of the reclaim ponds sludge is very small (less than 0.03 percent). The projected physical and chemical characteristics of the sludge waste will have no detectable effect on the overall operation of the MWDF. Therefore, this waste is proposed for disposal in the facility.

Water Treatment Plant Sludge - There will be two waste materials produced in the water treatment processes. One material will be the combined waste from lime/sulfide precipitation of the contaminated mine water and ground water and lime/soda ash softening of the process recycle water. The other waste product will be salt cake, which will be the ultimate result of the reverse osmosis, vapor compression evaporation, and crystallization processes.

The combined waste from the lime/sulfide precipitation and lime/soda ash softening steps will consist primarily of calcium carbonate and silt (from suspended solids in mine water) and is expected to contain less than 10 percent of other metal hydroxides, primarily zinc and iron. Other minor constituents including metal sulfide precipitates will amount to less than 0.2 percent. The projected amount of solids in the total sludge from these two unit operations will be about 17 tons per day, dry basis. This waste will be sent to the mill tailing thickener underflow sump and then disposed in the MWDF along with the mill tailings. The advantage of disposing of this sludge with the tailing is its acid neutralizing capacity.

The other waste material will result from the crystallization of the brine from the vapor compression evaporator. This waste will consist primarily of anhydrous sodium sulfate (commercially known as salt cake). It will be produced at an estimated rate of 11 tons per day. This material could potentially be marketed for use in kraft pulp and paper mills. Wisconsin currently has three kraft pulp mills which consume a total of 31 tons per day of salt cake. These data on consumption rate were obtained in a telephone survey and are shown below:

Wisconsin Kraft Pulp Mills

Company	Location	Salt Cake Consumption tons/day
Mosinee	Mosinee	3
Nekoosa	Nekoosa	4
Thilmany	Kaukauna	24*

* 30 tons per day of Copeland sulfate (80% Na_2SO_4, 20% Na_2CO_3) equivalent to 24 tons per day of pure sodium sulfate.

An additional 22 tons per day of salt cake is projected to be consumed by the states of Minnesota and Michigan and the Canadian provinces of Manitoba and Ontario.

If this by-product sodium sulfate is marketed, as expected, the frequency of transportation of salt cake to Kraft pulp mills would depend upon the mode of transportation and location of the mill. Assuming approximate 25-ton shipments, shipments from the Crandon Project would be required about twice a week.

Until the marketability of this material can be further defined, it will be assumed that salt cake will be stored in a separate isolated area in each tailings pond as required.

There is one other small waste stream to be produced in the water treatment plant. This will be the solution used to periodically clean the reverse osmosis membranes to remove any accumulations of scale and to retard bacterial growth on the membranes. Up to 980 gallons of cleaning solution will be used each month. Three different cleaning solutions will be used on a rotating 3-month basis, i.e., one solution would be used when cleaning during the first month of a cycle, the second solution in the second month, and the third solution in the third month of the cycle. Ingredients to be used in each cleaning solution are as follows:

Cycle Month	Ingredient	Concentration In Solution
1	Citric Acid	0.17 lb/gal
	Liquid Nonionic Detergent	0.0045 qt/gal
	Ammonium Hydroxide	Adjust to pH 4.0
2	Sodium Tripolyphosphate	0.17 lb/gal
	Sodium - EDTA	0.07 lb/gal
	Liquid Nonionic Detergent	0.0043 qt/gal
	Sulfuric Acid	Adjust to pH 7.5
3	Liquid Nonionic Detergent	0.0043 qt/gal
	Sodium Perborate	0.0415 lb/gal
	Sulfuric Acid	Adjust to pH 8.0

In addition to the expected cleaning ingredients a weak chlorine solution may also be utilized for a shock chlorination treatment.

Spent cleaning solution will be metered into the tailing thickener underflow sump at a rate of about 125 gallons per day on an intermittent basis (1,000 gallons per month). The ingredients in the cleaning solution will be degraded by their action in cleaning the membranes. However, assuming no degradation of any of the ingredients in the solutions, the following maximum concentrations will occur in the total flow to the tailings pond:

Ingredient	Concentration in Total Flow to Pond	Occurrence Cycle Month 1	2	3
Citric Acid	1.2 mg/1	X		
Detergent	<0.03 mg/1	X	X	X
Sodium Tripolyphosphate	1.2 mg/1		X	
Sodium - EDTA	0.5 mg/1		X	
Sodium Perborate	0.3 mg/1			X

4.2 Waste Disposal

It is estimated that the wastes (tailing and sludges) generated will require a disposal design volume encompassing approximately 18.8 million cubic yards or 11,667 acre-feet. Therefore, waste properties are an important consideration in the location, design, operation, construction, maintenance, and monitoring of the MWDF. Specifically, Project waste characteristics were considered in the design, handling, storage, disposal, and location of the facility as follows:

1) Chemical testing of the wastes indicates that most may be acid-producing if oxygen is available in the environment. If the wastes containing sulfide minerals undergo biological or chemical oxidation, the leachate could solubilize various sulfate salts and mobilize metals. The design of the MWDF and lime additions during disposal will limit acid production during the operational life of the MWDF and after the facility is reclaimed. Data from the tailings chemistry (waste characterization) indicate that there is sufficient buffering capacity within the tailings to greatly inhibit the production of acid leachate (CSMRI, 1982). Also, the MWDF will be located where soil conditions provide excellent attenuation/buffering capacity for environmental protection (see Section 10.2);

2) Acid-producing potential of the wastes and liner compatibility with regard to seepage pH and ion exchange were included in the evaluation. In addition, the effects of metals which may be in solution were evaluated for compatibility with the liner. The design included these considerations to ensure a liner compatible with the wastes;

3) Chemical constituents of the waste were utilized in the development of a monitoring plan for the facility. These constituents are also useful for determining treatment for leachate which will be collected from the facility;

4) Efforts were made through the design to develop and maintain a containment system which will limit oxygen transport through the tailings and subsequently limit potential acid production and the amount of leachate generated during both facility operation and after reclamation. This was a major design factor for the reclamation cover;

5) The permeability of the tailings is estimated to be 1.64 x 10^{-7} feet per second. The tailings (82 percent silt and 18 percent clay particle sizes) will dewater slowly, and because of their inherently low permeability characteristics, transmit little leachate. The permeability results, when correlated to the grain size analysis and density, indicate that the movement of water through the tailings and the production of leachate will also be extremely limited;

6) Consolidation and density tests performed on samples of the tailing fines indicate that primary compaction occurs very quickly to a dry density of approximately 108 pounds per cubic foot. Settlement from any additional consolidation will be minimal as the tailings will be near maximum density. Atterburg limits indicate that the tailing fines are essentially nonplastic, but may be subject to liquefaction in the upper 15 feet from predicted maximum vibrations. However, after such vibrations subside, settlement will again occur to near maximum density (Golder, 1981e);

7) Grain size analyses were used to develop settling characteristic for the tailing fines and to predict their final surface grade assuming a 0.5 percent slope (Golder Associates - Tailing Pond Reclamation Cover, 1982e). In addition, these characteristics indicated that settling will occur rapidly and allow a quicker phased reclamation of the facility; and

8) Grain size analysis of the tailing fines also suggests that if the tailing fines dry, they will approximate the consistency of silt or clay particle sizes; therefore, windblown dust may be a potential problem. However, crusting of the tailing fines surface will alleviate some of this potential problem. Accordingly, windblown dust controls and/or operating procedures to ensure that the tailings are maintained at or above optimum moisture at all times were developed. Total suspended particle monitoring is planned to ensure that if windblown dust from the MWDF is detected, corrective measures such as sprinkling can be implemented. The tailing fines were shown not to contain asbestiform minerals.

5.0 TERRESTRIAL AND AQUATIC ECOSYSTEMS

Studies of the terrestrial and aquatic ecosystems of the mine waste disposal facility area are referenced here to fulfill requirements in NR 182.08(2)(d)8a and b. For a more detailed presentation of ecosystems of the environmental study area, refer to Sections 2.6 (Terrestrial Ecology) and 2.5 (Aquatic Ecology) in Chapter 2 of the Environmental Impact Report (EIR) for the Crandon Project. These two sections of the EIR are based on available literature and field survey data of the site area compiled by Dames & Moore, Normandeau Associates, Inc. (NAI) and Interdisciplinary Environmental Planning, Inc. (IEP). A brief synopsis of the information is provided in this chapter.

The setting for the Crandon Project is a portion of northern Wisconsin known as the Northern Hardwood province of the Laurentian Mixed Forest (Bailey, 1978). The regional study area, which is typical of this part of the northern conifer-hardwood forest, generally consists of heavily forested uplands interspersed with forested lowlands (Curtis, 1959). The dominant species in upland forests include northern red oak, white pine, red pine, and aspen. Animals associated with these forests are characteristic of this region and include white-tailed deer, black bear, snowshoe hare, river otter, beaver, and raccoon (EIR, Section 2.6).

5.1 Terrestrial Ecosystems

5.1.1 Regional Flora and Fauna

The Crandon Project environmental study area, including the proposed MWDF, is located in a region of transition between two major biotic communities: the hardwood forest of southern Wisconsin, and the coniferous forest of northern Wisconsin (EIR, Section 2.6).

The northern coniferous forest is composed of three distinct communities: mesic, xeric, and lowland. In the northern mesic forest the dominant species are sugar maple, yellow birch, and hemlock. The northern xeric forest is composed of two segments: the dry segment, dominated by jack pine, red pine, and white pine; and the dry mesic segment, dominated by white pine, red maple, and red oak.

The northern lowland forest is also composed of two segments: the wet segment, and the wet mesic segment. The wet segment includes the tamarack-black spruce bog forest and the white cedar-balsam fir coniferous swamps. The wet mesic segment of the northern lowland forest is dominated by the black ash-yellow birch-hemlock hardwood swamps (Curtis, 1959).

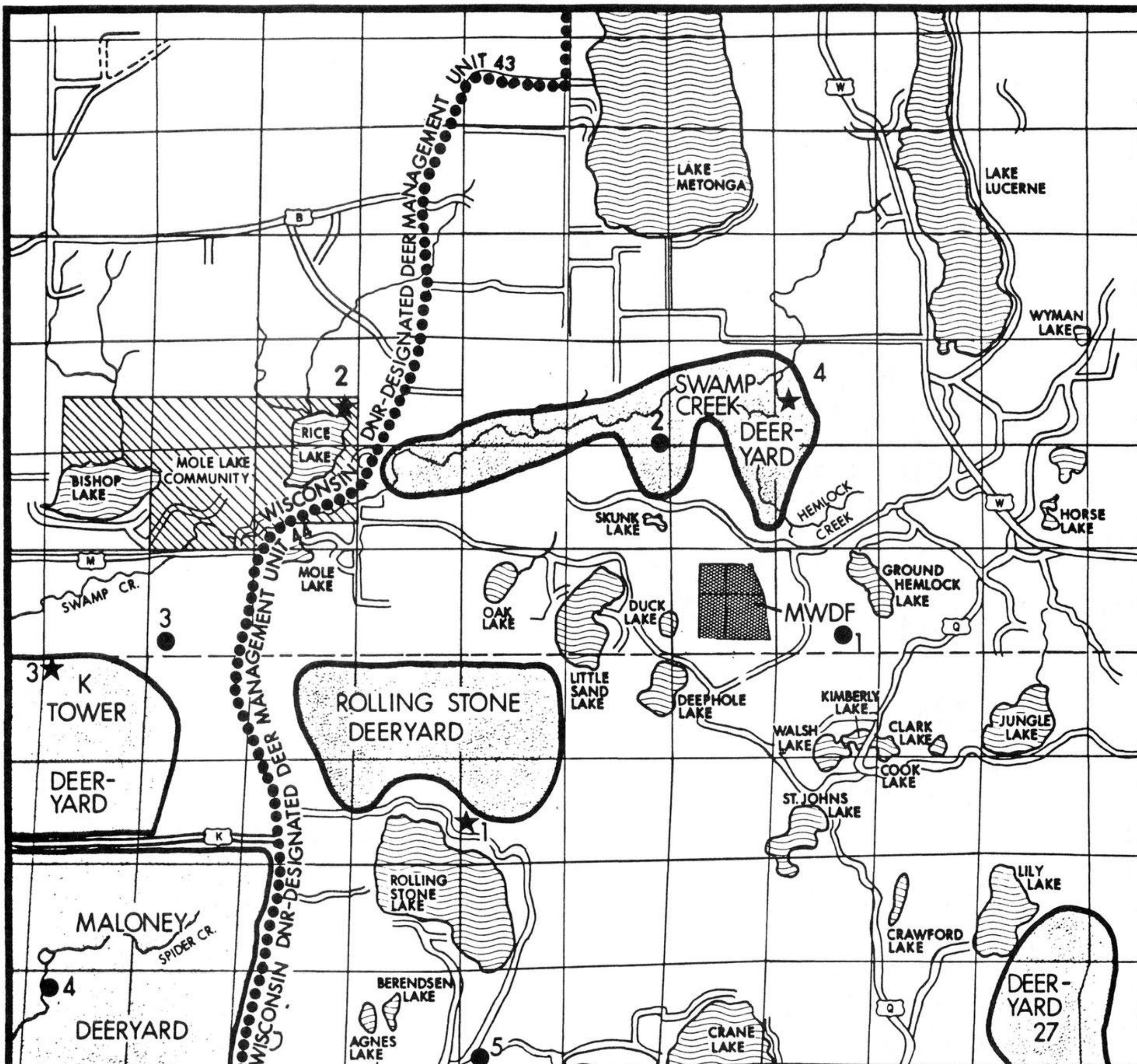
The main wetland vegetative communities of northeastern Wisconsin include bog, shrub swamp, deciduous swamp, coniferous swamp, marsh, and aquatic bed (NAI and IEP, 1982). The bog community consists of a shrub layer dominated by heath species and an herbaceous layer dominated by sedge species. Deciduous vegetation is most characteristic of shrub swamps and alder is frequently the predominant species. Deciduous swamp wetlands are synonymous with Curtis's wet mesic northern lowland forest.

Coniferous swamp wetlands are synonymous with Curtis's wet northern lowland forest in which white cedar and balsam fir are dominant. In swamps where yellow birch and white cedar dominate, the community is classified as a wet mesic northern forest (Curtis, 1959). The dominant species in marshes are sedges and blue-joint grass; this conforms to the southern sedge meadow or the wet prairie community described by Curtis (1959). Aquatic beds are dominated by water lilies and bur reed.

The faunal species of Wisconsin are largely related to the transition zone vegetation. Animals of the environmental study area include species characteristic of both the northern coniferous forests and southern deciduous forests (NAI and IEP, 1982). Sixty-seven species of mammals occur in Wisconsin and over 50 of these species have suitable habitat in the environmental study area (EIR, Section 2.6).

Most mammals have broad habitat requirements and, hence, their home ranges include a variety of both upland and wetland ecosystems. The large mammals include white-tailed deer and black bear, species which frequently inhabit wetlands (NAI and IEP, 1982). In winters of deep snow and severe low temperatures, deer often congregate in deeryards, usually lowland areas of swamp conifer that provide food and shelter. Five Wisconsin DNR-designated deeryards are identified within the environmental study area (Figure 5-1). The proposed MWDF is not located in any of the deeryards.

Black bear habitat includes heavily forested areas containing a mixture of terrestrial communities such as forests, bushlands, swamps, and scattered openings. The black bear population number, estimated from approximate county-wide densities, is 1 per 4 square miles (EIR, Section 2.6).



★ BALD EAGLE NESTS

1. ROLLING STONE LAKE
2. RICE LAKE
3. MOLE LAKE
4. SWAMP CREEK

● OSPREY NESTS

1. GROUND HEMLOCK LAKE
2. SWAMP CREEK
3. MOLE LAKE
4. SPIDER CREEK FLOWAGE
5. PICKEREL CREEK

N

MILES
1 .5 0 1 2
1 .5 0 1 2 KILOMETERS

●●●●● DEER MANAGEMENT UNIT BOUNDARY

WISCONSIN DNR DESIGNATED DEERYARD

NOTE: K TOWER, MALONEY AND NUMBER 27 DEERYARDS EXTEND OUTSIDE OF THE ENVIRONMENTAL STUDY AREA

EXXON MINERALS COMPANY CRANDON PROJECT					
TITLE DESIGNATED ANIMAL HABITATS IN THE ENVIRONMENTAL STUDY AREA					
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY BWM	DATE 07/28/82	CHECKED BY R.P.Hartel		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-'82	
APPROVED BY	DATE	EXXON D.E. Hine		DATE	
DRAWING NO FIGURE 5-1			SHEET OF		REVISION 1

Several species of small mammals are characteristic of the upland and wetland communities of the environmental study area. These include the snowshoe hare, gray squirrel, water shrew, southern bog lemming, and woodland jumping mouse. These species generally have high reproduction rates and their population levels change readily in response to habitat differences. The important commercially harvested mammals (furbearers) of the environmental study area are muskrat, river otter, beaver, and raccoon (EIR, Section 2.6; NAI and IEP, 1982).

Approximately 245 species of birds occur in northeastern Wisconsin and Vanderschaegen (1981) has documented 244 of these species in Forest, Oneida and Vilas counties. Species typical of the northern coniferous forests such as raven, ruby-crowned kinglet, and evening grosbeak are found together with those characteristic of the deciduous forests to the south, including great crested flycatcher, black and white warbler, and red-eyed vireo. The majority of these species migrate south during the winter.

It is estimated that one-third of all species of North American birds rely upon wetlands for some resource (NAI and IEP, 1982). However, less than 1 percent of the environmental study area is meadow or marsh type wetlands and, therefore, it does not attract large numbers of waterfowl for breeding (EIR, Section 2.6). As reported for other types of habitats, the variety of breeding bird species occurring in a particular wetland community is related to its vegetational, spatial, or structural complexity, and those with permanent open water appear to have a greater variety of species than do similar habitats without water (NAI and IEP, 1982).

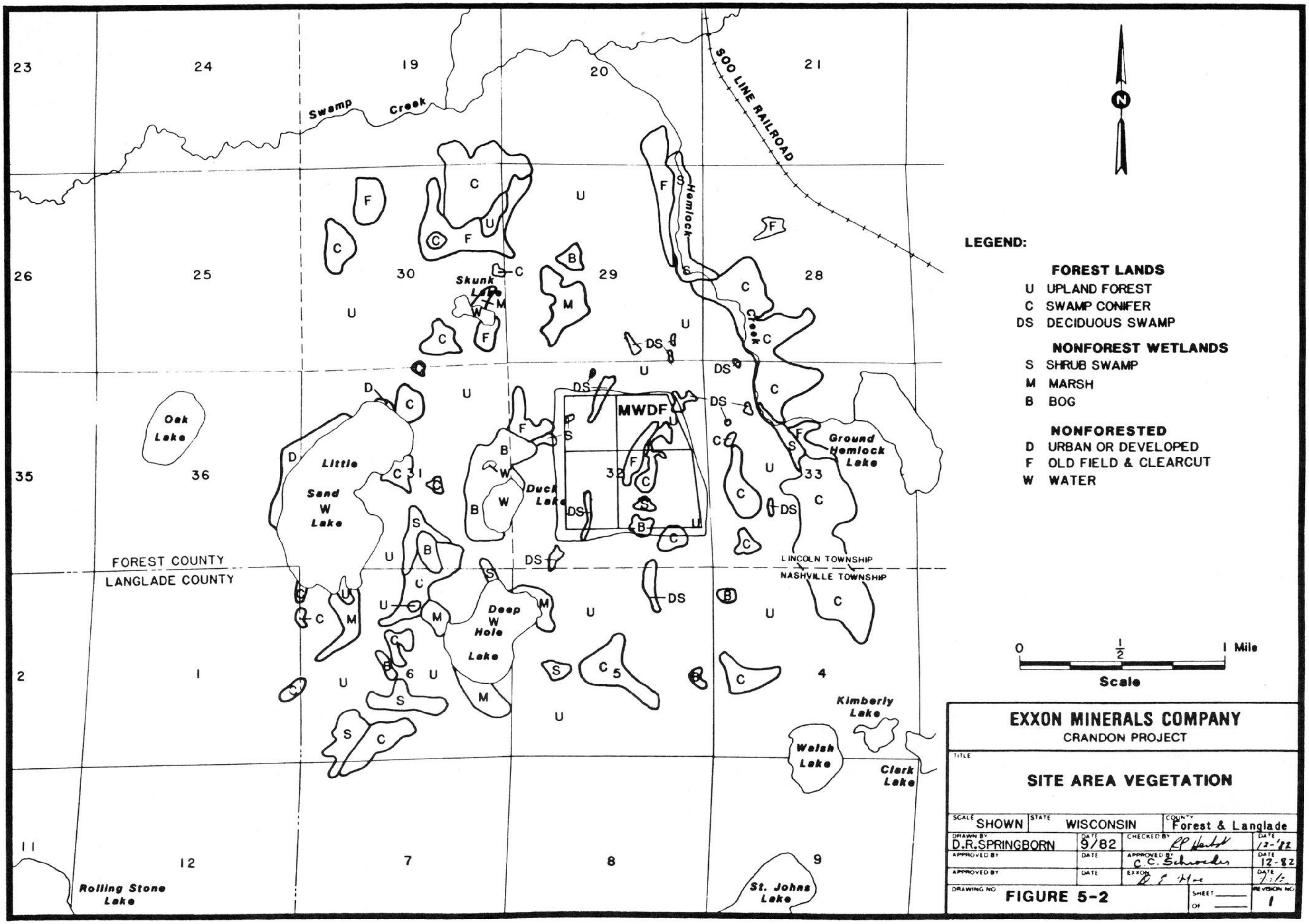
The ranges of 34 amphibian and reptile species extend into northeastern Wisconsin (NAI and IEP, 1982). Of these, 29 could be expected to occur in Forest County (EIR, Section 2.6). Species typical of the northern coniferous forests such as the mink frog and blue spotted salamander are found together with more southern species such as the water snake, bullfrog, and pickerel frog (NAI and IEP, 1982).

Generally, all amphibians require wet areas during the breeding season and many reptiles use them for both feeding and cover. Wetlands in the environmental study area that typically have northern and southern plant species, also have amphibians and reptiles adapted to both. These species include the green frog, spring peeper, American toad, and garter snake (NAI and IEP, 1982).

5.1.2 Site-Specific Flora and Fauna

The site area lies in southern Forest County and northeastern Langlade County. The most abundant vegetation type at the proposed MWDF is forested upland (EIR, Section 2.6; Figure 5-2). Vegetative wetland types include bogs, shrub swamps, deciduous swamps, coniferous swamps, marshes, and aquatic beds (NAI and IEP, 1982). Coniferous swamps are the most common wetland type in the site area. This type is primarily composed of hemlock, tamarack, and black spruce. The various vegetation types of the site area are listed in Table 5.1.

The wetland terrestrial vegetation at the proposed MWDF location (Figure 5-2) consists of 2 conifer swamps, 5 deciduous swamps, 1 bog, and 1 shrub swamp that will be affected by this facility. Qualitative and quantitative descriptions of the terrestrial communities found at the proposed MWDF are provided in the EIR and other reports (NAI and IEP, 1982; Steigerwaldt, 1982). Results of these quantitative investigations indicated that species composition and community characteristics were representative of the terrestrial ecosystems found in northern Wisconsin.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SITE AREA VEGETATION

SCALE SHOWN	STATE WISCONSIN		COUNTY Forest & Langlade		
DRAWN BY D.R.SPRINGBORN	DATE 9/82	CHECKED BY RP Hartzl		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO FIGURE 5-2		SHEET ___ OF ___		REVISION NO 1	

TABLE 5.1

VEGETATION TYPES OF THE SITE AREA WITH APPROXIMATE SIZES AS DETERMINED FROM FIELD STUDIES*

TYPES	APPROXIMATE AREA ACRES	PERCENT OF TOTAL
Upland Forest	11,490	59
Swamp Conifer	3,865	20
Shrub Swamp	544	3
Marsh	383	2
Bog	211	1
Urban or Developed	98	< 0.5
Water	1,347	7
Old Field and Clearcut	839	4
Agriculture	823	4
TOTALS	19,600	100

*Source: EIR, Section 2.6

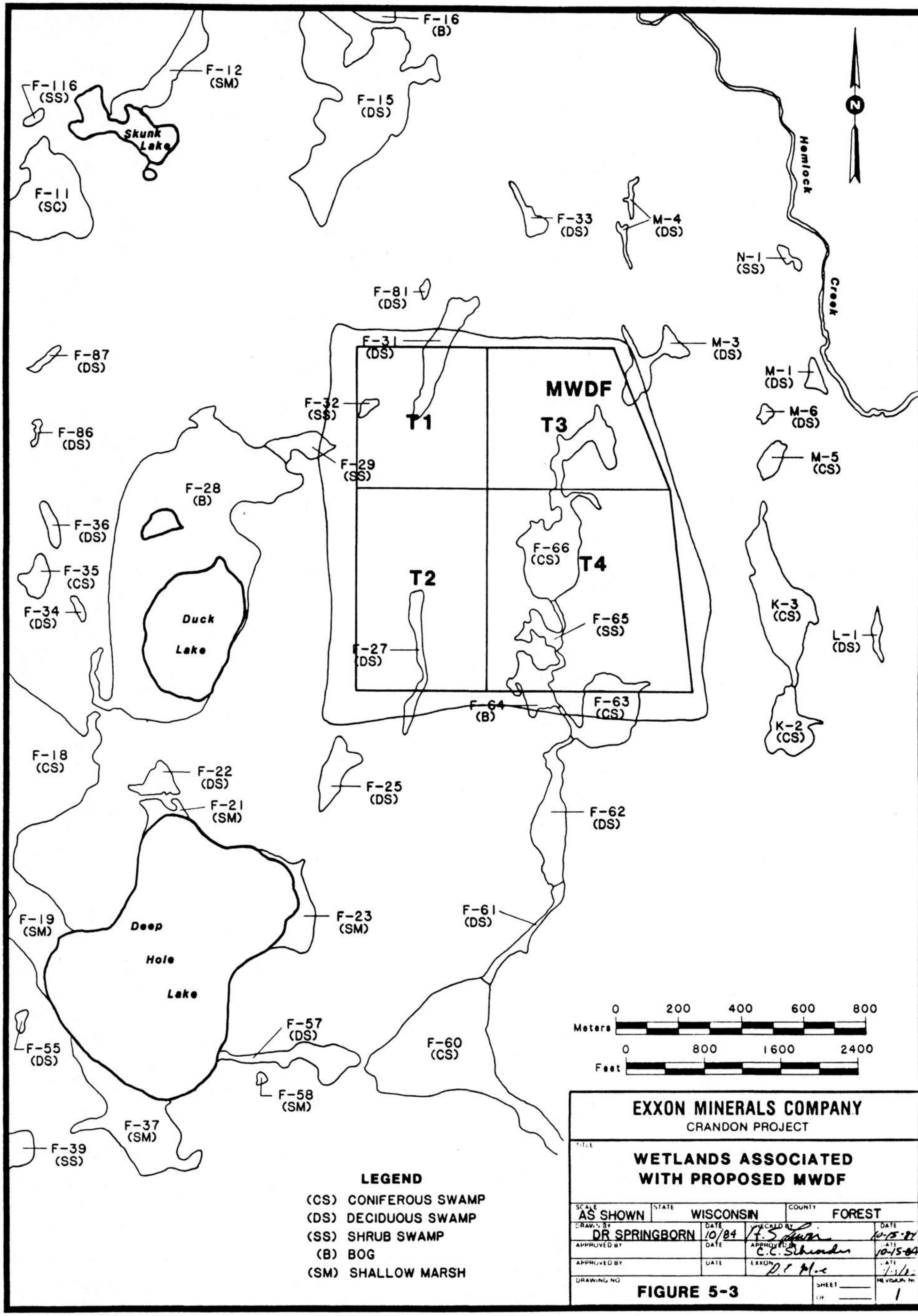
characteristics were representative of the terrestrial ecosystems found in northern Wisconsin.

The wetlands near the proposed MWDF have been characterized in detail by NAI and IEP (1982). Figure 5-3 shows the location, type, and identification number (NAI and IEP, 1982) of wetlands studied within the proposed boundaries of the MWDF. These wetlands are: F25, F27, F31, F32, F63, F64, F65, F66, and M3. A brief description of these wetlands is presented below.

Wetlands F25 and F27 - Wetlands F25 and F27 are wetlands in which water flows through and into Deep Hole Lake. Wetland F25 is a high density wooded swamp containing black spruce and a deciduous portion composed mainly of American elm, balsam poplar, and green ash with a sparse ground cover. Wetland F27 consists of nearly equal proportions of low density deciduous swamp and shrub swamp, and is composed mainly of American elm and green ash, with wild leek and dutchmans breeches representing the ground cover. Wetlands F25 and F27 are surrounded by mixed upland forest and both are within 100 feet of access roads.

Wetlands F25 and F27 are perched on glacial till. They occur in semi-closed basins and receive, store, and slowly discharge water downstream as part of a riparian system contributing to Deep Hole Lake. They afford opportunities for storm water control, water quality maintenance, and hydrologic support to Deep Hole Lake.

Wetland F31 - Wetland F31 is in the upper part of a chain of wetlands in which water ultimately flows into Duck Lake. Wetland F31 is a medium dense deciduous swamp dominated by a tree layer of red maple and American elm, with speckled alder in the shrub layer and blue-joint grass, dutchmans breeches and wild leek constituting the ground cover. Wetland F31



F-16 (B)
F-12 (SM)
F-116 (SS)
Skunk Lake
F-15 (DS)
F-11 (SC)
Hemlock
Creek
F-33 (DS)
M-4 (DS)
N-1 (SS)
F-81 (DS)
F-31 (DS)
M-3 (DS)
F-87 (DS)
M-1 (DS)
MWDF
F-32 (SS)
T1
T3
M-6 (DS)
F-86 (DS)
F-29 (SS)
M-5 (CS)
F-28 (B)
F-36 (DS)
F-66 (CS)
T4
F-35 (CS)
T2
K-3 (CS)
F-34 (DS)
Duck Lake
F-65 (SS)
L-1 (DS)
F-27 (DS)
F-64 (B)
F-63 (CS)
K-2 (CS)
F-18 (CS)
F-22 (DS)
F-25 (DS)
F-21 (SM)
F-62 (DS)
F-19 (SM)
Deep Hole Lake
F-23 (SM)
F-61 (DS)
0 200 400 600 800
Meters
0 800 1600 2400
Feet
F-55 (DS)
F-57 (DS)
F-60 (CS)
F-58 (SM)
F-37 (SM)
F-39 (SS)
LEGEND
(CS) CONIFEROUS SWAMP
(DS) DECIDUOUS SWAMP
(SS) SHRUB SWAMP
(B) BOG
(SM) SHALLOW MARSH
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WETLANDS ASSOCIATED WITH PROPOSED MWDF
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 10/84
CHECKED BY
DATE 10-15-84
APPROVED BY
DATE
APPROVED BY C.C. Schroeder
DATE 10-15-84
APPROVED BY
DATE
EXXON
DRAWING NO FIGURE 5-3
SHEET
OF
REVISION NO 1

is a semi-closed basin occurring on glacial till with no definable water flow channel within the wetland. This wetland has relatively thin, low permeability soils allowing prolonged water interaction between the soils and vegetation.

Red maple, green ash and american elm are the dominant tree species in wetland F32. This wetland is in a closed basin and is surrounded by mixed upland forest.

Wetland F63 - Wetland F63 is part of a chain of wetlands in which water flows through and into Deep Hole Lake. This wetland is a coniferous swamp and is dominated by dense black spruce, tamarack, hemlock, and white cedar in the overstory and a shrub layer of leatherleaf, large cranberry, and Labrador tea. This wetland is surrounded by mixed upland forest. Structural diversity, amount of edge, and interspersion of the vegetation provides wildlife habitat.

Wetland F63 has a continuous surface water hydrologic connection without a definable stream channel, and water is transported by shallow interflow within the organic soils. This wetland occurs on glacial till and surface water must pass through its dense vegetative communities and the organic soils before reaching Deep Hole Lake.

Wetlands F64, F65, and F66 - Wetlands F64, F65, and F66 are poorly connected by surface water. Wetland F64, a bog, is dominated by dense leatherleaf and black spruce with sedges and manna grass comprising the herbaceous layer. Wetland F65 is mainly a dense shrub swamp with a small proportion of associated coniferous swamp. The predominant shrub swamp species are green ash, meadowsweet, and willow. Wetland F66 is primarily a moderately dense coniferous swamp with a small area of sapling shrub swamp. Predominant tree species in the coniferous swamp are black spruce, hemlock, and balsam fir, and winterberry, willow, and speckled alder are most common in the shrub layer. These wetlands are surrounded by mixed upland forest and are without road access. Overall, life form variability and edge were favorable which is indicative of high wildlife habitat potential.

Wetlands F64, F65, and F66 are located in semi-closed basins in glacial till. All have ephemeral outlets with water flow between and within the wetlands predominantly soil interflow. Surface water flow seldom occurs in these wetlands.

Wetland M3 - Wetland M3 is one of the three wetlands (including M2 and M1) in a connected system whose surface water flows through them and into Hemlock Creek. Wetland M3 is a wooded swamp consisting of high density deciduous and coniferous species. The deciduous portions are composed mainly of green ash with fewer numbers of red maple, yellow birch, and American elm; the coniferous component consists primarily of hemlock with lesser numbers of black spruce. This wetland is surrounded by mixed upland forest and lacks road access. Vegetative structural diversity, edge and life form variability indicated moderate potential for wildlife habitat.

Wetland M3 is perched on till. It has a low nearly flat area which collects surface water and stores it in organic wetland soils. Water passes slowly through this wetland and is discharged intermittently downstream to wetland M2. The wetland occurs at the top of the watershed and has a low water budget.

Of the species of mammals reported for Forest County, 29 were observed in the site area, including white-tailed deer and black bear (EIR, Section 2.6). The density of deer was estimated at 6 per 1 square mile of deer range, which was half of the DNR goal (15 per 1 square mile of deer range) for management units in the vicinity (EIR, Section 2.6). Indications of black bear occurrence in the site area were also observed during field activities (EIR, Section 2.6). Thirteen species of small mammals were captured in the area; of these, the five most abundant were the deer mouse, southern red-backed mole, masked shrew, short-tailed shrew, and eastern chipmunk (NAI and IEP, 1982).

Bird species observed included raptors, gamebirds, waterfowl, marsh birds, and songbirds (NAI and IEP, 1982). The site area attracts few waterfowl for breeding because most of the species require marshes with open water nearby for successful reproduction. The majority of terrestrial ecosystems in the site area are wooded swamps and shrub swamps which are not major waterfowl breeding habitats (EIR, Section 2.6). Estimates of ruffed grouse population densities, when compared to other reported densities for other areas in northern Wisconsin, suggest that habitats of the site area are of low value to ruffed grouse (EIR, Section 2.6). Songbirds were the most numerous species in the site area (EIR, Section 2.6).

Of the 23 species of reptiles and amphibians reported for Forest County, 14 were observed in the site area (EIR, Section 2.6). Blue spotted salamanders, spotted salamanders, American toads, spring peepers, and wood frogs were observed around water bodies during the spring. Reptiles observed in the site area included painted turtles, garter snakes, and a fox snake (NAI and IEP, 1982).

5.1.3 Mine Waste Disposal Facility Relationships to Terrestrial Ecosystems

From construction until reclamation, the proposed mine waste disposal facility, including the borrow area, would affect approximately 400 acres of terrestrial ecosystems. Of the most abundant vegetation community type of the site area, upland northern hardwood forest, the proposed MWDF (400 acres) will eliminate less than 4 percent of the available 11,490 acre habitat. Similarly, for the wetland ecosystems of the site area, the proposed MWDF (assuming the 400 acres design was developed solely in wetlands) would replace approximately 8 percent of available habitat (5,003 acres).

If the comparison is made on the basis of the environmental study area (EIR, Section 2.6) or wetlands regional study area (NAI and IEP, 1982), the percent of disturbed terrestrial ecosystems is even smaller. For the northern hardwood forest and wetland type communities, these percentages are less than 0.01 and 0.007 for the environmental study area (41,888 acres) and wetland regional study area (60,655 acres), respectively. The location of the proposed MWDF will, therefore, disrupt a small portion of the terrestrial ecosystems and available animal habitat.

5.2 Aquatic Ecosystems

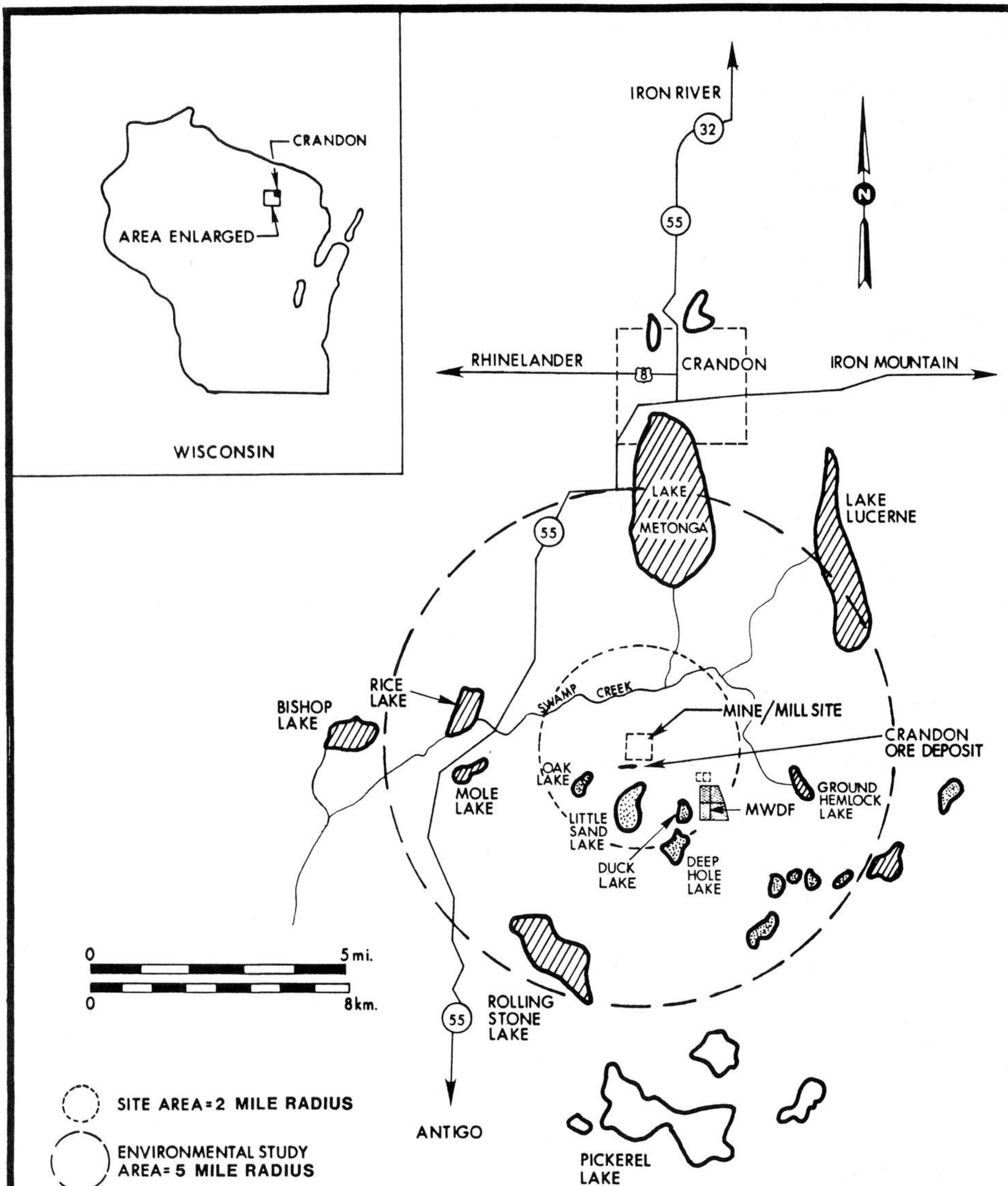
5.2.1 Regional Flora and Fauna

Aquatic biological communities in the environmental study area of the Crandon Project are found in surface water (Figure 5-4) which can be classified as recharge and discharge lakes and streams (EIR, Section 2.5). Recharge lakes contain water that is characteristically soft (10-20 mg/1 $CaCo_3$ hardness) and low in pH (less than 6), because precipitation and the surface water drainage of their watersheds are the principal water sources. Streams of the environmental study area are generally small with base water flow rates derived mostly from ground water sources, and have moderately hard and slightly basic pH (above 7) water quality. Discharge lakes receive stream water and possibly ground water inputs and contain water that has pH and hardness values similar to those of the streams. The aquatic flora within each water body type can be characterized by the dominant species of phytoplankton, periphyton, and aquatic macrophytes (EIR, Section 2.5).

Phytoplankton populations within the lakes of the environmental study area are in general dominated by golden-brown algae. Patterns of phytoplankton composition and abundance vary seasonally among golden-brown algae, blue-green algae, green algae, and diatoms (EIR, Section 2.5).

Diatoms are the most abundant periphyton found in these lakes and streams. Other major taxa found comprising the periphyton community include golden-brown algae, blue-green algae, and green algae (EIR, Section 2.5).

Aquatic macrophytes in the lakes differ largely because of water chemistry and lake morphometry. Aquatic macrophytes typical of hard water bodies are water milfoil, blackstem pondweed, whitestem pondweed, and coontail (Moyle, 1945; Hellquist, 1980). Aquatic macrophytes found typically in soft



EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

RECHARGE AND DISCHARGE LAKES OF THE ENVIRONMENTAL STUDY AREA

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DMC	DATE 7/82	CHECKED BY R P Herbst		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C. C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON D E Moe		DATE	
DRAWING NO. FIGURE 5-4		SHEET ___ OF ___		REVISION 1	

water bodies of the environmental study area are water lobelia, bur reed, pipewort, mud plaintan, and pondweed. Wild rice is abundant and harvested commercially from Rice Lake (EIR, Section 2.5).

Regional study area aquatic ecosystems can also be characterized by their major components of zoöplankton, benthic macroinvertebrates and fish communities. Zooplankton communities of hard water lakes are dominated by rotifer and copepod species. For soft water lakes, copepods dominate those with clear water, whereas rotifers dominate brown stained, or bog lakes (EIR, Section 2.5).

Whereas water quality of a lake is important in determining zooplankton distribution, the composition of benthic macroinvertebrates primarily depends upon habitat characteristics such as substrate types, current velocity, and dissolved oxygen content. Aquatic midge larvae are the most abundant benthic macroinvertebrates found in lake and bottom areas of slow moving water in streams. Although they occur over a wide range of substrates, midges are more productive in soft sediments of muck and detritus where they can withstand periods of dissolved oxygen depletion. Mayflies and caddisflies are benthic macroinvertebrates that more commonly occur in fast flowing waters with gravel and rubble substrate (EIR, Section 2.5).

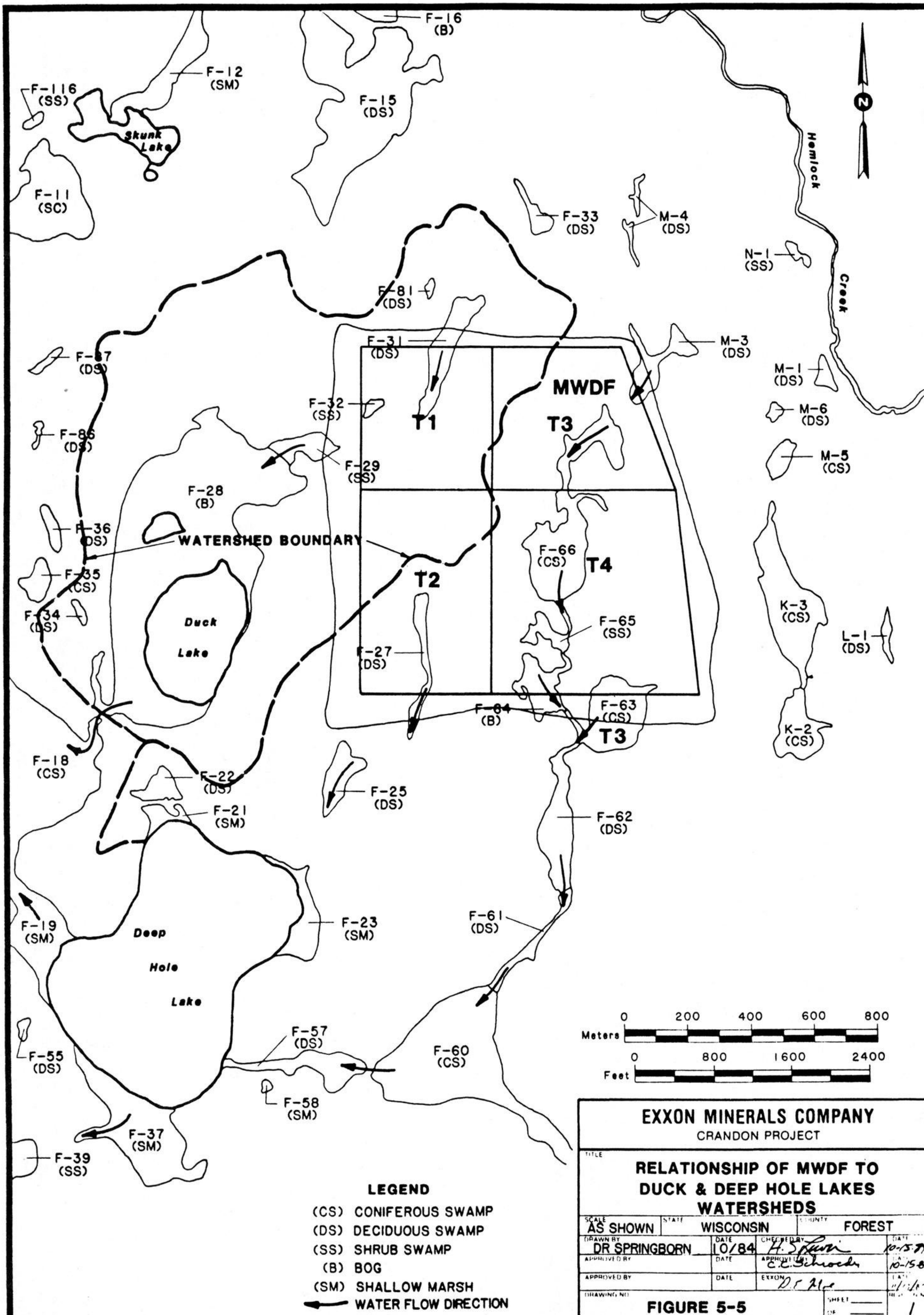
In the hard water lakes and the Wolf River, fish fauna are dominated by black bullhead, white sucker, yellow perch, and/or some species of the sunfish family. The diversity of fish in hard water lakes is much higher than that in soft water lakes where yellow perch are the dominant species. Large creeks are generally dominated by minnows. Brook trout and molted sculpin dominate the small head water creeks (EIR, Section 2.5).

5.2.2 Site-Specific Flora and Fauna

The proposed MWDF would be located primarily in the watersheds of Duck and Deep Hole lakes (Figure 5-5). The aquatic flora of these lakes is similar to that described for soft water lakes of the environmental study area (EIR, Section 2.5). The pondweed *Potamogeton confervoides* collected once from Duck Lake is listed by the DNR as a state threatened species. The location of the MWDF does not contain any distinguishable streams. Zooplankton communities of Duck and Deep Hole lakes were dominated by rotifer and copepod species. Copepods were generally found in highest numbers in the summer months. Although the total abundance of the species varied between the lakes, they did not differ appreciably (EIR, Section 2.5).

Benthic macroinvertebrate populations in both lakes were also quite similar. However, their dominant groups differed; worms were the major species in Duck Lake and midges the most abundant organisms in Deep Hole Lake. Midges, caddisflies, and mayflies were also found abundantly in Duck Lake, whereas worms, caddisflies, and clams were collected in moderate densities from Deep Hole Lake (EIR, Section 2.5).

Yellow perch, black bullhead, and mudminnows were the only fish species collected from Duck Lake. Similarly, yellow perch, walleye, white sucker, and golden shiner were the only species collected from Deep Hole Lake. Yellow perch were the most abundant in the sampling periods (EIR, Section 2.5). Neither lake supports major fish populations.



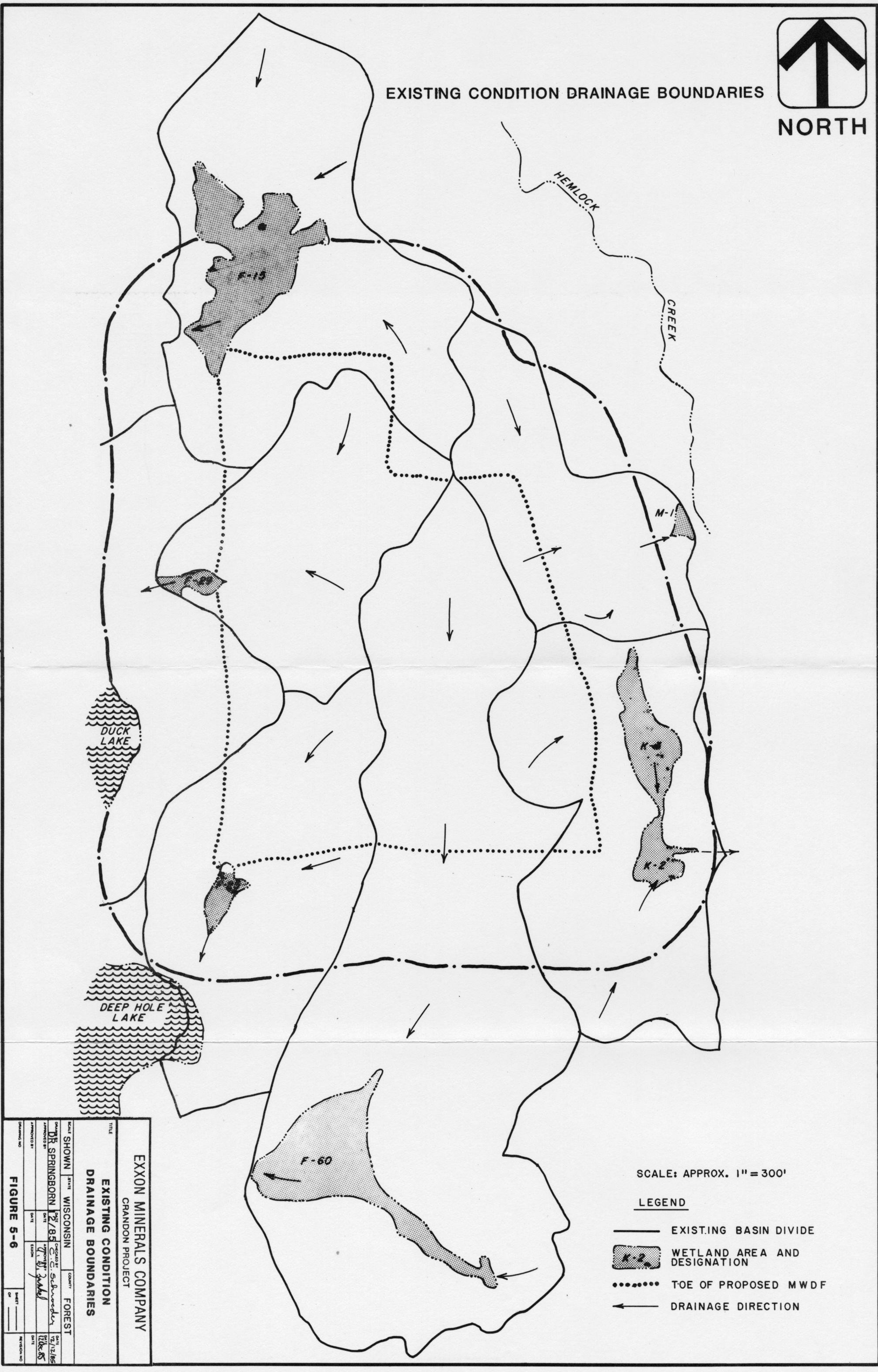
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RELATIONSHIP OF MWDF TO DUCK & DEEP HOLE LAKES WATERSHEDS

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 10/84	CHECKED BY H. S. [illegible]	DATE 10-15-84
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 10-15-84
APPROVED BY	DATE	EXXON D. F. [illegible]	DATE [illegible]
DRAWING NO. FIGURE 5-5		SHEET ___ OF ___	REV. NO. 1

5.2.3 Mine Waste Disposal Facility Relationships To Aquatic Ecosystems

The proposed MWDF is located in the upper portions of the watersheds for Duck and Deep Hole lakes. Less than 10 percent of each watershed will be affected by the location of the proposed MWDF. The watersheds in the immediate MWDF area are shown on Figure 5-6. Except for a small area (less than 10 percent) on the east side of the MWDF, which is within the Swamp Creek watershed, all of the MWDF area is within the Pickerel Creek watershed.


EXISTING CONDITION DRAINAGE BOUNDARIES
NORTH
HEMLOCK
CREEK
F-13
M-1
F-59
DUCK LAKE
K-2
DEEP HOLE LAKE
F-60
SCALE: APPROX. 1" = 300'
LEGEND
EXISTING BASIN DIVIDE
K-2 WETLAND AREA AND DESIGNATION
TOE OF PROPOSED MWDF
DRAINAGE DIRECTION
EXXON MINERALS COMPANY
CRANDON PROJECT
EXISTING CONDITION
DRAINAGE BOUNDARIES
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DR SPRINGBORN 12/85
FIGURE 5-6

5.3 Threatened and Endangered Species

Endangered species are those species of plants or wildlife that are in danger of extinction throughout all or a significant portion of their range (U.S. Department of the Interior, 1973). Populations of these species have usually been severely reduced in distribution and density from past levels. Threatened species are those that are likely to become endangered within the foreseeable future throughout all or a significant portion of their range (EIR, Section 2.6). The location of the proposed MWDF does not directly disrupt any habitat utilized by a species listed as endangered or threatened by either the federal or state government.

There are no federally listed plant species identified for the environmental study area (EIR, Section 2.6). Floating uprooted vegetation was found along the east and southeast shoreline of Duck Lake in July 1978. Among this vegetation were specimens identified as pondweed (*Potamogeton confervoides*) which is listed as threatened in Wisconsin. A search of the littoral area of Duck Lake specifically for this species in July and October 1980 produced no specimens (EIR, Section 2.5).

No mammals on either the federal or state endangered species lists were observed in the environmental study area. The federal government and Wisconsin do not list any threatened mammals for the state (EIR, Section 2.6).

The bald eagle is a threatened species at the federal level and endangered at the state level. There are four known bald eagle territories in the environmental study area (see Figure 5-1), two of which were active in 1982. Of the four bald eagle territories in the environmental study area, three appear to contain alternate nest sites. The mean number of young produced per active territory in the environmental study area during the period 1974-1982 was 1.2. The Rolling Stone Lake nest, active annually for over 5 years, has been the most productive (EIR, Section 2.6) and is approximately 2.5 miles southwest of the proposed MWDF.

The environmental study area also contained five active osprey nests in 1982 (Figure 5-1). The osprey is listed as endangered at the state level. Of these five nests, three produced a total of eight young in 1982. Annual osprey production in the area has varied from a high of 2.0 young per active territory in 1975, to 0.6 young per active territory in 1978. The mean number of young produced per active territory in the area during the period 1974-1982 was 1.0 (EIR, Section 2.6).

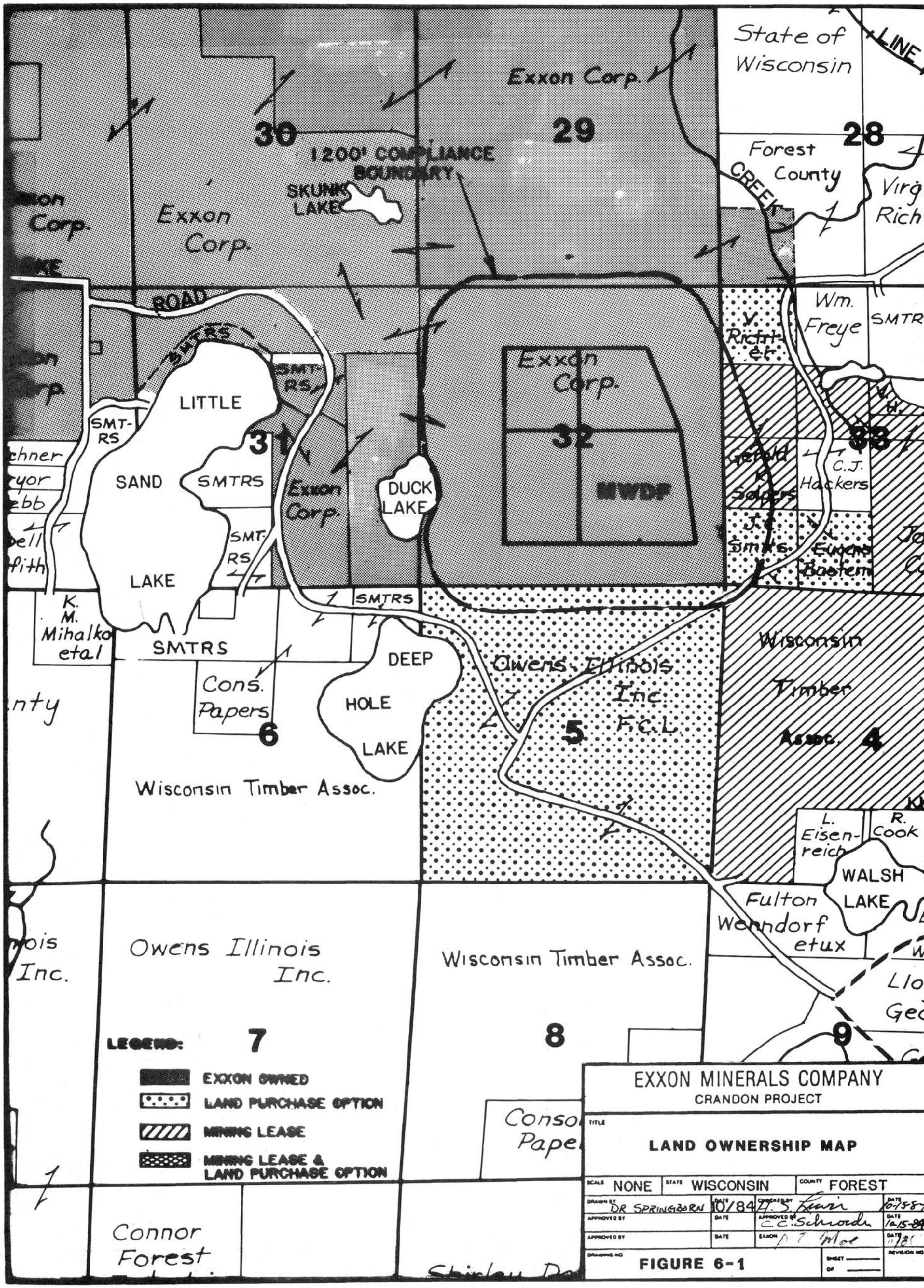
The Cooper's hawk occurs throughout Wisconsin and is listed as threatened by the state. Cooper's hawks have been observed in the area, and their numbers have declined in response to pesticide-induced lowering of productivity (EIR, Section 2.6).

No amphibians or reptiles that are considered endangered by the federal government occur in Wisconsin. There are 10 species of amphibians and reptiles that are listed by the DNR as endangered or threatened. Of these 10 species, two have ranges and habitat preferences that make their occurrence in the environmental study area possible; these include the wood turtle and Tremblay's salamander. Neither of these species was observed in the environmental study area (EIR, Section 2.6).

6.0 LAND USE

6.1 Land Ownership

Approximately 85 percent of the land within 5 miles of the proposed MWDF is privately owned. The remaining 15 percent of the land is publicly owned (EIR, Section 2.9). Land ownership adjacent to and near the proposed MWDF is shown on Figure 6-1 and Plan Sheet 3, Ownership and Zoning Map. As shown, Exxon owns, leases, or has purchase options for the land for the proposed MWDF and for all property within the 1,200-foot compliance boundary for the MWDF.



EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE **LAND OWNERSHIP MAP**

SCALE NONE	STATE WISCONSIN	COUNTY FOREST
DRAWN BY DR SPRINGBORN 10/84	CHECKED BY H. S. Lenz	DATE 10-15-84
APPROVED BY	APPROVED BY C.C. Schroeder	DATE 10-15-84
APPROVED BY	EXXON	DATE

FIGURE 6-1

6.2 Zoning

There are currently no zoning ordinances for the site area which would require modification or change to the proposed MWDF design.

A summary of current zoning for the site is presented below.

Forest County - On June 10, 1980, the Forest County Board of Supervisors approved and adopted a revised zoning ordinance prepared by the North Central Wisconsin Regional Planning Commission (1980). The revised ordinance has not been accepted by any of the towns in Forest County. However, the Towns of Lincoln and Nashville have enacted their own zoning ordinances which were submitted to, and approved by, the Forest County Board.

Mining is covered by the Forest County ordinance in Chapter 15 - Planned Development. Specifically, a Metallic Mineral Mining and Prospecting Planned Development (M-PD) is described in Section 15.29 of the code. However, since the Project is located in the Towns of Lincoln and Nashville which have their own zoning ordinances, the MWDF does not require any approvals from Forest County.

Town of Lincoln - The Town of Lincoln zoning ordinance is based on the County ordinance. The mining section of the ordinance is contained in Chapter 15 - Planned Development. The specific standards for a Metallic Mineral Mining and Prospecting Planned Development are described in Sections 15.29 through 15.36. Exxon has filed a Mining Planned Development Application for approval by the Town of Lincoln.

Town of Nashville - The Town of Nashville zoning ordinance is modified after the Forest County ordinance. The mining section of the ordinance is contained in Chapter 15 - Planned Development. The specific standards for a Metallic Mineral Mining and Prospecting Planned Development are described in Sections 15.30 through 15.41. Exxon has filed a draft Mining Planned Development Application based on a draft of the Town of Nashville zoning ordinance. A formal application will be submitted for approval by the Town of Nashville in the near future.

6.3 Land Use

The regional study area is primarily forested upland and forested wetland with an abundance of lakes and streams. Forests, along with the abundant lakes and streams in northern Wisconsin, provide for fishing, hunting, swimming, boating, camping, snowmobiling, and site-seeing (Langlade County and Wisconsin Department of Natural Resources, 1974; Johanesen, 1976; EIR, Section 2.9). The regional study area contains a large percentage of publicly owned land (15 percent) (EIR, Section 2.9). The percentage of each type of land use, estimated from topographic maps, aerial photographs, and reconnaissance of the environmental study area, is presented in Table 6.1.

Approximately 77 percent of the land in the environmental study area is used for forestry, 12 percent for recreation and 6 percent for residential use. Approximately 5 percent of the land area is used for agriculture, including dairy farming, livestock production, and crops of oats, alfalfa, hay, and potatoes. Agricultural uses are limited because of the irregular slopes, stoniness, dryness of higher elevations, wetness in depressions, and short growing season (EIR, Section 2.9). Less than 1 percent of the land area in the environmental study area is used for transportation purposes.

The environmental study area is located in the Towns of Nashville and Lincoln in Forest County and the Town of Ainsworth in Langlade County. The 1981 population densities for these townships were 10.7, 8.2 and 6.1 people per square mile, respectively. This is far below the 1980 state average of 86.4 people per square mile (EIR, Section 2.9). Most residences are concentrated along lakes. The community nearest the proposed MWDF is the unincorporated community of Mole Lake. In early 1982 the Sokaogon Chippewa Community at Mole Lake had a population of 262 (Divine, 1982).

TABLE 6.1

LAND USE
WITHIN THE ENVIRONMENTAL STUDY AREA

LAND USE	PERCENT OF TOTAL AREA	AREA SQUARE MILES
Forestry	76.5	76.5
Recreation	11.8	11.8
Residential	6.4	6.4
Agriculture	5.0	5.0
Transporation	0.3	0.3
Total	100.0	100.0

Except for the City of Crandon, which is approximately 5 miles north of the proposed MWDF, there are no major commercial or retail centers in the regional study area. The community of Mole Lake has rental cottages, a tavern, and a small shopping center. There are also several resorts, inns, boat rentals, private campgrounds, and eating and drinking establishments in the environmental study area (EIR, Section 2.9).

Approximately 15 percent of the land in the environmental study area is publicly owned, mostly county forest land. Other public lands include state trust and DNR owned lands, the city airport approximately 3 miles northwest, and a county park 2.5 miles north of the proposed MWDF (EIR, Section 2.9).

There are no state or federally designated scenic areas, such as state parks, Wisconsin scientific areas, or natural landmarks within the environmental study area. A State Historical Society roadside marker is located in the Mole Lake Indian Community. There is a distant view of the Crandon Project site area from a lookout tower on Sugarbush Hill approximately 6 miles northeast of the proposed MWDF (EIR, Section 2.9).

The regional study area has a developed system of federal, state, and county highways, and town roads, and all lands in the environmental study area are within at least approximately 2-3 miles of a highway or road.

Special attention has been given to the archaeology of the environmental study area, as well as that of the MWDF. Fifty-four archaeological and historical sites were identified in the regional study area as part of a background literature search (Salzer and Birmingham, 1978; Overstreet and Brazeau, 1982). None of the sites identified in the literature search are within the boundaries of the proposed MWDF. More extensive field surveys were conducted near and in the area of the proposed MWDF by Salzer and

Birmingham (1978) and Overstreet and Brazeau (1982). It was concluded from the literature and field surveys that no important archaeological resources would be threatened by development of the MWDF.

Plan Sheet 2, Existing Conditions/Land Use, shows the land use information for the proposed MWDF. The land within the proposed MWDF is currently used primarily for forestry purposes and includes both upland and wetland forested communities. Forestry (upland and wetland areas), recreational (lakes) and residential/institutional uses are designated on the plan sheet. This sheet also shows that no threatened or endangered species or habitats, or archaeological and historical sites have been identified within the area designated for the proposed facility.

7.0 GEOLOGY AND HYDROLOGY

During siting of the MWDF, Exxon conducted geotechnical work in much of the environmental study area (within 5 miles radius of the ore deposit). Pertinent regional study area findings are presented in this report and detailed discussions are available in the referenced reports. This information is also useful for identifying site-specific characteristics.

Following the regional studies and the subsequent selection of Area 41 for the MWDF, detailed site-specific geologic and hydrologic investigations were conducted to characterize Area 41. This chapter summarizes the results of these investigations. Methods of investigation and original data interpretations are available in the reports which are referenced in this chapter.

7.1 Topography

The MWDF site, located in the Northern Highlands region of Wisconsin, has hills of moderate elevation with a poorly developed surface water drainage system. Many wetlands, including perched upland wetlands, and numerous lakes and streams, are present in the regional study area (NAI and IEP, 1982).

Elevations in the environmental study area range from approximately 1,535 feet MSL, 3 miles west to 1,850 feet MSL, 5 miles northwest of the proposed MWDF. The upland areas are largely composed of glacial till and typically trend to the southwest. Deposits from glacial meltwater adjacent to the glacial ice front exhibit a hummocky irregular topography. Glacial drift deposits have a relatively flat topographic surface and sometimes occur as valley fills. The lacustrine deposits adjacent to some existing lakes represent ancient lake beds which had a higher water level, and have a generally flat topographic surface.

The topography and landforms are presented on the existing conditions map (Plan Sheet 2). The proposed MWDF will be located on a north-south trending wooded upland area which is predominantly between elevation 1,640 and 1,700 feet. Elevations are as low as 1,600 feet near the lakes, streams, and wetlands which surround much of the site area (Figure 7-1). Immediately north of the facility, there are hills as high as 1,740 feet. The upland location of the MWDF will provide setbacks from lakes, wetlands, and ground water discharge areas. It also provides for a large separation distance from the main ground water aquifer with a large unsaturated zone beneath the facility for attenuation of potential seepage.

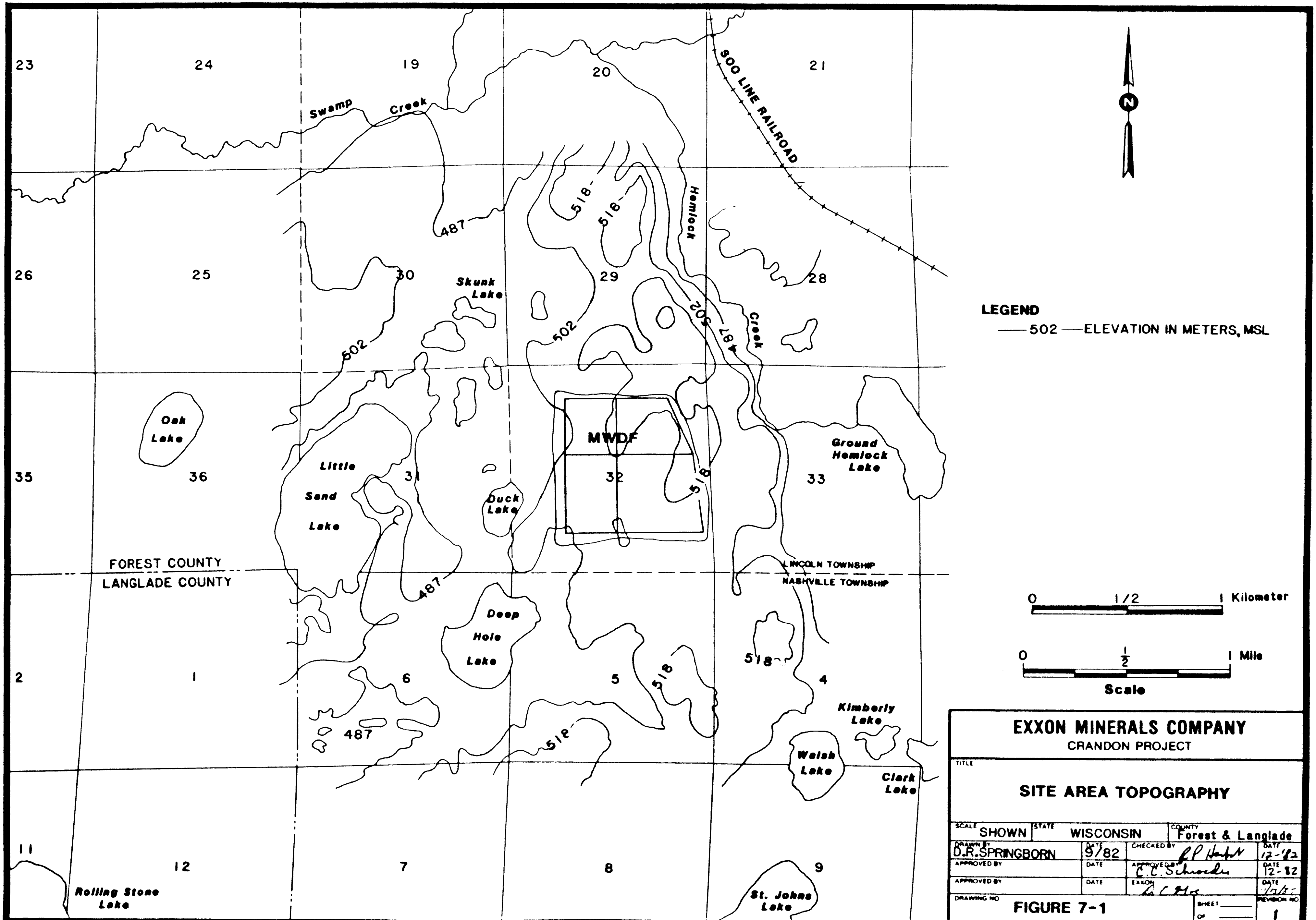


FIGURE 7-1

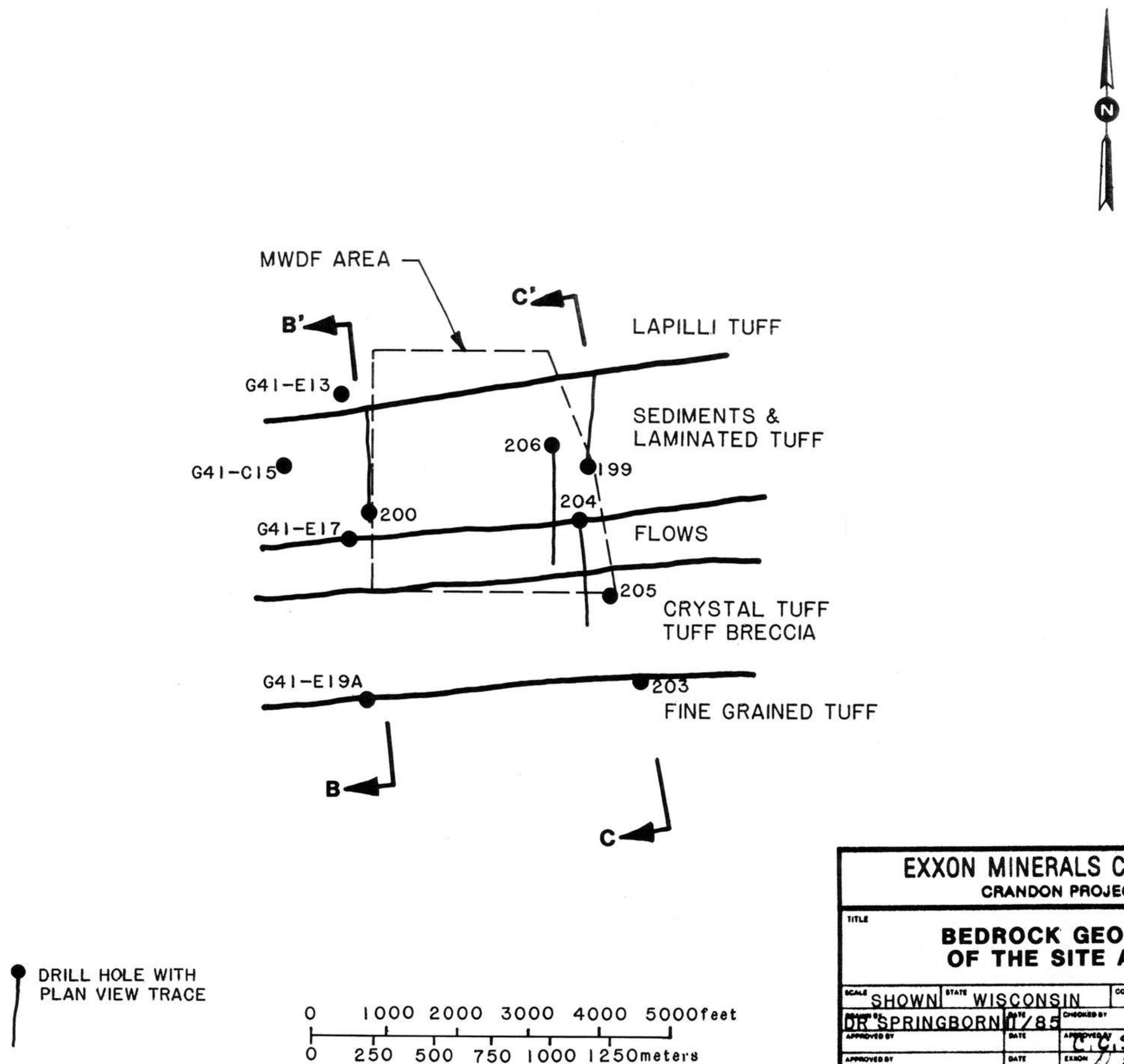
SITE AREA TOPOGRAPHY

7.2 Bedrock

The bedrock of northern Wisconsin is an extension of the Canadian Shield, a continental block of the earth's crust which has been relatively stable tectonically over a long period of time (EIR, Section 2.2). The bedrock types in the region are Precambrian age igneous and metamorphic. Within the Crandon Project environmental study area, the bedrock is primarily metamorphosed volcanic tuffs (Golder, 1981b).

The regional trend of the bedrock surface in north-central Wisconsin is downward to the east and southeast at approximately 7 to 10 feet per mile. Within Forest County and the environmental study area, the bedrock surface is irregular (Golder, 1981b). The interpreted bedrock surface for the MWDF and site area is shown on Figure 7-2. Beneath the MWDF, the average bedrock elevation is 1,410 feet MSL, or approximately 260 feet below ground surface.

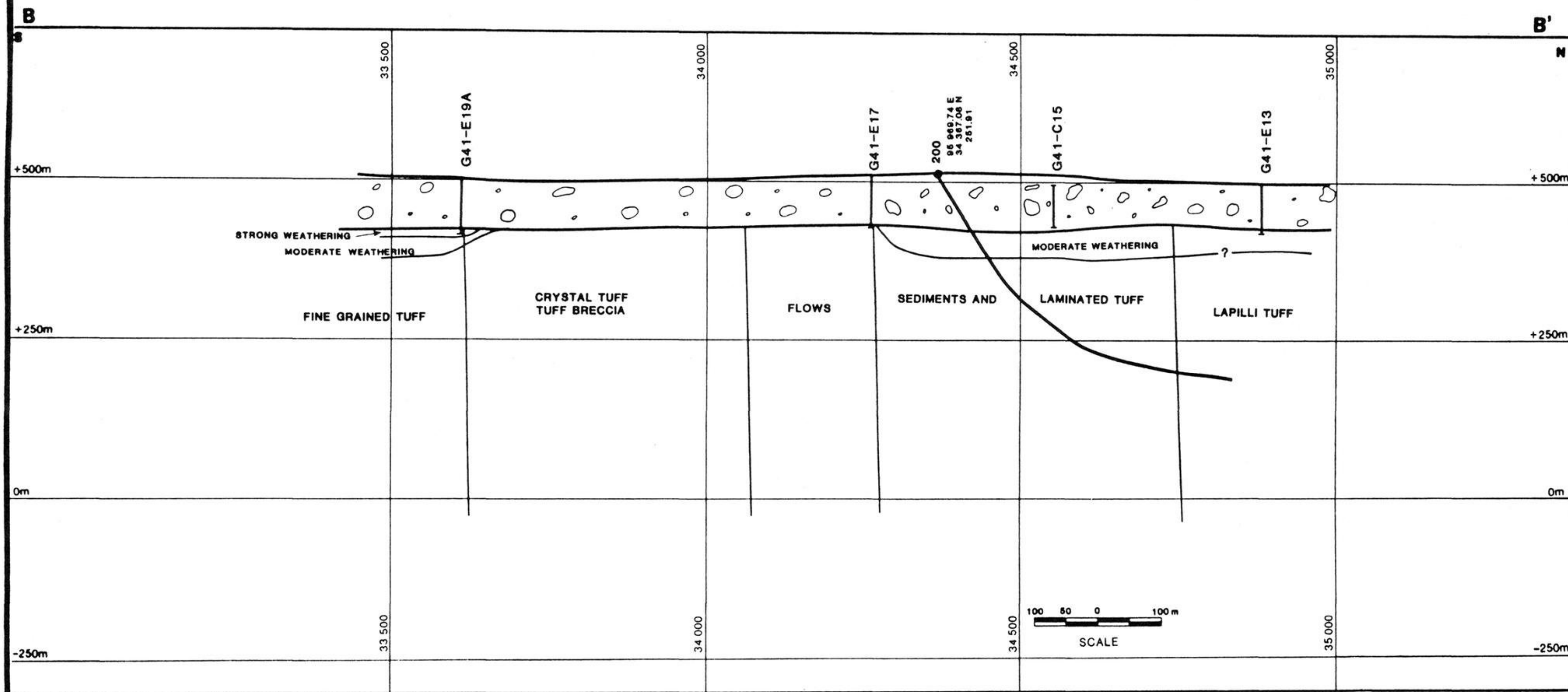
Six 984 feet bedrock diamond drill core holes (#199, 200, 203, 204, 205 and 206) were placed in the proposed MWDF area (Area 41). A few meters of bedrock core were also taken from the bottom of six glacial overburden holes (G41-C15, G41-E13, G41-E17, G41-E19A, G41-F24 and G41-P24) (also see Bedrock Permeability Report) to further delineate bedrock geology. A plan view of the geology in the proposed MWDF area is presented in Figure 7-3 and north-south cross sections in Figures 7-4 and 7-5. The bedrock is predominantly a fine grained tuffaceous sequence, with crystal tuffs predominanting. The unit labeled "flows" is a series of 10 to 49 feet flows commonly found with interflow tuff beds. The laminated tuff sequence to the north of the flows is very fine grained, indicating a distal volcanic source and quiet conditions. To the north of the laminated tuff lies a crystal tuff sequence.



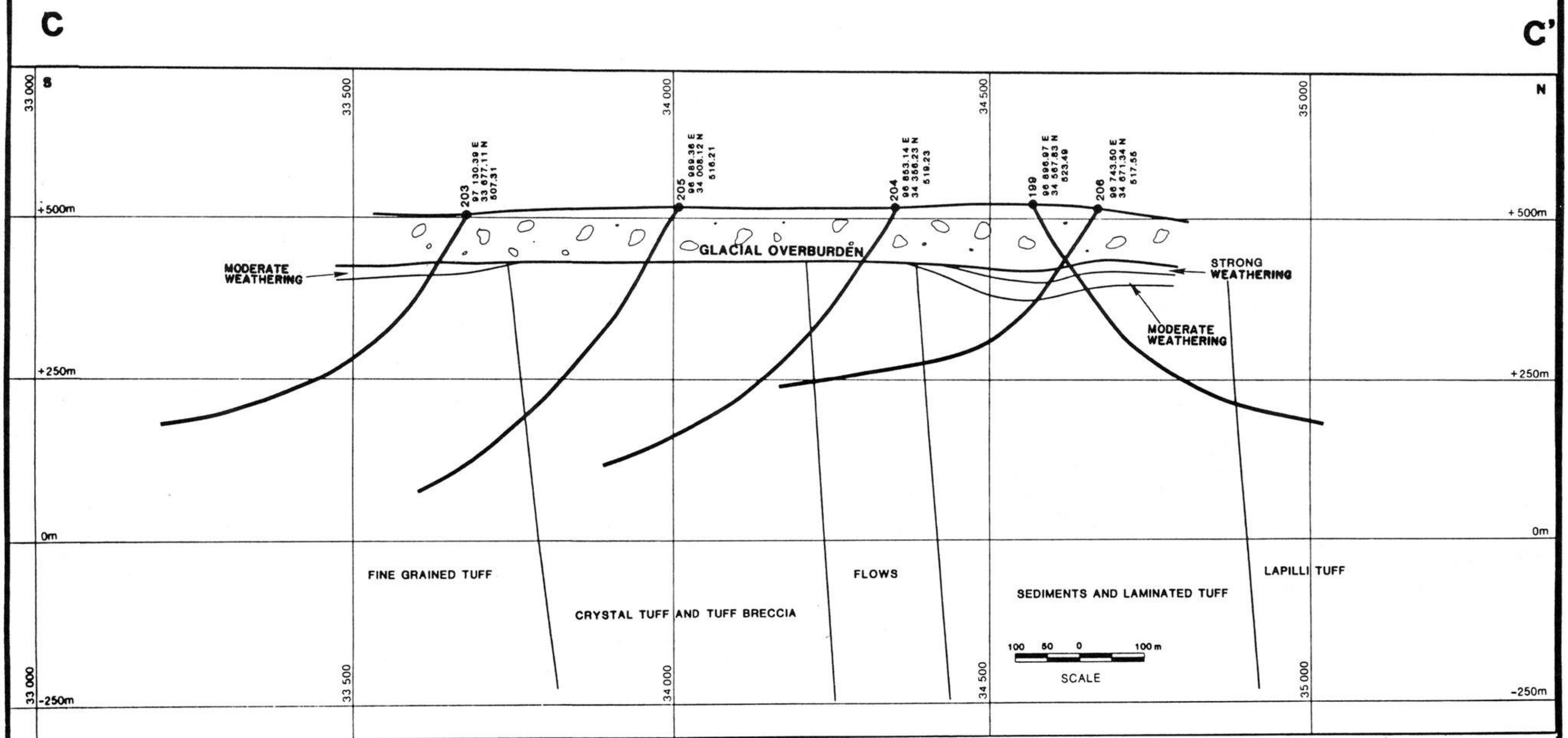
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
BEDROCK GEOLOGY OF THE SITE AREA

SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 11/85	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY C.C. Schneider		DATE 11/85	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO **FIGURE 7-3**			SHEET OF	REVISION NO	



EXXON MINERALS COMPANY CRANDON PROJECT					
TITLE: NORTH-SOUTH CROSS SECTION THROUGH MWDF SITE 41 AREA					
SCALE: SHOWN	STATE: WISCONSIN		COUNTY: FOREST		
DRAWN: ROGER ROWE	DATE	CHECKED BY: H. S. Lum		DATE: 10-15-84	
APPROVED BY	DATE	APPROVED BY: C.C. Schroeder		DATE: 10-15-84	
APPROVED BY	DATE	EXXON: [illegible] Moe		DATE: 11/8[illegible]	
DRAWING NO: FIGURE 7-4			SHEET ____ OF ____		REVISION NO



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
NORTH-SOUTH CROSS SECTION THROUGH MWDF SITE 41 AREA

SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY ROGER ROWE	DATE	CHECKED BY H. S. Lewis		DATE 10-15-84	
APPROVED BY	DATE	APPROVED BY C. C. Schroeder		DATE 10-15-84	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO		SHEET	OF	REVISION NO	

FIGURE 7-5

The bedrock in the MWDF area has been subjected to uninterrupted weathering since Precambrian time. At present, the total thickness of weathered rock is relatively thin because of extensive stripping by glacial action. The degree and extent of weathering are shown on the geologic cross sections (Figures 7-4 and 7-5). Additional details on geology and weathering are presented in the EIR.

The last major geologic change in the regional study area occurred during the period when erosion and glaciation (Wisconsin Stage) deposited as much as 360 feet of glacial sediments over the bedrock (EIR, Section 2.2). Since the end of glaciation, surface water has percolated through these surficial deposits.

7.3 Unconsolidated Deposits

7.3.1 Origin and Distribution

Most surficial glacial material (soil) in the site area probably was deposited during the Woodfordian substage of Wisconsin Stage glaciation, from approximately 22,000 to 12,500 years ago (Golder, 1981a). During this period, ice from the Green Bay Lobe advanced from the southeast and ice from the Langlade Lobe moved from the northeast. These ice advances met in northeastern Wisconsin, resulting in complex interfingering and overlapping of materials (D'Appolonia, 1982b).

The Green Bay Lobe moved soil material from Ordovician dolomites and Cambrian sandstones and deposited a sandy, calcareous drift. Gravel in this drift contains from 2 to 56 percent carbonate fragments (EIR, Section 2.2). The Langlade Lobe glacial soil deposits are similar except they contain fewer large carbonate fragments.

Plan Sheet 6 shows the locations of the geologic cross-sections and borings, wells and piezometers. MWDF site stratigraphy is illustrated on the geologic cross sections (Plan Sheets 7 through 11). The boring profiles used for these plan sheets indicate some variability in soil characteristics within the stratigraphic layers. Generally, soil characteristics within each layer vary gradually rather than forming separate definable layers. Stratigraphic boundaries on the geologic profiles depict major changes in the soil materials as a result of differing modes of glacial deposition (Golder, 1981b). This differentiation helps define the primary hydraulic and attenuative characteristics of the soil, which are important in determining the facility's potential effect on the environment.

The glacial stratigraphy of the site area is complex but can be characterized by three general units (Figure 7-6):

1) Lacustrine deposits commonly overlie the bedrock in the MWDF area. These deposits probably represent an early advance of the Langlade Lobe;

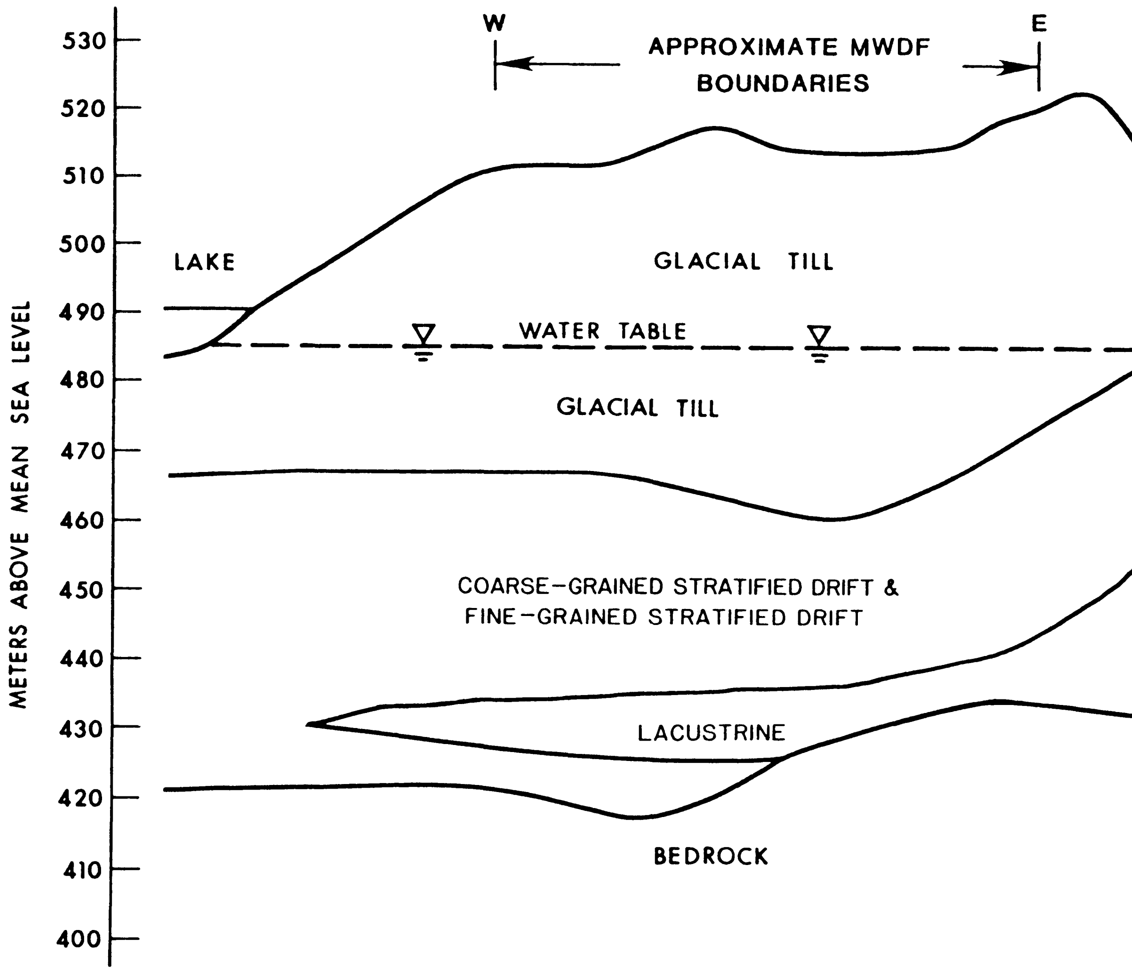
2) The lacustrine deposits are commonly overlain consecutively by fine-grained stratified drift and coarse-grained stratified drift of the Green Bay Lobe. These deposits are the most permeable in the area and are considered the ground water aquifer; and

3) The Langlade glacial till is the upper unit and is generally 130 to 160 feet thick at the MWDF. Since this is the predominant soil material near the surface, it will provide most of the construction material for the MWDF.

Thickness of the upper till and drift unit varies considerably across the MWDF site, ranging from only a few feet to over 200 feet, but is generally 70 to 150 feet for each unit. Discontinuous lenses of lacustrine and glaciofluvial deposits (outwash) occur principally within and below the drift unit and at the upper till-drift interface. Surface lacustrine deposits are also present, mainly surrounding and beneath present-day lakes and wetlands (D'Appolonia, 1982b).

7.3.2 Physical Characteristics

The physical characteristics of the soils on the site are important in the design and function of the MWDF. These soils will form the foundation for the MWDF and will be used to construct embankments. They will also provide attenuative capacity beneath the MWDF for seepage from the ponds.



PHYSICAL-CHEMICAL CHARACTERISTICS

USCS	K_H [1] m/s (feet/sec)	K_V [1] m/s (feet/sec)	pH	NEUTRALIZATION CAPACITY % $CaCO_3$ EQUIVALENT
SM and SP-SM	2.8×10^{-6} (9.2×10^{-6})	9.4×10^{-7} (3.1×10^{-6})	9.1	2.3 (< 3 to > 9)
SP and SP-SM	1.3×10^{-4} (4.3×10^{-4})	1.3×10^{-5} (4.3×10^{-5})	9.8	1.6 (< 3 to 9)
ML	2.8×10^{-6} (9.2×10^{-6})	9.4×10^{-7} (3.1×10^{-8})		
—	—	—		

1. HORIZONTAL (K_H) AND VERTICAL (K_V) HYDRAULIC CONDUCTIVITY VALUES ESTIMATED FROM PUMPING TEST

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: **GENERALIZED SOIL GEOLOGY AND PHYSICAL-CHEMICAL CHARACTERISTICS**

SCALE		STATE WISCONSIN		COUNTY FOREST	
DRAWN BY LCG	DATE 7/27/82	CHECKED BY		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO FIGURE 7-6		SHEET ___ OF ___		REVISION NO 0	

Laboratory and field tests were conducted on the soils to characterize their engineering, hydraulic, and attenuation (see subsection 7.3.3) properties. Samples of each of the glacial materials have been subjected to index properties tests (grain size distribution and Atterburg limits) and each has been classified in accordance with the Unified Soil Classification System. These data were used in the interpretation of the origin of the material. Strength and density parameters were measured or estimated in the till and coarse-grained stratified drift to determine their suitability for foundations and construction (Golder, 1981a).

In-place density of the glacial till soil was measured in five test pits on the MWDF site and values ranged from 110.4 to 138.3 pounds per cubic foot. Bulk samples from these pits were tested in the laboratory for compaction, permeability, and strength. Triaxial test results show that the friction angle of this material ranged from 34 to 40 degrees (Golder, 1981a). These results indicate that the soil is suitable for a wide range of embankment designs.

With the grain size distribution and high density exhibited by the penetration resistance, the friction angle of the coarse-grained stratified drift is estimated to be 35 degrees and in-place density is estimated to range from 100 to 130 pounds per cubic foot (Golder, 1981a). These results indicate this soil will provide a stable base for a properly designed facility.

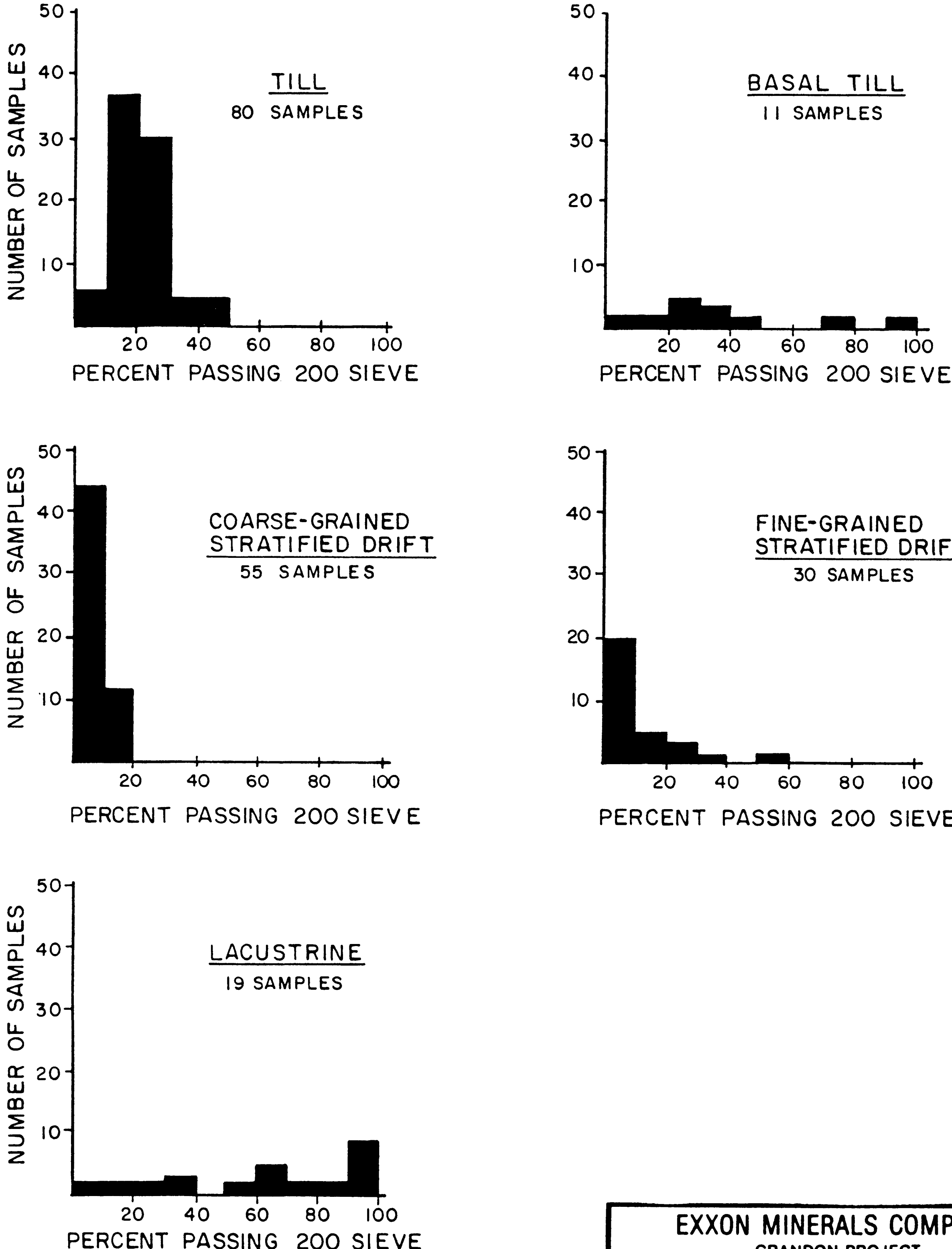
Several types of tests were used to determine the hydraulic characteristics of the glacial soils. Aquifer characteristics were directly investigated by a pumping test and permeability testing was performed in test borings. Laboratory measurements were made on compacted samples from the test pits, and Hazen's approximation was used to estimate soil permeability from the grain size data (Golder, 1981a).

Five genetic types of glacial deposits are found at the Crandon Project. Each is distinguished by particle size distribution, shape of the gradation curve, percent passing the No. 200 sieve (P200), degree of sorting, and depositional features which can be seen in representative samples. The terminology for these five general categories, glacial till, basal till, coarse-grained stratified drift, fine-grained stratified drift and lacustrine is consistent with previous reports. However, refinements have been made to some of the definitions used previously (Golder, 1981a).

Figure 7-7 presents the P200 distribution for the various glacial deposits at the Crandon Project based on the gradation curves for samples from the EX borings (STS Ltd., 1984c).

Glacial Till - Eighty (80) samples of the glacial till were analyzed and had an average P200 of 20 percent within a range of 6 to 45 percent. The majority of the samples had a P200 in the range of 10 to 30 percent (Figure 7-7). A composite gradation curve for the 80 samples of the glacial till is presented in Figure 7-8. All the samples were either classified as SM-SP or SM under the Unified Soil Classification System. Typically, the samples were described as slightly silty fine to medium sand to silty fine to coarse sand. Gradation curves from the glacial till samples have a characteristic shape. The till consists of a well-graded mixture (poorly sorted of silt, sand, gravel and cobbles with only a trace of clay (less than 10 percent). The glacial till deposits are extensive across the site and form many upland areas.

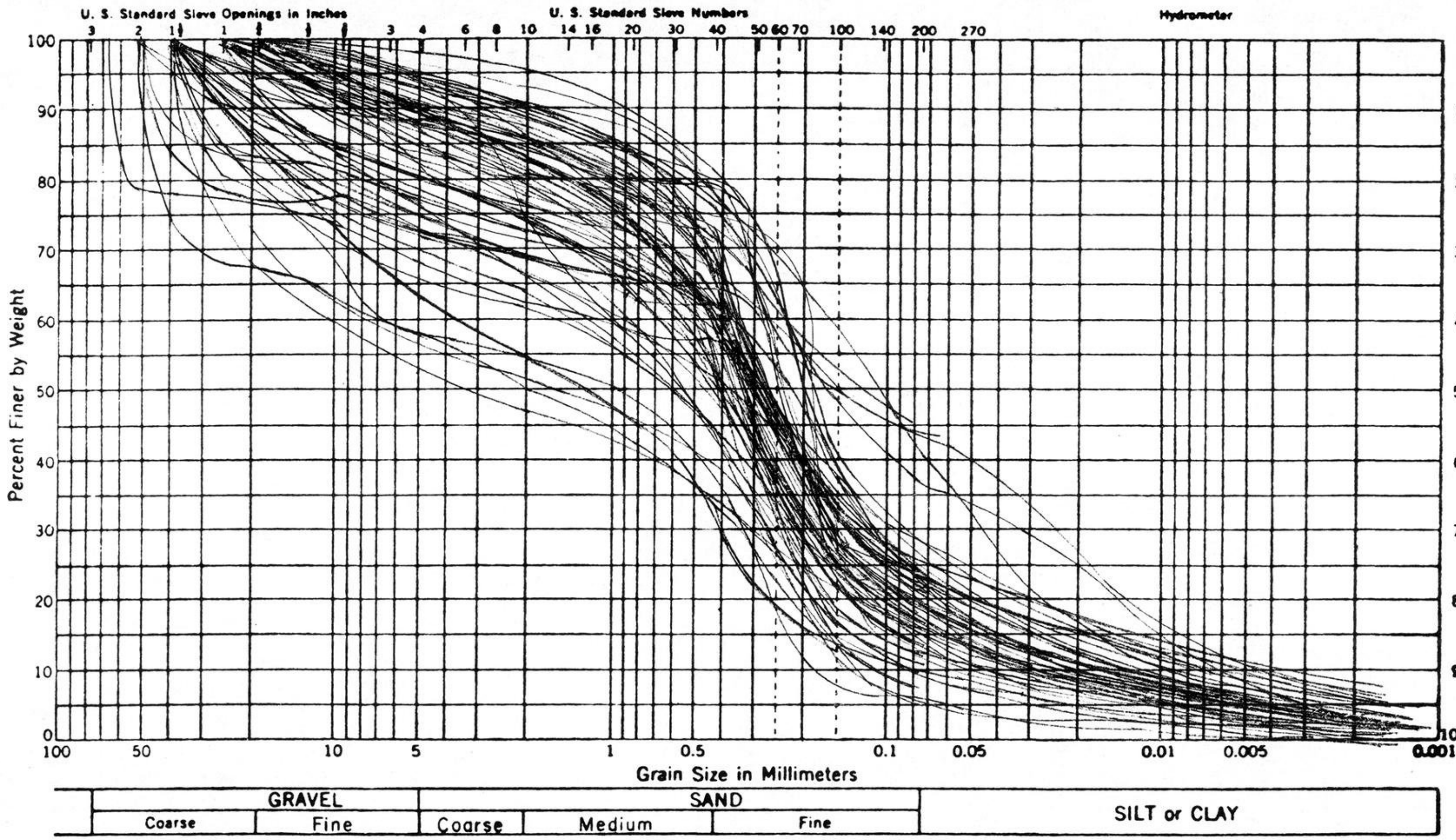
Basal Till - A layer of glacial till was found on the bedrock surface under portions of the site. It was designated as basal till because it could be distinguished from the other till deposits generally by color and



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: P200 DISTRIBUTION FOR VARIOUS GLACIAL DEPOSITS		
SCALE	STATE: WISCONSIN	COUNTY: FOREST
DRAWN BY: JJT	DATE	CHECKED BY: H.S. [illegible] — DATE: 10-15-8[illegible]
APPROVED BY	DATE	APPROVED BY: C. C. Schroeder — DATE: 10-15-8[illegible]
APPROVED BY	DATE	[illegible] — DATE: [illegible]
DRAWING NO: FIGURE 7–7	SHEET ___ OF ___	REVISION NO

UNIFIED CLASS[illegible]ICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Glacial Till SM-SP, SM

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CRANDON PROJECT

TITLE
COMPOSITE GRADATION CURVES

SCALE	STATE WIS.	COUNTY FOREST	
DRAWN BY SMD	DATE	CHECKED BY H. S. Rain	DATE 10-15-84
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 10-15-84
APPROVED BY	DATE	EXXON D. E. [illegible]	DATE
DRAWING NO FIGURE 7–8		SHEET ___ OF ___	REVISION NO

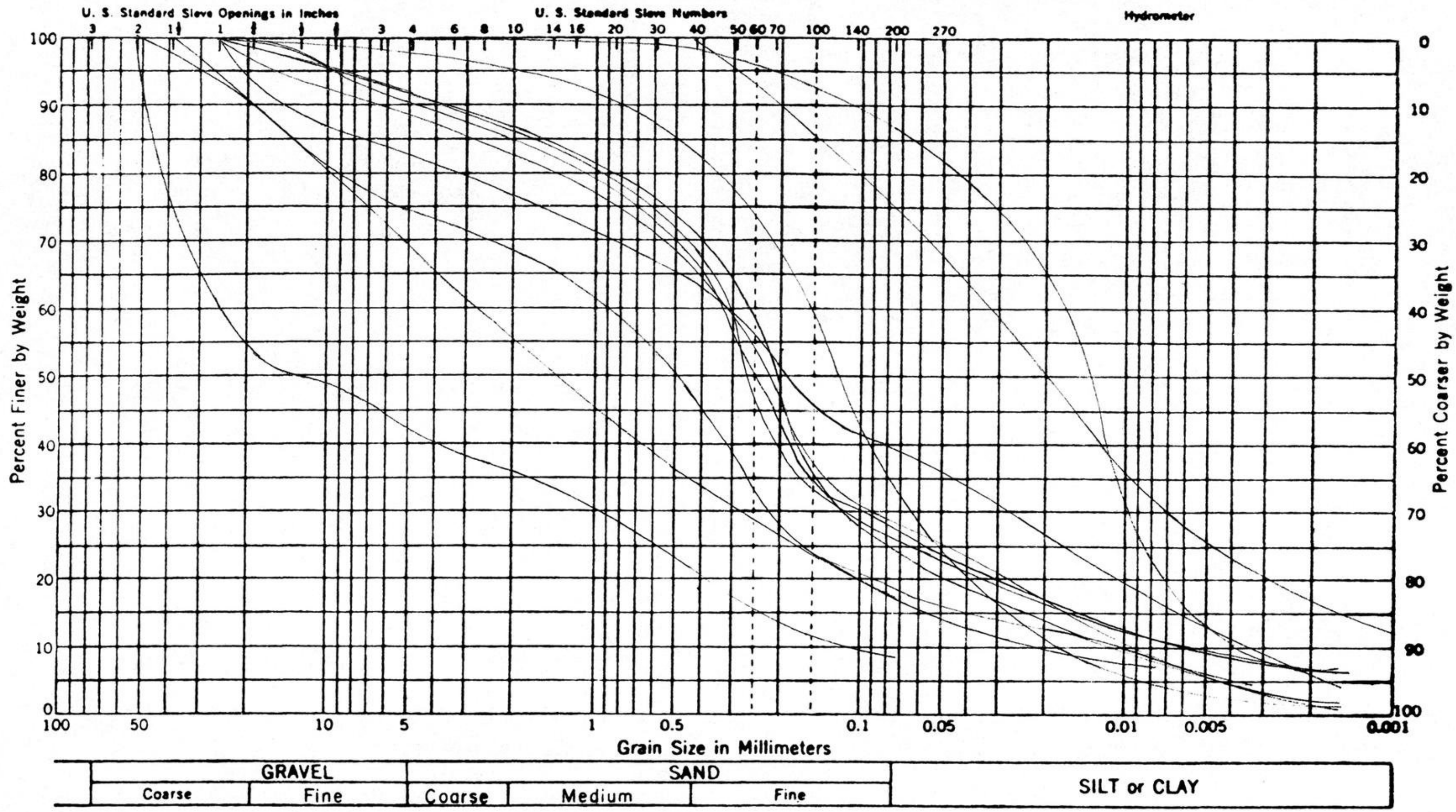
grain size distribution. The basal till generally had a reddish brown color and a higher P200 content. The basal till layer was relatively thin, usually less than 30 feet thick.

The 11 basal till samples which were analyzed for grain size had a range of 9 to 90 percent passing the No. 200 sieve with an average P200 of 36 percent. They were described as silty fine to coarse sand (SM), slightly silty fine to coarse gravel (GM-GP), or fine to coarse sandy silt (ML). The composite gradation curve for the basal till (Figure 7-9) is similar to the surficial till except that the samples had slightly higher P200 content. The basal till was encountered both above and below basal lacustrine deposits.

Coarse-Grained Stratified Drift - As used in this report, the term coarse-grained stratified drift refers to glacial outwash deposits. Fifty-five (55) samples of the coarse-grained stratified drift were analyzed and had a range of 1 to 16 percent passing the No. 200 (0.075 mm) sieve with an average P200 of 7 percent (Figure 7-10). The samples ranged from well-sorted silty fine to medium sand to well-graded sand and gravel. Figure 7-7 illustrates that the majority of the coarse drift samples had a P200 of less than 10 percent. Besides the relatively low P200 content, the coarse-grained stratified drift samples were distinguished by the presence of stratification indicating fluvial deposition which was absent in the till samples.

Fine-Grained Stratified Drift - The definition of fine-grained stratified drift used in this report differs from the one used by Golder (1981a). The Golder definition for fine-grained stratified drift included primarily fine-grained deposits of glacial lacustrine origin consisting of very fine sands and varved silts and clays. Instead, STS Consultants Ltd. has placed the varved deposits into the lacustrine category and has defined the

UNIFIED CLASSIFICATION SYSTEM



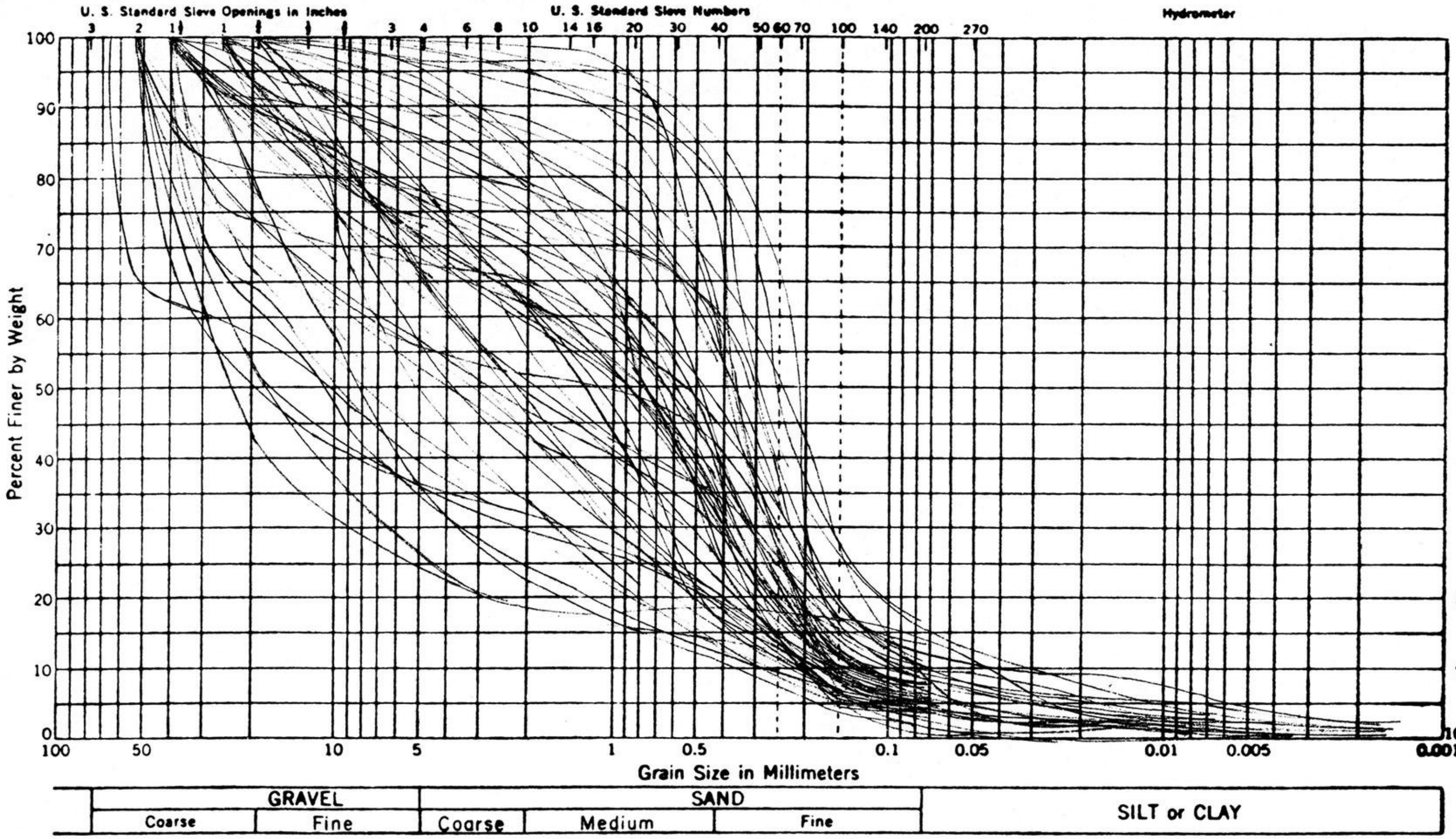
SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Basal Till SM, ML, GM-GP

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
COMPOSITE GRADATION CURVES

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SMD	DATE	CHECKED BY [signature]	DATE 10-15-84
APPROVED BY	DATE	APPROVED BY C. C. Schroeds	DATE 10-15-84
APPROVED BY	DATE	EXXON [signature]	DATE
DRAWING NO FIGURE 7-9	SHEET ___ OF ___		REVISION NO

UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Coarse Grained Stratified Drift
					SP, SW, SM-SP, SM, GP-GM, GP, GW, GM

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
COMPOSITE GRADATION CURVES

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SMD	DATE	CHECKED BY P. S. Lewis	DATE 10-15-84
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 10-15-84
APPROVED BY	DATE	EXXON	DATE
DRAWING NO FIGURE 7-10		SHEET ___ OF ___	REVISION NO

fine-grained stratified drift as relatively well-sorted, uniformly-graded, fine-grained glacial outwash deposits.

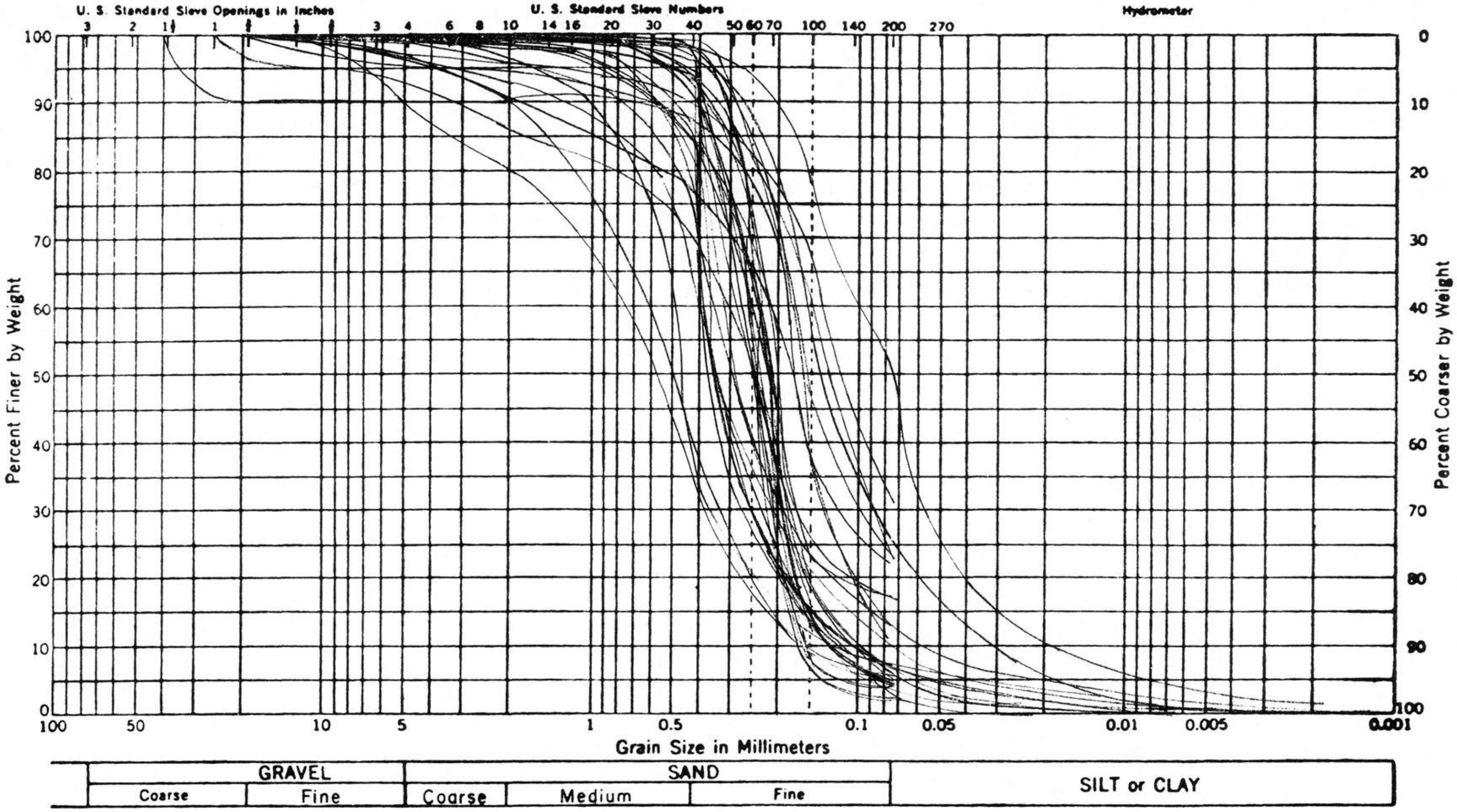
Figure 7-11 is the composite gradation curve for 30 fine-grained stratified drift samples from the EX borings. These samples had an average P200 of 11 percent within a range of 2 to 51 percent. Under the Unified Soil Classification System, these samples were classified as SP, SM-SP, SM or ML. They were generally described as fine sand, silty fine sand, and fine sandy silt. The fine-grained stratified drift, together with the coarse-grained stratified drift, form what is called the aquifer material at the Crandon Project. These are glacial outwash deposits as opposed to the glacial till or fine-grained lake deposits.

Lacustrine - The lacustrine category includes relatively fine-grained sediments deposited at the bottom of lakes, both during glacial times (glacial lacustrine) and post-glacial times (lake lacustrine). The post-glacial lake lacustrine deposits include Little Sand, Oak, Skunk, Duck and Deep Hole lakes as well as the present wetlands. The definition of lacustrine sediments in the previous reports (Golder, 1981a) included only the more recent (post-glacial) deposits under the present lakes and wetlands.

The 19 samples of the glacial lacustrine sediments had an average P200 of 66 percent within a range of 9 to 98 percent. The lacustrine sediments were characterized by their fine-grained nature and presence of varves. The varves were generally very thin layers (less than 0.2 inch thick) of very fine sand, silt and moderate to high plasticity clay reflecting the seasonal and annual fluctuations in deposition. Figure 7-12 is a composite drawing of the glacial lacustrine soil gradation curves.

Permeability - Table 7.1 presents the results of the statistical analyses of the field permeability test data for the five geologic units. Only the data from the EX piezometers and the Little Sand Lake piezometers

UNIFIED CLASSIFICATION SYSTEM



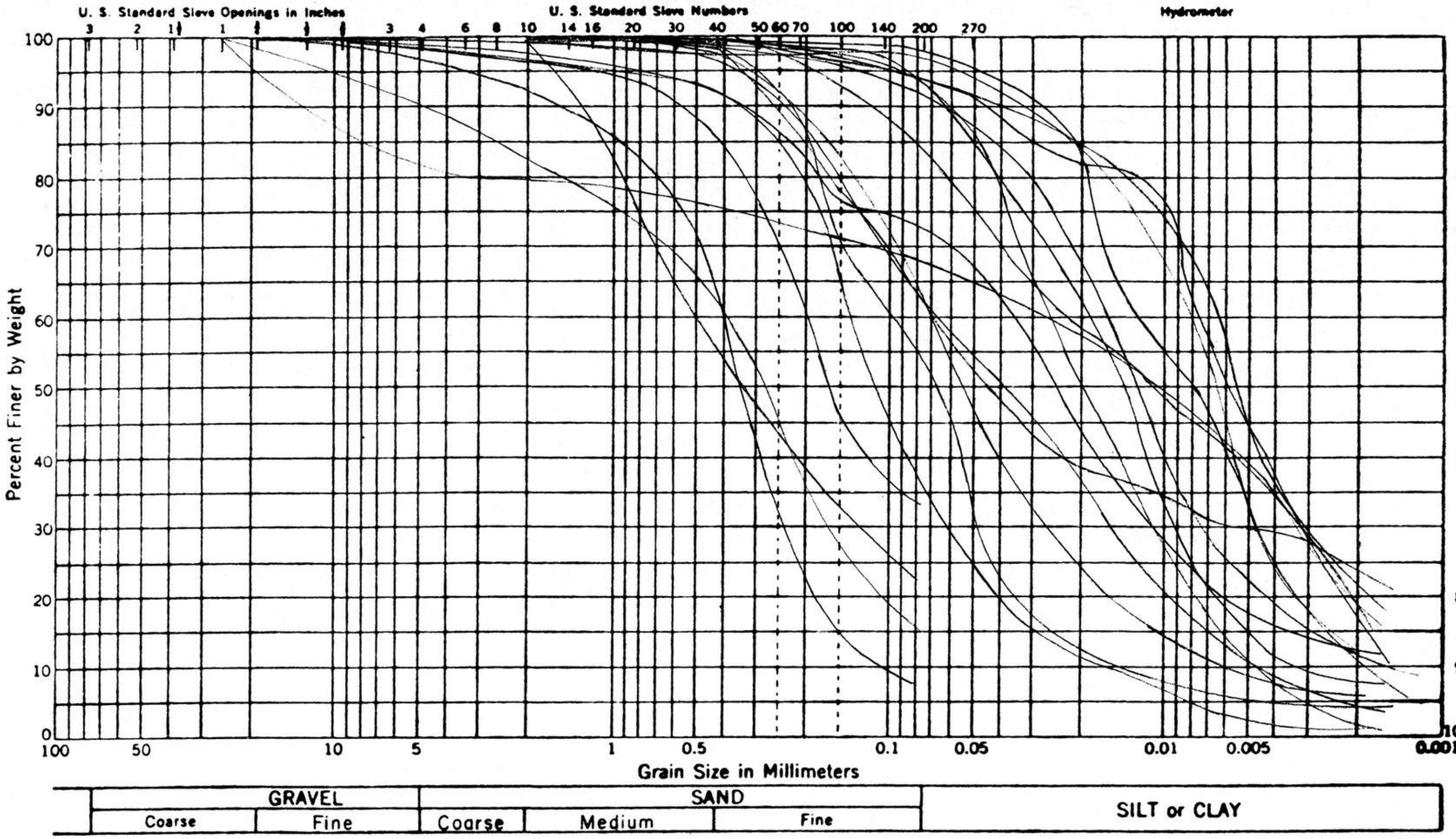
SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Fine Grained Stratified Drift
					SP, SM-SP, SM, ML

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
COMPOSITE GRADATION CURVES

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SMD	DATE	CHECKED BY H.S. Lurie	DATE 10-15-8[illegible]
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 10-15-84
APPROVED BY	DATE	EXXON [illegible]	DATE 1[illegible]
DRAWING NO FIGURE 7-11		SHEET OF	REVISION NO

UNIFIED CLASSIFICATION SYSTEM



SAMPLE NO.	W.C.	LL	PL	PI	CLASSIFICATION
					Lacustrine SM-SP, SM, ML, CL
					Note: Gradation Curves Represent
					Composite Samples and Not Individual
					Varves

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
COMPOSITE GRADATION CURVES

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SMD	DATE	CHECKED BY H.S. [illegible]	DATE 10/15/84
APPROVED BY	DATE	APPROVED BY C.C. Schroedy	DATE 10-15-84
APPROVED BY	DATE	EXXON [illegible]	DATE
DRAWING NO FIGURE 7-12		SHEET ___ OF ___	REVISION NO

TABLE 7.1

Field Permeability Test Data
Crandon Project

Statistical Analysis

Geologic Unit	Number of Tests	Permeability[a] Range, cm/s	Arithmetic Mean, cm/s	Geometric Mean, cm/s	Standard Deviation cm/s
Coarse drift	15	1×10^{-2} to 1×10^{-3}	4×10^{-3}	3×10^{-3}	3×10^{-3}
Fine drift	12	6×10^{-3} to 7×10^{-4}	2×10^{-3}	1×10^{-3}	7×10^{-4}
Till	10	3×10^{-3} to 9×10^{-6}	6×10^{-4}	2×10^{-4}	9×10^{-4}
Basal till	7	9×10^{-4} to 9×10^{-5}	4×10^{-4}	3×10^{-4}	3×10^{-4}
Glacial Lacustrine	4	5×10^{-4} to 1×10^{-5}	2×10^{-4}	9×10^{-5}	2×10^{-4}
Lake Lacustrine[b]	59	2×10^{-6} to 4×10^{-8}	5×10^{-7}	2×10^{-7}	6×10^{-7}

[a]Horizontal permeability.

[b]Laboratory vertical permeability test results from shelby tube samples for the recent deposits under Little Sand, Skunk, Oak, Deep Hole and Duck lakes (STS Consultants Ltd., 1982, 1984a).

preparing this table. The geometric means and standard deviations were determined using methods described in Tuma (1979).

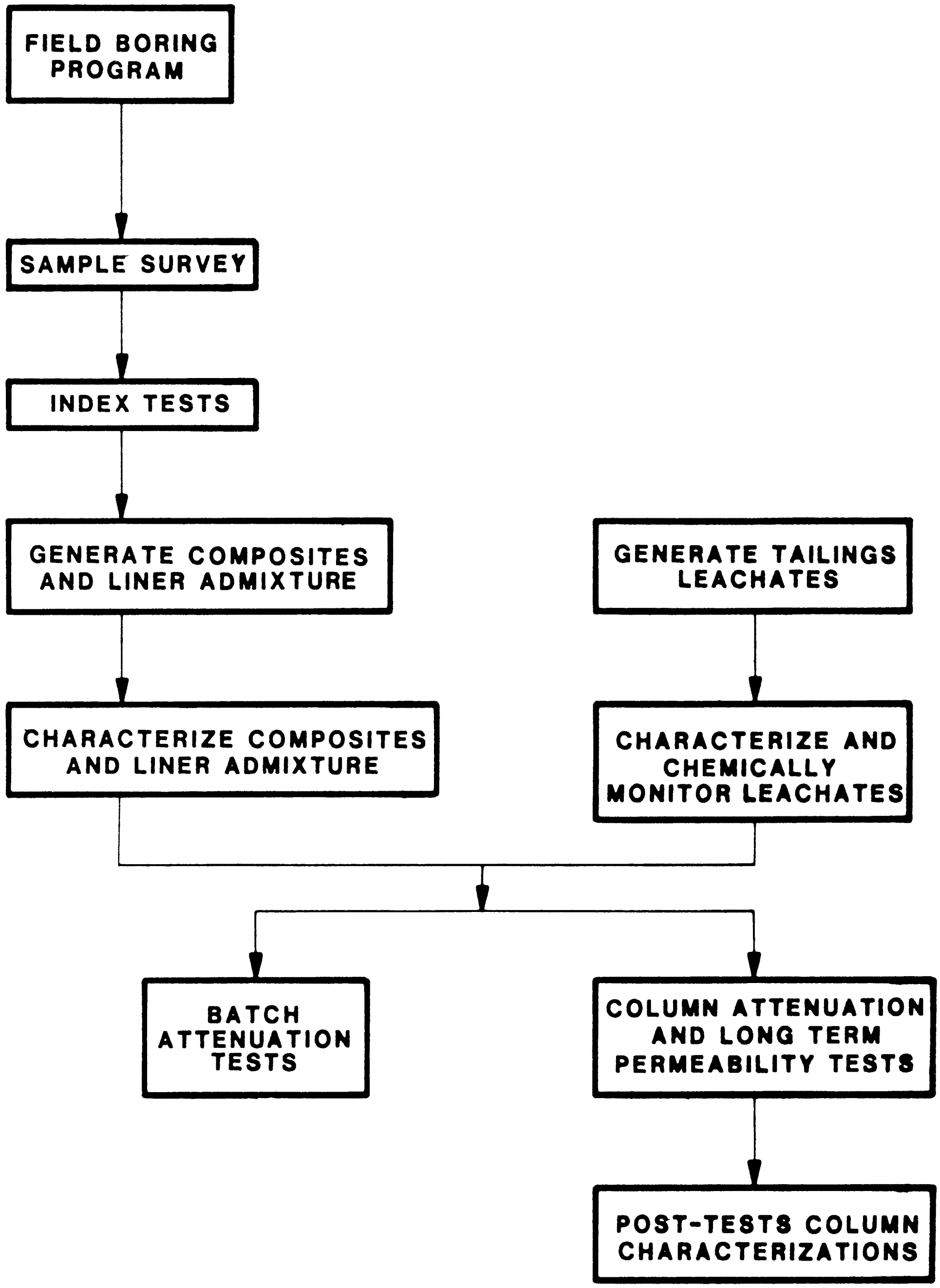
The coarse-grained stratified drift had the highest permeability with the fine-grained stratified drift being slightly less permeable. These two units are most important in terms of ground water flow because of their relatively high permeability. The glacial till and basal till had average horizontal permeabilities about one order of magnitude less than the drift units. The lacustrine sediments had the lowest average permeabilities.

7.3.3 Suitability for Facility Development

Two major stratigraphic units near the surface (glacial till and coarse-grained stratified drift) have been identified as the primary source of construction material and the foundation of the facility. Another important function of these soils will be to attenuate any leachate which percolates through the liner (seepage).

Extensive laboratory studies have been conducted to determine the capacity for liner materials and the underlying soil to attenuate potential seepage from the MWDF (D'Appolonia, 1982b). Figure 7-13 illustrates the study outline for the attenuation work. These studies began with determination of the acid neutralization capacity and distribution of carbonate minerals in the soil materials surrounding the MWDF.

Composite samples were developed to represent the overall physical and chemical characteristics of the two major stratigraphic units through which potential seepage percolation would occur (Table 7.2). They are in the middle of the range for grain-size distribution plots shown on Figures 7-8, 7-10 and 7-11. The attenuation studies used two composite samples from the upper glacial till and one from the coarse-grained stratified drift. The



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE

ATTENUATION STUDY OUTLINE

SCALE NONE		STATE WISCONSIN		COUNTY FOREST	
DRAWN BY D.R.SPRINGBORN	DATE 0/82	CHECKED BY		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO **FIGURE 7-13**		SHEET OF		REVISION NO	

TABLE 7.2

GRAIN SIZE DISTRIBUTION OF COMPOSITE SAMPLES FOR SOIL ATTENUATION TESTS AT THE MWDF[a]

GRAIN SIZE DISTRIBUTION[b]

SAMPLE	COARSE GRAVEL (76.2-19.05 mm)	FINE GRAVEL (19.05-4.75 mm)	COARSE SAND (4.75-2.0 mm)	MEDIUM SAND (2.0-0.425 mm)	FINE SAND (0.425-0.075 mm)	SILT AND CLAY[b] (<0.075 mm)	SILT (0.075-0.002 mm)	CLAY (<0.002 mm)
Composite No. 1 (Glacial Till)	11.1	23.8	3.7	15.0	32.3	14.1	10.2	3.9
Composite No. 2 (Stratified Drift)	0.9	6.7	2.5	29.1	51.5	9.3	7.5	1.8

[a](D'Appolonia, 1982b)

[b](Appendix C in D'Appolonia, 1982b)

[c]ASTM D 422-63(72). (See Appendix C, D'Appolonia, 1982b for grain size distribution curves.)

composites, which were based on grain-size analysis and neutralization capacity, were:

1) Glacial Till

-- low neutralization capacity (Composite Sample No. 1)
-- high neutralization capacity (Composite Sample No. 3)

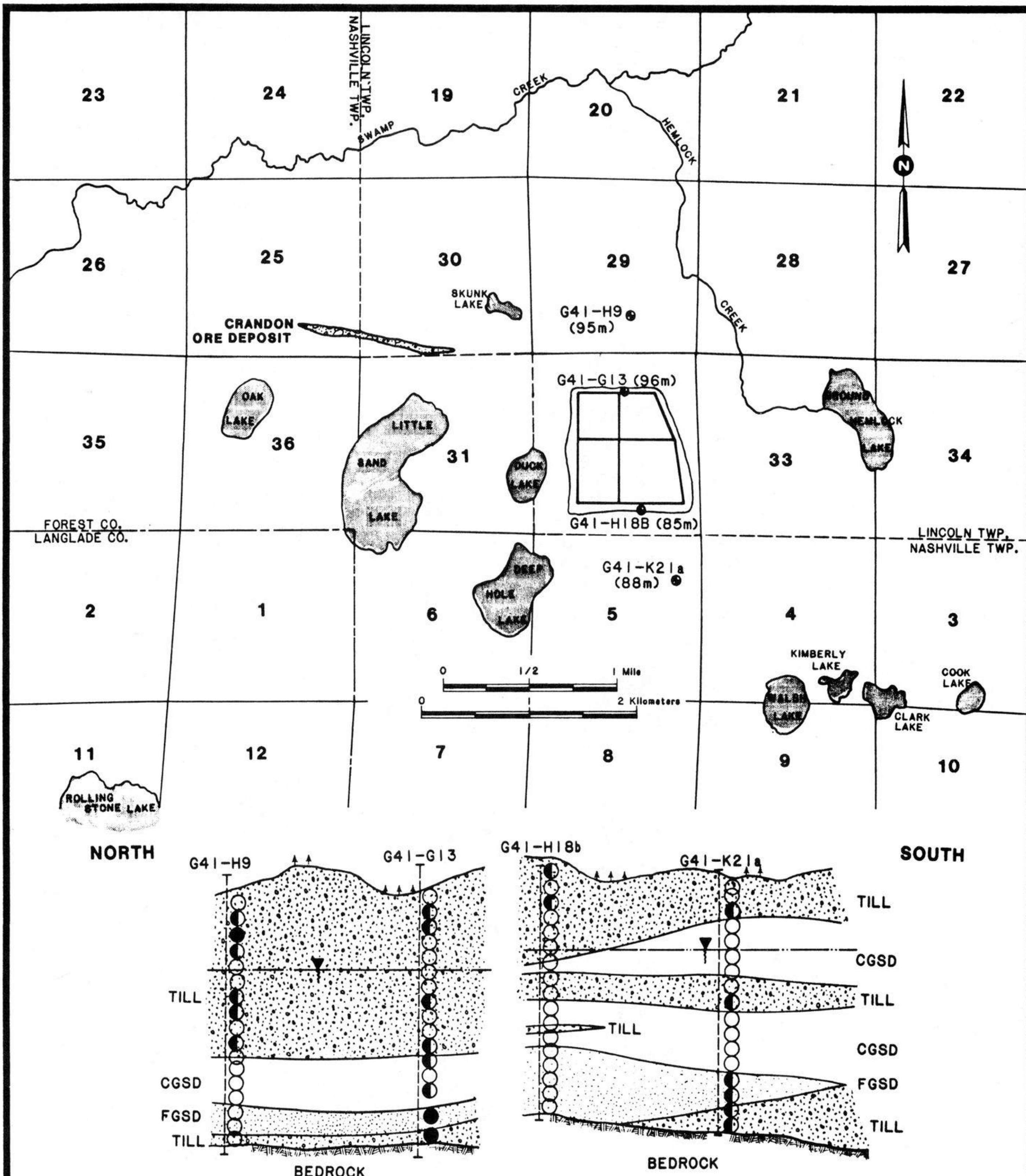
2) Coarse-Grained Stratified Drift

-- low neutralization capacity (Composite Sample No. 2).

Composite sample locations are shown on Figure 7-14. The composite samples were physically and chemically analyzed for grain-size distribution, reaction pH, neutralization capacity, exchangeable cations and cation exchange capacity (CEC), anion exchange capacity (AEC), organic matter content, mineralogy, and long-term buffering capacity (D'Appolonia, 1982b).

Chemical characterization data (Table 7.3) indicate that reaction pH for all samples is strongly alkaline (9.15 to 9.80). Under these pH conditions, the solubility of most metals is very low (D'Appolonia, 1982b). Consequently, precipitation reactions involving metal ions from percolating leachate will occur as long as the pH remains basic (>7).

Neutralization capacities are moderate to high and range from 1.6 to 7.2 percent calcium carbonate equivalent. The "low neutralization capacity" till and drift composite samples have neutralization capacities of 2.3 and 1.6 percent calcium carbonate equivalent (Table 7.3). These values represent 35, 51, and 159 pounds of calcium carbonate per 2,200 pounds of soil and indicate that any acid seepage, should it occur, would be neutralized as it percolates through the soil material (D'Appolonia, 1982b).



LEGEND

CGSD = COARSE-GRAINED STRATIFIED DRIFT

FGSD = FINE-GRAINED STRATIFIED DRIFT

○ <3%
◐ 3-9%
● >9%
ESTIMATED % $CaCO_3$ EQUIVALENT

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE **SAMPLE LOCATIONS FOR ATTENUATION STUDY**			
SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY D.R.SPRINGBORN	DATE 9/82	CHECKED BY C P Herbst	DATE 12/82
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON D. E. Hue	DATE 11/1/85
DRAWING NO **FIGURE 7-14**		SHEET ___ OF ___	REVISION NO. 0

TABLE 7-3

RESULTS OF CHEMICAL CHARACTERIZATION ANALYSES OF COMPOSITE SAMPLES [a] FOR SOIL ATTENUATION TESTS AT THE MWDF[b]

SAMPLE	1:1 REACTION pH^g	NEUTRALIZATION CAPACITY[d] (% $CaCO_3$) Equivalent	EXCHANGEABLE CATIONS[c] HYDROGEN (meq/100g)	CALCIUM (meq/100g)	MANGNESIUM (meq/100g)	POTASSIUM (meq/100g)	SODIUM (meq/100g)	CATION EXCHANGE CAPACITY[e] (meq/100g)	ANION EXCHANGE CAPACITY[f] (meq/100g)	ORGANIC MATTER (%)
Composite No. 1 (Glacial Till)	9.15	2.3	<0.1	4.2	3.0	<0.1	0.2	7.4	1.7	0.31
Composite No. 2 (Stratified Drift)	9.80	1.6	<0.1	2.6	1.4	<0.1	0.2	4.2	1.6	0.22
Composite No. 3 (High Carbonate Effervescence)	8	7.2	h	—	—	—	—	—	—	—

[a] Characteristics analyses performed only on sample fraction less than 4.75 mm (0.19) inches) coarse sand and below.
[b] D'Appolonia, 1982b.
[c] Ammonium acetate extraction at pH 7.0 in accordance with Black (1965). Analytical determinations in accordance with the U.S. EPA (1979). No exchangeable acidity is present by definition for 1:1 reaction pH's above 7.0 (Sobek et al., 1978).
[d] HCL Treatment - NaOH titration in accordance with Sobek et al. (1978). Average of duplicate terminations. In addition, the gravel fraction of each composite sample was tested for carbonate effervescence (Sobek et al., 1978). These results followed:
- Composite No. 1 had a typical carbonate effervescence numeric rating of 2 (estimated neutralization capacity of 3 to 5% $CaCO_3$ equivalent).
- Composite No. 2 had a typical carbonate effervescence numeric rating of 0 (estimated neutralization capacity of <1.5% $CaCO_3$ equivalent).

[e] Extractable and adsorbed phosphorous (Mahlick Method) in accordance with Hesse (1971). Analytical determination in accordance with the APHA (1981).
[f] Potassium dichromate oxidation (Modified Walkley Method) in accordance with Richards (1954).
[g] pH of a 1:1 soil to distilled water mixture at 25°C (Sobek et al., 1978).
[h] "—" indicates not determined.

Calcium is the dominant exchangeable cation, followed by magnesium and sodium in the composite samples. Levels of potassium and exchangeable acidity (hydrogen) are very low. The relative proportions of exchangeable cations, considered in conjunction with adsorption affinities and soil solution concentrations, can be used to evaluate the potential occurrence of exchange reactions between the soil solution (i.e., leachate) and soil particle cation exchange activity. A small but important amount of exchangeable sodium occurs in the composite samples. Since sodium is weakly adsorbed on soil particles, the potential exists for cations with greater adsorption affinities to enter into exchange reactions with sodium and to be retained on soil particles (D'Appolonia, 1982b).

Total cation exchange capacity for all samples is low. These CEC values reflect, in part, the low clay content of the soils, since CEC resides principally in clay minerals and colloidal materials. The grain size distribution analysis supports these determinations (Table 7.2). These data indicate that soil particles at the proposed MWDF area have limited capacity to exchange cations. However, field condition CEC values may be greater than indicated in Table 7.3, because the compositing procedure was very conservative. In addition, the analytical procedure for CEC determinations utilizes a pH 7.0 buffered solution, while actual soil reaction pH at the proposed MWDF area is 9.15 or higher. CEC increases at higher pH values and in soils with substantial amounts of variable charge clay minerals (e.g., kaolinite); thus, a major increase in field conditions CEC may result (D'Appolonia, 1982b).

Anion exchange capacity values range from 1.6 to 1.7 meq/100 g. The data indicate a potential for anionic species in solution to enter into exchange reactions and be attenuated by soil particles. The principal source of AEC in soils typically resides in sesquioxides (e.g., goethite and amorphous compounds) (D'Appolonia, 1982b).

Bulk mineralogy studies on the till and coarse-grained stratified drift composite samples show that both strata have at least 5 percent dolomite, and thus provide a large acid neutralization capacity.

These results characterize the attenuative capacity of the till and coarse-grained stratified drift that will underlie the proposed facility. Attenuation tests have also been conducted to quantify the potential attenuation of seepage by the underlying soils associated with the MWDF design. They included:

1) Determination of constant pH batch distribution ratios (K_d) for selected metals at pH 3, 6, and 9;

2) Determination of attenuation characteristics for the test leachates and their effect on the hydraulic conductivity of a compacted soil column;

3) Determination of the suction pressure versus moisture content of a potential liner and soil materials in the unsaturated zone beneath the MWDF; and

4) Determination of the key factors controlling unsaturated and saturated zone percolation of seepage and chemical species migration from the MWDF. Controlling factors were identified by evaluating laboratory, literature, and existing Project data in parametric/sensitivity evaluations.

These results are presented in Chapter 10 under the discussion of predicted effects of MWDF.

7.4 Climatology

The climate of the regional study area is continental, modified slightly by Lake Michigan 80 miles to the east and Lake Superior 93 miles to the north. During most of the year, this area is in the path of eastwardly moving pressure systems in the prevailing westerly air movements (EIR, Section 2.1).

Temperatures are mild to warm in summer and cold in winter. Summer days are generally mild but temperatures may exceed 35°C (95°F) on the hottest days of the year. Winter temperatures generally range from -18° to -4°C (0° to 25°F) and occasionally will be below -34°C (-30°F) (National Oceanic and Atmospheric Administration, 1974). Wind data were collected from January through December 1978 at Station 1 approximately 3 miles west of the proposed facility. These data are presented on Figure 7.15 on the annual wind rose for 1978. The predominant wind direction was from the south (10.3 percent). South-southwest, southwest, and north-northeast were the next most frequently observed directions (9.0, 7.5, and 7.0 percent, respectively) (EIR, Section 2.1). Mean wind speed observed at Station 1 ranged from 5.0 to 8.2 miles per hour for the individual quarters, and averaged 7.2 miles per hour for the 1978 calendar year. At Station 1 calm wind (less than 1.0 mile per hour) occurred 13.66 percent of the time in 1978, and was almost exclusively recorded at night.

Average annual precipitation in the area is 30.77 inches. 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 50 inches (EIR, Section 2.1). Precipitation records measured from the NOAA weather station at Nicolet College at Rhinelander, Wisconsin, the nearest of AEC in soils typically resides in sesquioxides (e.g., goethite and amorphous compounds) (D'Appolonia, 1982b).

Bulk mineralogy studies on the till and coarse-grained stratified drift composite samples show that both strata have at least 5 percent dolomite, and thus provide a large acid neutralization capacity.

These results characterize the attenuative capacity of the till and coarse-grained stratified drift that will underlie the proposed facility. Attenuation tests have also been conducted to quantify the potential attenuation of seepage by the underlying soils associated with the MWDF design. They included:

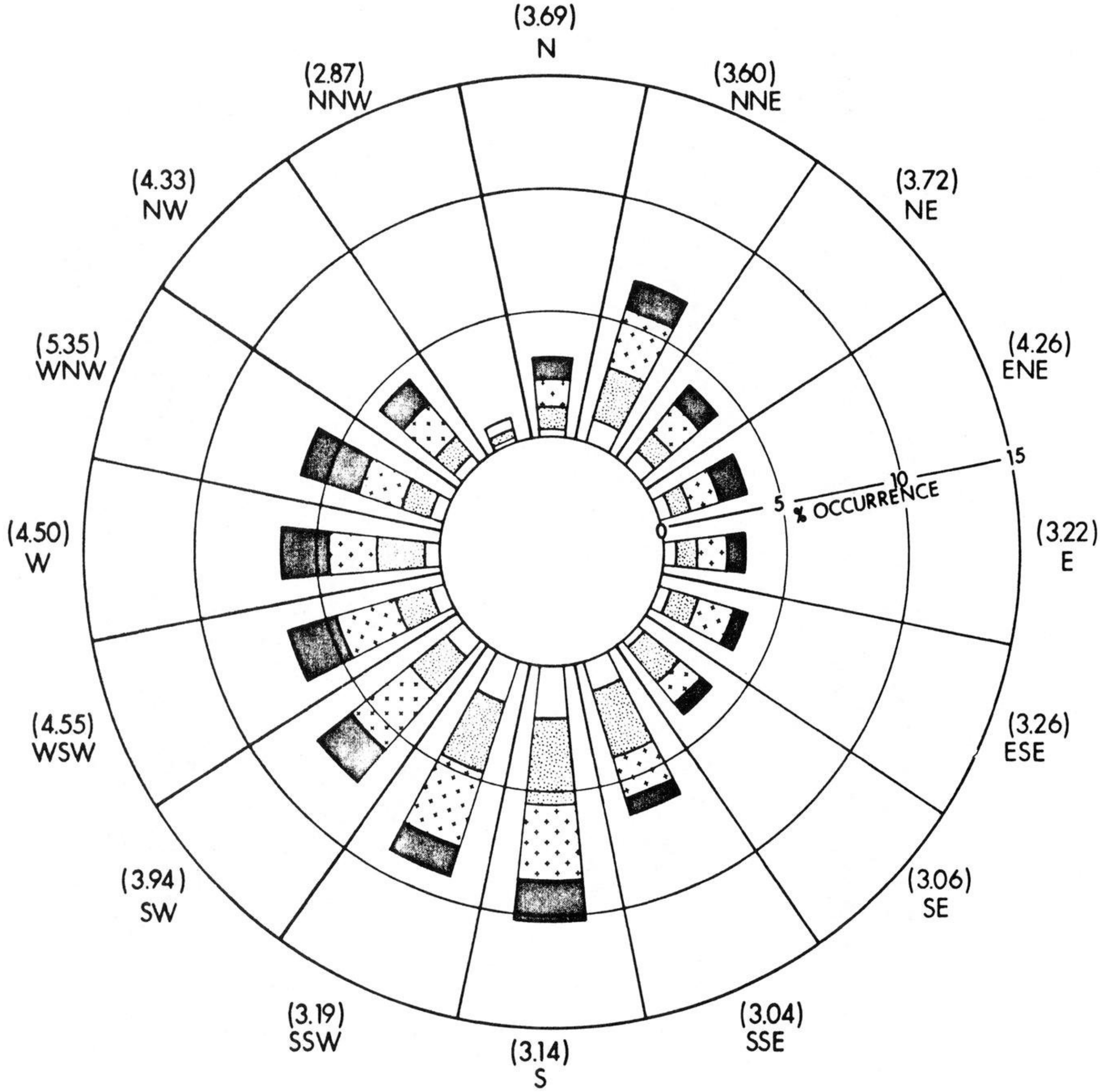
1) Determination of constant pH batch distribution ratios (K_d) for selected metals at pH 3, 6, and 9;

2) Determination of attenuation characteristics for the test leachates and their effect on the hydraulic conductivity of a compacted soil column;

3) Determination of the suction pressure versus moisture content of a potential liner and soil materials in the unsaturated zone beneath the MWDF; and

4) Determination of the key factors controlling unsaturated and saturated zone percolation of seepage and chemical species migration from the MWDF. Controlling factors were identified by evaluating laboratory, literature, and existing Project data in parametric/sensitivity evaluations.

These results are presented in Chapter 10 under the discussion of predicted effects of MWDF.



LEGEND

(0.00) MEAN WIND SPEED (m/s) FOR SECTOR

WIND SPEED (m/s)

> 5.0

3.0 - 5.0

1.5 - 3.0

0.0 - 1.5

MEAN WIND SPEED FOR ALL SECTORS: 3.24 m/s

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
ENVIRONMENTAL STUDY AREA WIND ROSE
(ANNUAL, 1978)

SCALE	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY BWM	DATE 07/21/82	CHECKED BY R P Harbst		DATE 12-'82
APPROVED BY	DATE	APPROVED BY C. C. Schroeder		DATE 12-82
APPROVED BY	DATE	EXXON R E Moe		DATE 1/-/82
DRAWING NO	FIGURE 7-15		SHEET ___ OF ___	REVISION NO 0

long-term data record, are assumed to be representative of the regional study area. Rhinelander is approximately 24 miles northwest of the site area. On the average, the wettest month is June with almost 15 percent of the annual precipitation, and the driest is February with only 3.3 percent (EIR, Section 2.1).

There are no long-term precipitation chemistry records for Wisconsin. In the autumn of 1979, the DNR initiated precipitation event monitoring at several locations around Rhinelander. The results, through March 1980, have been pH values ranging from 3.6 to 6.1 with most values (80 percent) at pH of 4.6 or less (Wisconsin DNR, 1980).

7.5 Hydrogeology

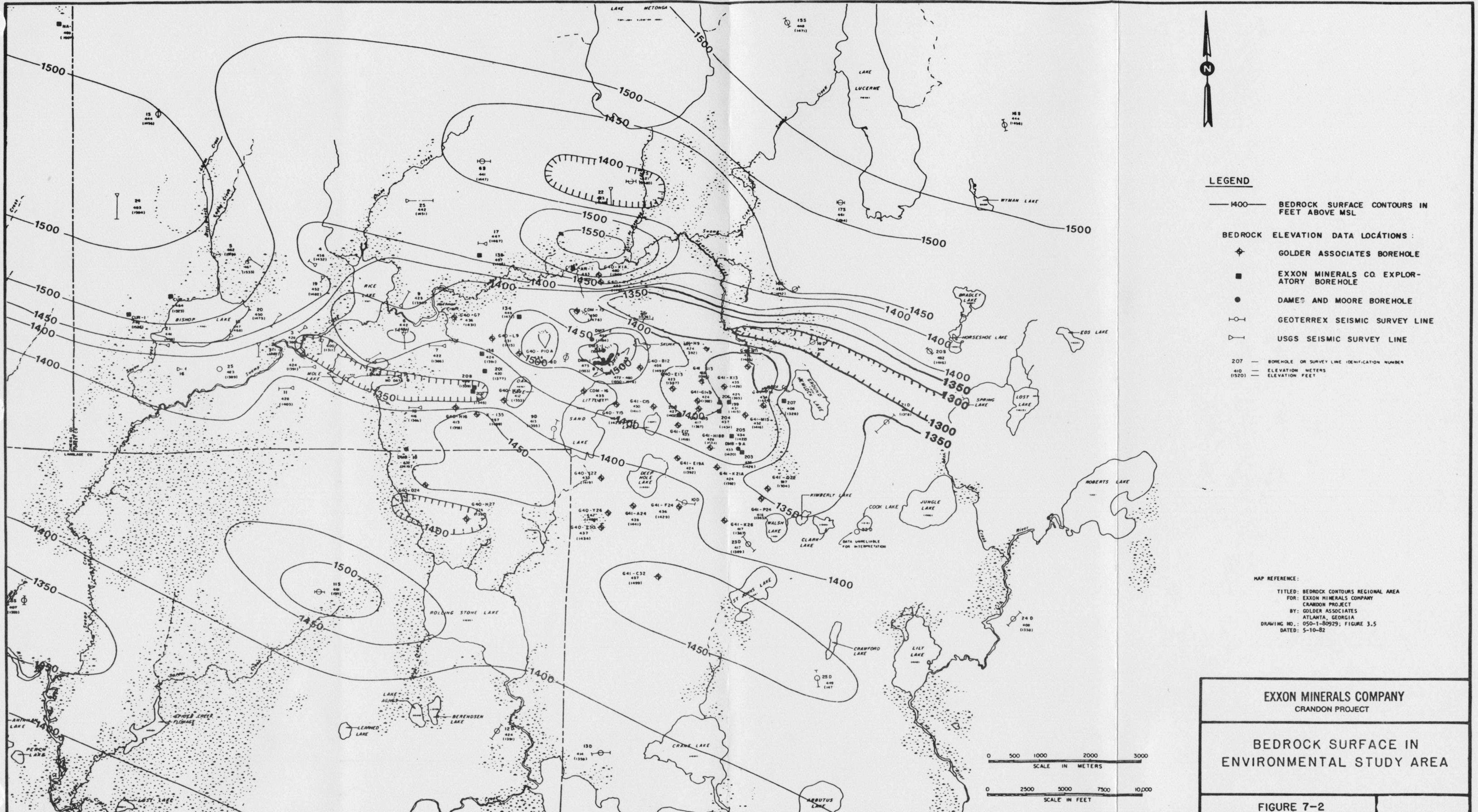
7.5.1 Ground Water Occurrence

The main ground water aquifer system is estimated to cover approximately the same acreage as the Fox-Wolf River surface water drainage basin (Olcott, 1968). The site area is located at the northern end of this basin. The principal aquifer for this basin is the unconsolidated glacial overburden soil material. The crystalline bedrock, although locally fractured, generally does not yield usable quantities of water to wells (Olcott, 1968). Under normal ground water flow rate conditions, the bedrock is considered functionally impermeable (D'Appolonia, 1982a).

The proposed MWDF will be located in a recharge area with ground water discharges to lakes, wetlands and streams 0.3 to 3 miles from the facility (Figure 7-16). Within this ground water system, the coarse-grained stratified drift is the primary soil material of the main aquifer. In general, the configuration of the main aquifer water table reflects the surface topography with the potentiometric surface highest in the upland areas and near ground surface in the lowlands.

Locally perched ground water conditions occur above the main aquifer. These perched zones are limited in extent and are primarily associated with low permeability soil which was deposited in upland depressions (EIR, Section 2.3). Many of the wetlands and lakes near the proposed MWDF are the result of these conditions. In these cases, surface water levels are above water table levels in the main aquifer (EIR, Section 2.3).

From May 1977 to July 1984, ground water level measurements in upland recharge areas such as the proposed MWDF location fluctuated approximately 4 feet (EIR, Section 2.3). The greatest amount of percolation



EXXON MINERALS COMPANY
CRANDON PROJECT

BEDROCK SURFACE IN ENVIRONMENTAL STUDY AREA

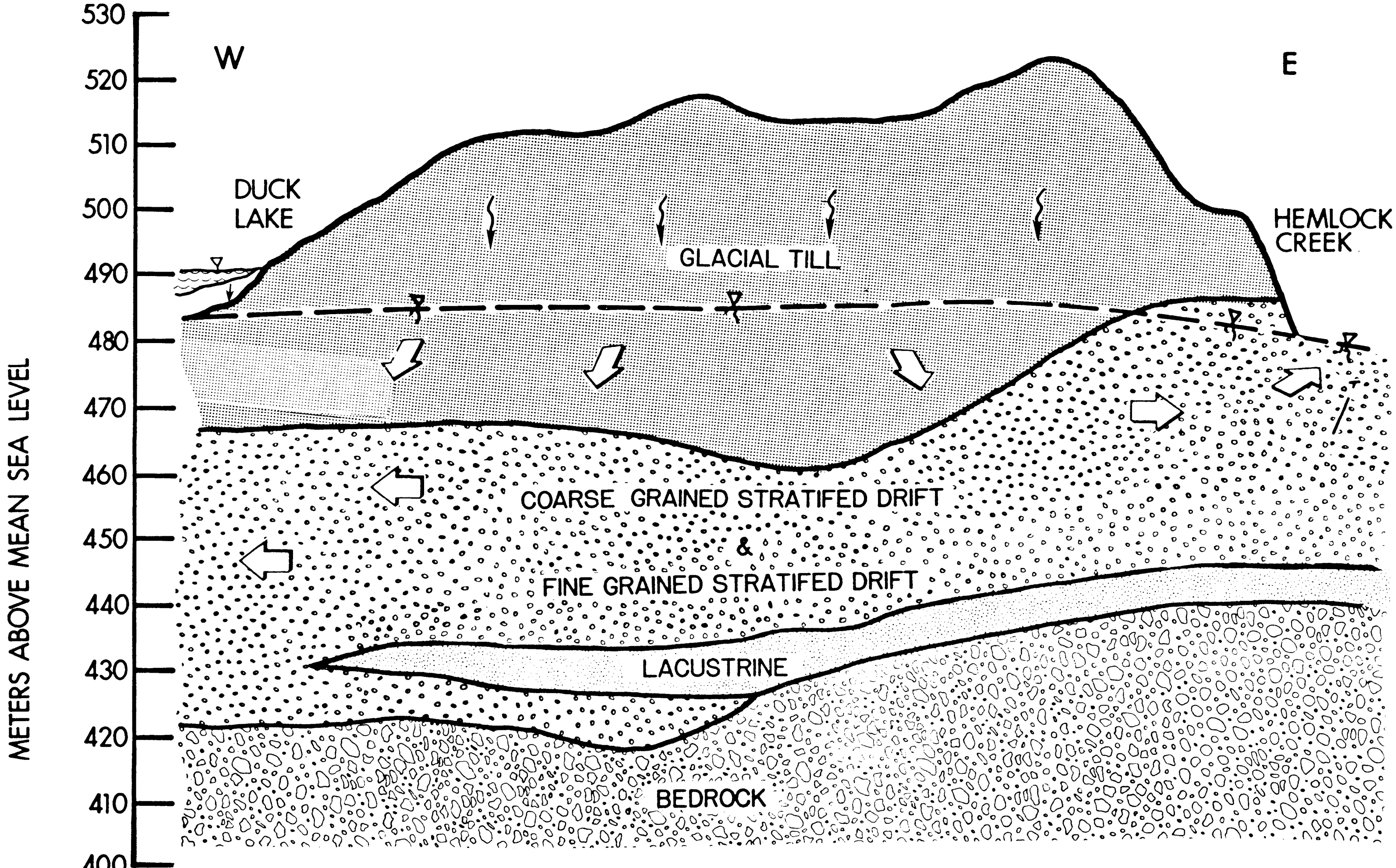
FIGURE 7-2

(recharge) to the main aquifer water table occurred in April each year after snow melt. Ground water levels at discharge areas are more uniform because they are strongly influenced by the constant flow of water from the main aquifer (EIR, Section 2.3).

7.5.2 Ground Water Movement

A summary of ground water movement at the MWDF is illustrated on the hydrogeologic concepts cross section (Figure 7-17). Plan Sheet 13 shows the location of boring wells near the proposed MWDF and Plan Sheet 14 shows the water table. The precipitation in the site area averages 31 inches per year. The majority of this precipitation evaporates and/or transpires; smaller fractions become direct surface runoff and percolation to ground water. Subsection 9.5 provides additional detail of the hydrologic water balance. In some areas where surface water drainage collects in depressions underlain with silty colluvial deposits, wetlands have formed. Figure 7-17 also illustrates that some lakes (e.g., Duck Lake) are located on fine-grained organic and lacustrine sediments. These lakes are also recharge areas to the main aquifer. Hemlock and Swamp creeks and their associated wetlands are examples of ground water discharge areas. There may be some near surface ground water movement within the local aquifer systems but there is no evidence that this is important in relation to the main ground water system (EIR, Section 2.3).

Ground water movement through the 83 to 132 feet unsaturated zone is predominantly vertical. There is little lateral movement in the unsaturated zone because of the uniformity of the soil mass (D'Appolonia, 1982a). In the saturated zone, ground water movement is predominantly downward in the till and lateral in the coarse-grained stratified drift (D'Appolonia, 1982a).



PERCOLATION THROUGH THE UNSATURATED ZONE

REPRESENTATION OF DIRECTION OF GROUND WATER MOVEMENT

POTENTIOMETRIC SURFACE

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
HYDROGEOLOGIC CONCEPTS

SCALE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY BWM	DATE 07/26/82	CHECKED BY		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO. FIGURE 7-17		SHEET ___ OF ___		REVISION NO. 0	

Potentiometric contours near the MWDF are illustrated on Figure 7-16 and Plan Sheet 12. Ground water movement is radially outward from the proposed facility with relatively small gradients. Horizontal hydraulic gradients are approximately 0.01 feet per feet east of the proposed facility and average approximately 0.002 feet per feet to the north, south, and west.

Most ground water movement in the main aquifer beneath the MWDF occurs in the coarse-grained stratified drift layer because of its relatively high permeability. For example, assuming an average gradient of 0.002 feet per feet and a horizontal hydraulic conductivity of 36.9 feet per day with a porosity of 30 percent, the ground water velocity in the drift would be 0.24 feet per day.

7.5.3 Ground Water Quality

Analyses of ground water samples from the glacial drift (EIR, Section 2.3) indicate that ground water quality in the environmental study area meets federal and state drinking water standards with the exception of some reported values for cadmium, iron, and manganese. Typically, pH is neutral but ranges from slightly acidic to basic. The ground water is moderately hard and moderately alkaline and contains low levels of metals (D'Appolonia, 1982b). Table 7.4 summarizes the ground water quality for samples collected from the main aquifer in the environmental study area.

Ground water quality changes as it moves through the soil materials from recharge to discharge locations. Recharge water is relatively soft (and acidic) before it percolates. This is shown by the low alkalinity and hardness values for recharge (perched) lakes in the environmental study area. Once water percolates through the carbonate soils, the mean values for alkalinity, calcium, and hardness are relatively high (typically 175 mg/l,

TABLE 7.4

SUMMARY OF GROUND WATER QUALITY FROM SAMPLES ANALYZED OF THE MAIN AQUIFER IN THE ENVIRONMENTAL STUDY AREA FROM 1977 TO 1981[a,b]

PARAMETER	RANGE	MEAN (x)	STANDARD DEVIATION (S)	NUMBER OF SAMPLES
Field temperature[c] (°C)	3.0 - 12.0	7.1	1.8	220
Total laboratory alkalinity	14.0 - 453.0	123.0	50.0	234
Total field alkalinity	11.0 - 487.0	127.0	53.0	221
Specific conductance (umhos/cm)	50.0 - 1,300.0	237.0	107.0	235
Field conductivity[d] (umhos/cm)	29.0 - 1,150.0	178.0	92.0	218
Laboratory pH	6.09 - 11.2	7.6	0.69	204
Field pH	5.5 - 12.2	7.7	1.0	222
Total hardness	16.0 - 452.0	125.0	53.0	236
Total dissolved solids	14.0 - 836.0	166.0	84.0	235
Chemical oxygen demand	<1.0 - 365.0	<29.0	<56.0	143
Total phosphorus (P)	<0.01 - 0.84	<0.06	<0.10	135
Anions				
Arsenic	<0.001 - 0.004	<0.001	<0.001	236
Chloride	<1.0 - 78.0	<4.0	<10.0	236
Cyanide, total	<0.001 - 0.004	<0.001	<0.001	236
Fluoride	<0.12 - 0.57	<0.20	<0.09	142
Nitrate nitrogen (N)	<0.01 - 11.0	<0.37	<1.04	235
Phosphate (PO_4)	<0.01 - 0.31	<0.06	<0.06	10[illegible]
Sulfate	<1.0 - 86.0	<9.0	<9.0	23[illegible]
Cations				
Aluminum	<0.01 - 9.09	<0.53	<1.12	169
Barium	<0.01 - 0.24	<0.02	<0.03	142
Cadmium	<0.001 - 0.015	<0.002	<0.002	169
Calcium	4.9 - 92.4	29.8	12.6	94
Chromium, total	<0.001 - 0.021	<0.002	<0.003	169
Cobalt	<0.1	<0.01	0.0	169
Copper	<0.001 - 0.09	<0.007	<0.011	232
Iron	<0.01 - 38.9	<1.74	<4.34	236
Lead	<0.01 - 0.10	<0.01	<0.01	235
Magnesium	0.279 - 29.6	12.0	5.12	169
Manganese	<0.001 - 10.2	<0.423	<0.989	236
Mercury	<0.0001 - 0.0010	<0.0001	<0.0001	169
Molybdenum	<0.01 - 0.03	<0.01	<0.01	169
Nickel	<0.01 - 0.04	<0.01	0.01	169
Selenium	<0.001 - 0.001	<0.001	0.0	142
Silver	<0.001	<0.001	0.0	142
Zinc	<0.001 - 2.60	<0.052	<0.214	235

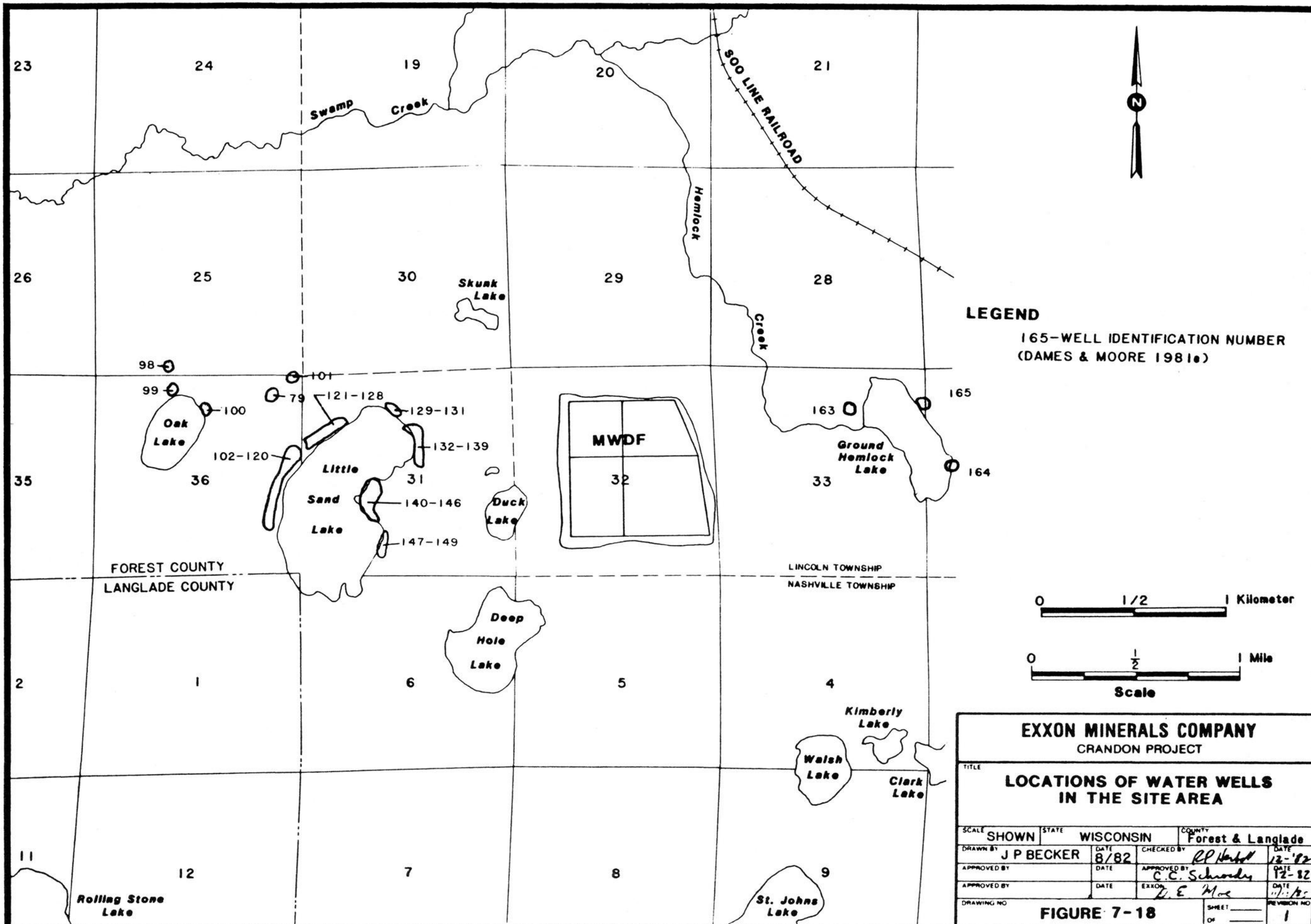
[a]Source: EIR, Section 2.3
[b]All units mg/l unless otherwise specified.
[c]Reflects seasonal temperature variation.
[d]Varies with temperature (U.S. EPA, 1976).

40 mg/1, and 200 mg/1, respectively). These values may increase or decrease as ground water moves toward a discharge location (EIR, Section 2.3).

7.5.4 Ground Water Use

The principal use of ground water in the environmental study area is for municipal and private domestic water supplies. Generally, the regional study area is very sparsely populated. Industries in the regional study area presently require relatively small volumes of ground water, which in many cases are obtained from the nearest municipal system. Where municipal water supplies are not available, industrial users rely on their own ground water wells (EIR, Section 2.3). Ground water is also used for irrigation in the vicinity of Mole Lake (EIR, Section 2.3).

An inventory of wells in the environmental study area indicates that the nearest wells are approximately 1 mile from the proposed facility. These wells are down-gradient from the facility. The nearest wells are along Little Sand and Ground Hemlock Lakes as shown on Figure 7-18.


23
24
19
20
21
Swamp Creek
SOO LINE RAILROAD
N
Hemlock Creek
26
25
30
Skunk Lake
29
28
LEGEND
165-WELL IDENTIFICATION NUMBER
(DAMES & MOORE 1981a)
98
99
101
79
121-128
100
129-131
163
165
Oak Lake
132-139
MWDF
Ground Hemlock Lake
102-120
Little Sand Lake
35
36
31
32
33
164
140-146
Duck Lake
147-149
FOREST COUNTY
LANGLADE COUNTY
LINCOLN TOWNSHIP
NASHVILLE TOWNSHIP
0 1/2 1 Kilometer
Deep Hole Lake
0 1/2 1 Mile
Scale
2
1
6
5
4
Kimberly Lake
Walsh Lake
Clark Lake
11
12
7
8
9
Rolling Stone Lake
St. Johns Lake
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
LOCATIONS OF WATER WELLS
IN THE SITE AREA
SCALE SHOWN
STATE WISCONSIN
COUNTY Forest & Langlade
DRAWN BY J P BECKER
DATE 8/82
CHECKED BY
DATE 12-'82
APPROVED BY
DATE
APPROVED BY C.C. Schroeder
DATE 12-82
APPROVED BY
DATE
EXXON
DRAWING NO
FIGURE 7-18
SHEET
OF
REVISION NO 1

7.6 Surface Water Hydrology

7.6.1 Lakes and Streams

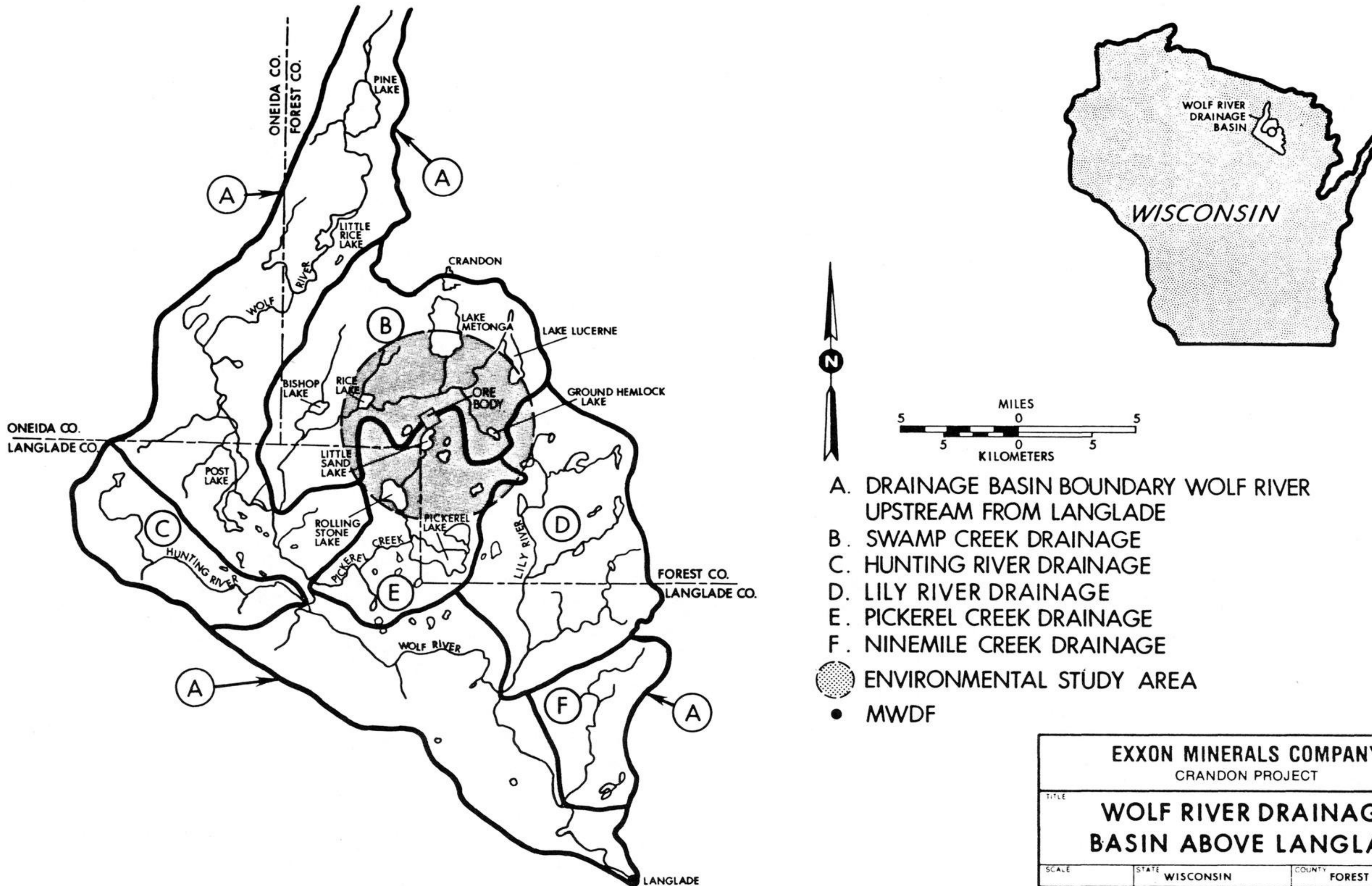
The site area lies entirely within the upper portions of the Wolf River drainage basin in northeast Wisconsin (Figure 7-19). In the regional study area, relatively slow-flowing streams with shallow gradients of 6.9 to 10.6 feet per mile frequently pass through lakes and wetlands. Surface water drainage in the Wolf River Basin ranges from approximately 10 to 13 inches per year (D'Appolonia, 1982a).

The MWDF is located in the Pickerel Creek surface water drainage basin (Figure 7-20). Surface water drainage from Pickerel Creek flows south and west to the Wolf River. Stream channels in the regional study area typically have sand substrates and, on many small tributary streams, the channels are poorly defined.

Numerous lakes and wetlands are present in the environmental study area. The lakes include those whose surface water level is maintained by streams or surface water drainage and a basin seal (e.g., Deep Hole Lake) and lakes whose water supply is maintained by ground water discharge (e.g., Rolling Stone Lake). The lakes are generally shallow (i.e., less than 16 feet in maximum depth) with a sandy substrate (EIR, Section 2.4).

Surface water levels indicate that the lakes near the proposed MWDF recharge to the main ground water table (Figure 7-21) (EIR, Section 2.4). Water seeps from the bottom of the lakes to the main ground water system.

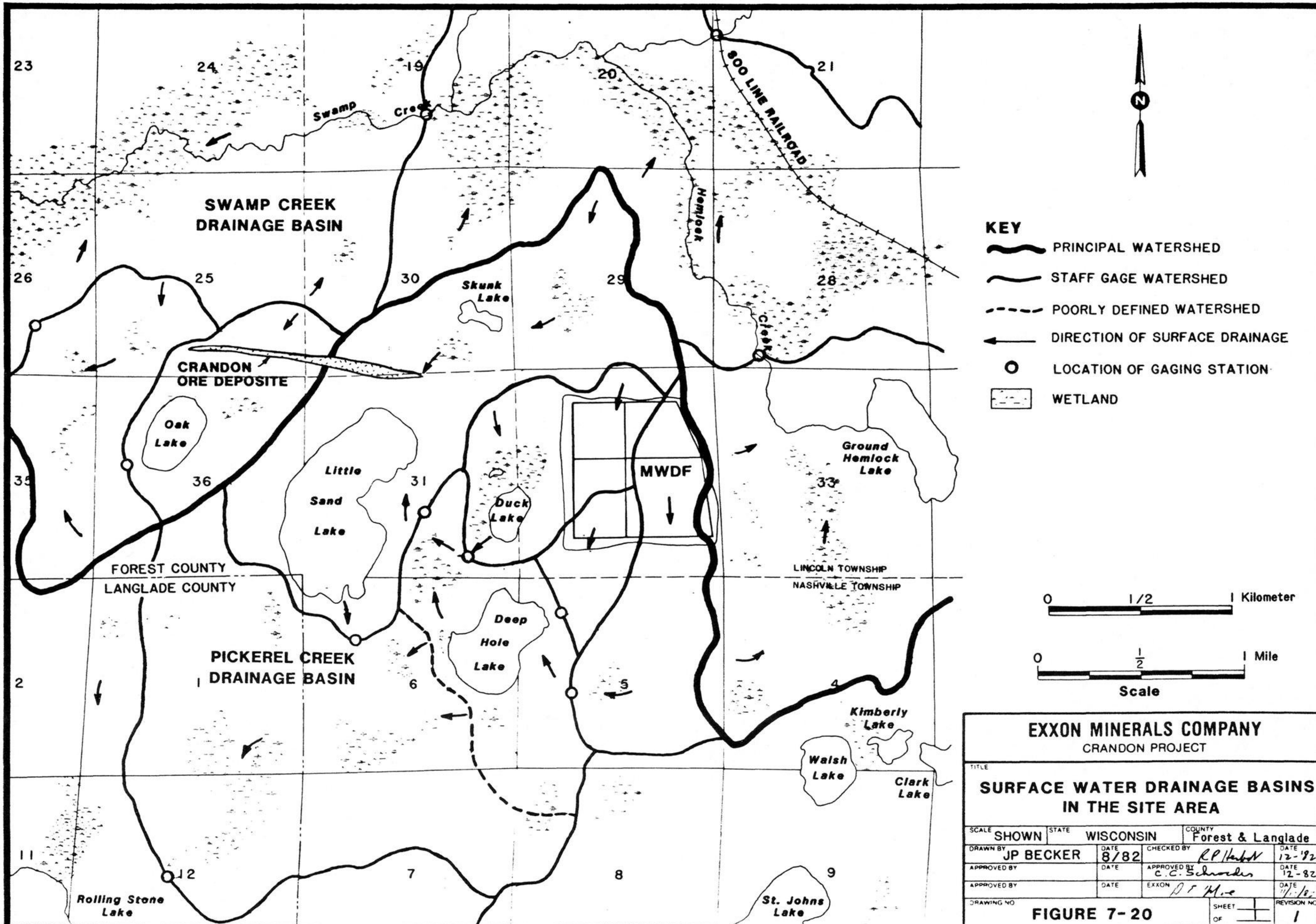
All the streams studied in the Swamp Creek and Pickerel Creek drainage basins are subject to localized flooding caused by beaver dams. Flooding on the lakes in the environmental study area consists of a temporary rise in surface water level from increased drainage usually associated with precipi-



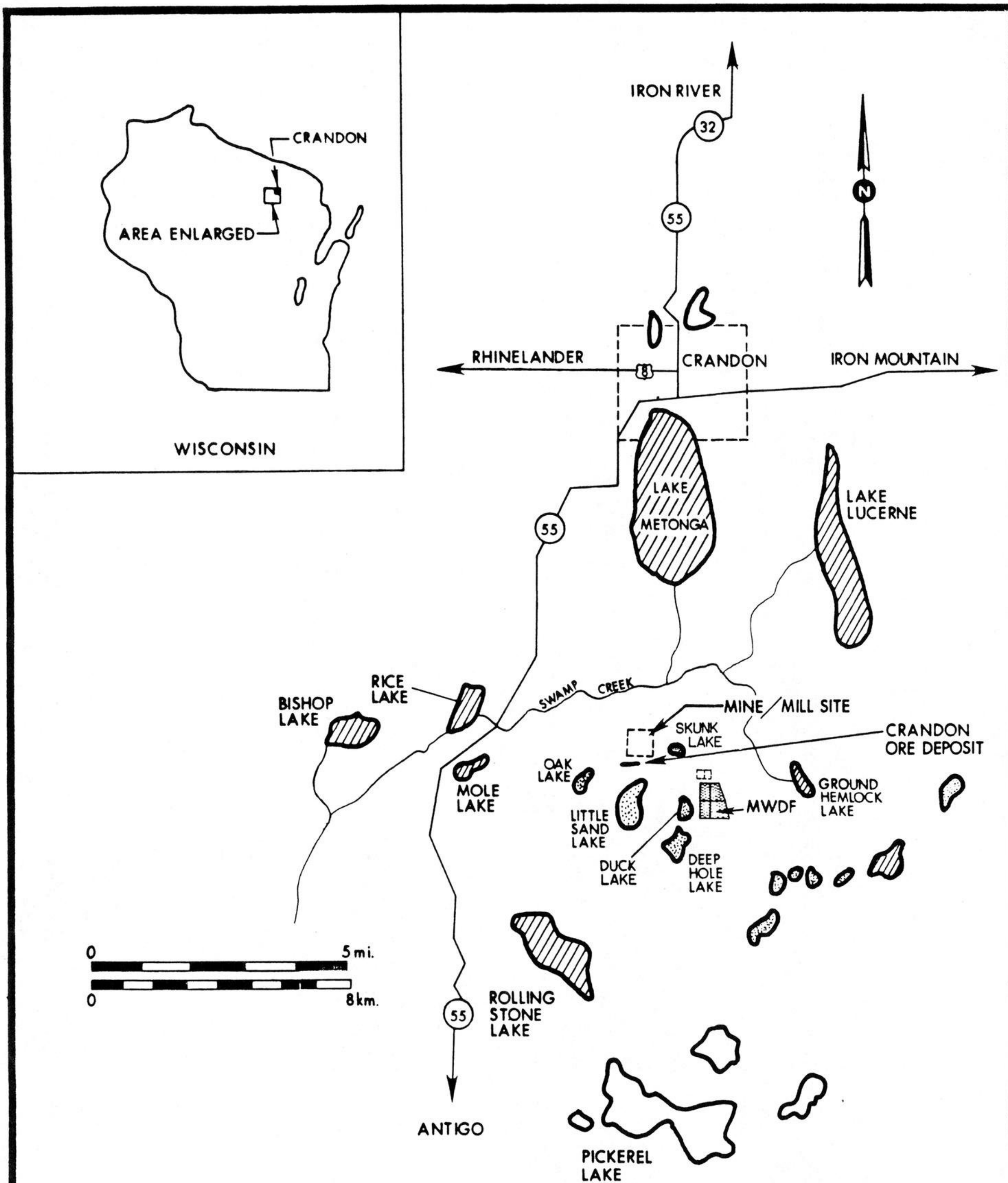
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: WOLF RIVER DRAINAGE BASIN ABOVE LANGLADE

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/27/82	CHECKED BY	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON	DATE
DRAWING NO. FIGURE 7-19		SHEET OF	REVISION NO. 0



23
24
19
20
21
Swamp Creek
SOO LINE RAILROAD
N
SWAMP CREEK DRAINAGE BASIN
Hemlock
KEY
PRINCIPAL WATERSHED
STAFF GAGE WATERSHED
POORLY DEFINED WATERSHED
DIRECTION OF SURFACE DRAINAGE
LOCATION OF GAGING STATION
WETLAND
26
25
30
Skunk Lake
29
28
Clear
CRANDON ORE DEPOSITE
Oak Lake
Little Sand Lake
31
Duck Lake
MWDF
Ground Hemlock Lake
35
36
33
LINCOLN TOWNSHIP
NASHVILLE TOWNSHIP
FOREST COUNTY
LANGLADE COUNTY
0 1/2 1 Kilometer
0 1/2 1 Mile
Scale
Deep Hole Lake
PICKEREL CREEK DRAINAGE BASIN
2
1
6
5
4
Kimberly Lake
Walsh Lake
Clark Lake
11
12
7
8
9
Rolling Stone Lake
St. Johns Lake
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
SURFACE WATER DRAINAGE BASINS IN THE SITE AREA
SCALE SHOWN
STATE WISCONSIN
COUNTY Forest & Langlade
DRAWN BY JP BECKER
DATE 8/82
CHECKED BY
DATE 12-82
APPROVED BY
DATE
APPROVED BY
DATE 12-82
APPROVED BY
DATE
EXXON
DRAWING NO
FIGURE 7-20
SHEET
OF
REVISION NO 1



EXXON MINERALS COMPANY
CRANDON PROJECT

MWDF VICINITY
RECHARGE AND DISCHARGE LAKES

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DMC	DATE 7/82	CHECKED BY	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-'82
APPROVED BY	DATE		
DRAWING NO.	FIGURE 7-21	SHEET	REVISION 1

tation and snow melt (EIR, Section 2.4). Flooding will have no effect on the MWDF because of its upland location.

7.6.2 Wetlands

Wetlands are a common topographic and landscape feature of the regional study area. This is a result of its glacial geologic origin (see subsection 5.1.2). Wetlands are found in kettle holes, melt-water channels, basins created by glacial erosion of thick till, and valleys developed from erosion by flowing water. Small wetlands occur throughout the environmental study area. The type and abundance of wetlands in the site area are similar to those of the region. Figure 5-3 illustrates the wetlands in the MWDF site.

Surface water hydrology is controlled by rainfall, surface soils, topography, and the upland and wetland vegetation. The net result for the majority of the MWDF wetlands is a slow rate of surface water drainage with no readily discernible streams or channels. This is also related, in part, to their location near the top of the watershed. The surface area of the watersheds contributing to the wetlands is small, especially in relationship to the surface water drainage for wetlands located topographically downstream. The ground water hydrology of the environmental study area is predominantly controlled by the dense glacial till and as a result many of the wetlands in the site area are perched (local) water table systems (Golder, 1980). Thus, the water budgets for wetlands in the MWDF location are relatively small (IEP, 1982) An assessment of the effect of the proposed facility on wetlands is presented in Chapter 10 of this report.

7.6.3 Surface Water Quality

Surface waters in the environmental study area have low levels of suspended sediments, averaging approximately 11 mg/l (EIR, Section 2.4). The low total suspended solids loads are a result of the predominant forest land cover, gentle slopes, low stream flow rate velocities, and a lack of fine-grained stream bottom material. In addition, the numerous lakes and wetlands function as sediment traps.

Surface water quality data for streams and lakes in the environmental study area indicate that the water is generally of high quality (EIR, Section 2.4). Table 7.5 summarizes some of the surface water chemistry data for aquatic ecosystems of the environmental study area. Typically, pH values range from slightly acidic to neutral. Hardness classification ranges from soft to moderately hard with low to high levels of alkalinity. Specific conductance and levels of total solids are low to moderate. Soluble metal concentrations are also low. The recharge lakes of the site area have low hardness, alkalinity, specific conductance, total solids, and pH values in contrast to the other lakes and streams of the Wolf River basin drainage (EIR, Section 2.4).

Little Sand Lake contains the clearest water of the lakes near the proposed MWDF. Deep Hole Lake is a light brown color and has higher levels of dissolved organic and inorganic matter than many other lakes of the site area. The mean pH in Duck Lake (5.0) was the lowest determined for any lake in the environmental study area.

TABLE 7.5

SUMMARY OF WATER CHEMISTRY DATA FOR AQUATIC ECOSYSTEMS OF THE ENVIRONMENTAL STUDY AREA[a]

MEAN OF 1977-1978 VALUES (MEAN OF 1979-1980 VALUES)

WATER BODY[b]	ALKALINITY mg/l as $CaCO_3$		HARDNESS mg/l as $CaCO_3$		pH		SPECIFIC CONDUCTANCE umhos/cm		TOTAL SOLIDS mg/l		TRUE COLOR		HARDNESS CLASSIFICATION[c]	pH CLASSIFICATION[c]	COLOR CLASSIFICATION[c]
Little Sand Lake	<2	(5)	12	(10)	5.4	(6.0)	29	(19)	44	(22)	<5	(<15)	soft	slightly acidic	clear
Little Sand Lake	<2	--	10	--	5.4	--	27	--	40	--	<4	--	soft	slightly acidic	clear
Oak Lake	<4	(6)	11	(14)	6.2	(6.5)	23	(16)	56	(30)	<4	(<13)	soft	neutral	clear
Oak Lake	<4	--	11	--	5.9	--	24	--	38	--	<1	--	soft	slightly acidic	clear
Duck Lake	<3	(19)	15	(33)	5.0	(6.1)	30	(50)	53	(47)	59	(87)	soft	slightly acidic	medium brown
Deep Hole Lake	<5	(5)	16	(15)	6.0	(6.2)	30	(21)	58	(24)	<23	(31)	soft	neutral	light brown
Skunk Lake	10	(8)	15	(13)	5.8	(5.7)	27	(20)	79	(26)	119	(64)	soft	slightly acidic	dark brown
Mole Lake	26	--	31	--	7.2	--	52	--	69	--	20	--	soft	neutral	clear-light brown
Rice Lake	<81	(69)	102	(106)	7.3	(7.5)	145	(137)	192	(124)	<40	(41)	moderately hard	neutral	light brown
Rolling Stone Lake	83	--	91	--	7.7	--	117	--	130	--	39	--	moderately hard	neutral	light brown
Rolling Stone Lake	87	--	93	--	7.7	--	118	--	121	--	40	--	moderately hard	neutral	light brown
Hemlock Creek	101	(108)	107	(113)	7.4	(7.7)	136	(133)	161	(129)	<23	(26)	moderately hard	neutral	light brown
Hemlock Creek	105	--	115	--	7.2	--	140	--	143	--	22	--	moderately hard	neutral	light brown
Montanga Creek	88	--	93	--	7.6	--	132	--	168	--	<7	--	moderately hard	neutral	clear
Swamp Creek[d]	103	--	110	--	7.4	--	140	--	182	--	<29	--	moderately hard	neutral	light brown
Swamp Creek	95	(96)	101	(97)	7.3	(7.4)	138	(124)	174	(106)	<28	(36)	moderately hard	neutral	light brown
Swamp Creek	94	(94)	99	(95)	7.3	(7.4)	132	(123)	171	(112)	<31	(36)	moderately hard	neutral	light brown
Swamp Creek	98	--	108	--	7.1	--	138	--	194	--	<24	--	moderately hard	neutral	light brown
Swamp Creek	88	--	110	--	7.4	--	115	--	144	--	75	--	moderately hard	neutral	medium brown
Swamp Creek	95	--	107	--	6.9	--	132	--	158	--	45	--	moderately hard	neutral	light brown
Swamp Creek	81	--	95	--	6.8	--	110	--	131	--	85	--	moderately hard	neutral	medium brown
Creek 12-9	100	(94)	108	(94)	7.4	(7.6)	132	(117)	174	(113)	<28	(27)	moderately hard	neutral	light brown
Creek 11-4	84	(96)	93	(102)	6.9	(7.3)	123	(142)	146	(105)	87	(47)	moderately hard	neutral	medium brown
Upper Pickerel Creek	73	(80)	83	(82)	6.9	(7.2)	92	(89)	126	(106)	106	(72)	moderately hard	neutral	dark brown
Wolf River	52	--	60	--	6.9	--	84	--	115	--	91	--	soft	neutral	medium brown
Wolf River	63	--	73	--	7.0	--	99	--	126	--	83	--	soft	neutral	medium brown
St. Johns Lake	--	(4)	--	(11)	--	(6.1)	--	(14)	--	(21)	--	(14)	soft[d]	neutral[d]	clear[d]
Walsh Lake	--	(5)	--	(13)	--	(6.2)	--	(22)	--	(24)	--	(18)	soft[d]	neutral[d]	clear[d]
Ground Hemlock Lake	--	(110)	--	(112)	--	(8.2)	--	(155)	--	(133)	--	(<12)	moderately hard[d]	slightly basic[d]	clear[d]
Ground Hemlock Lake	--	(129)	--	(128)	--	(7.7)	--	(180)	--	(171)	--	(<15)	moderately hard[d]	neutral[d]	clear[d]

a Source: EIR, Section 2.4

b Repeat of water body name indicates different sampling locations in the system.

c Based on 1977-1978 data.

d Additional water chemistry data in Swamp Creek in the vicinity of the proposed water discharge site are presented in Ecological Analysts, Inc. (1983, 1984).

8.0 FACILITY LOCATION AND DESIGN

8.1 General

The location and design criteria in NR 182, which are intended to ensure environmentally acceptable facilities, have been followed closely during the location and design process for the proposed facility. Particular attention has been given to siting criteria, minimization of seepage, staging of pond construction and reclamation, and maintaining high reclamation standards to reduce the potential for long-term care problems. Also, appropriate monitoring programs and contingency plans have been developed.

This chapter contains a brief summary of the location criteria in NR 182 and an evaluation of compliance with those criteria. The design criteria listed in NR 182 were also used as guidance for the facility design. Details of the preliminary facility design are presented in Chapter 9, Preliminary Engineering. Several major design decisions, included as the proposed MWDF engineering evolved, are presented in the last section of this chapter to provide a transition to the more detailed discussion of the engineering design in Chapter 9. Chapter 10, Environmental Evaluation of Facility, contains a discussion of the measures that protect the environment, with emphasis on wetlands and ground water. Surface waters are also discussed as they relate to facility location and design. Chapter 11, Alternatives, discusses the alternative designs and sites that were considered.

8.2 NR 182 Location Criteria

The location criteria listed in NR 182 are summarized in Table 8.1. Compliance with the location criteria is also addressed in this table.

TABLE 8.1

SUMMARY OF NR 182 LOCATION CRITERIA

CRITERIA	MWDF COMPLIANCE	REASON OR EVIDENCE
Mine Waste Disposal Facilities:		
NR 182.07(1)		
(a) Are excluded from areas defined by S.144.81(18). Stats. and NR 132.03(25) Wisconsin Administrative Code. The presence of endangered and threatened species will be considered.	Complies	No endangered species of wildlife or vegetation.
(b) Must be at least 1,000 feet from navigable lakes, ponds, and flowages.	Complies	See Plan Sheet 2.
(c) Must be at least 300 feet from a navigable river or stream.	Complies	See Plan Sheet 2.
(d) Must be outside floodplains.	Complies	See Plan Sheet 2.
(e) Must be at least 1,000 feet from the right-of-way of a state trunk, interstate, or federal primary highway, parks, wild rivers, and other recreational and scenic areas unless visually screened to be aesthetically pleasing.	Complies	See Plan Sheet 2.
(f) Must be at least 1,200 feet from a water supply well.	One Special Purpose Well	Only known water supply well within MWDF compliance boundary is TW-41, constructed for hydrogeological testing but planned to be abandoned prior to construction of pond T1. A new water supply well for construction water will be installed in the construction support area.

Table 8.1 (continued)

CRITERIA	MWDF COMPLIANCE	REASON OR EVIDENCE
(g) Must not overlie known mineral resources likely to be mined and within 1,000 feet of the surface.	Complies	Drill holes have not indicated any mineral resource beneath the MWDF.
(h) Must be at least 200 feet from the property line.	Complies	See Plan Sheet 3.
(i) Must not be in an area where the Department finds there is a reasonable probability of surface water quality violations per NR 102 to 104, Wisconsin Administrative Code.	Complies	See Chapter 10.0.
(j) Must not be in an area where the Department finds there is a reasonable probability of ground water violations per NR 182.075, Wisconsin Administrative Code.	Complies	See Chapter 10.0.
(2) Must comply with NR 132.06(4), Wisconsin Administrative Code regarding disturbance to wetlands.	Complies	See Chapter 10.0 and Attachment 14 Mining Permit Application.
NR 182.011(2)		
(a) Should be located, where practicable, in the same watershed as the mining surface facilities.	Partial Compliance	The mining surface facilities are located in the Swamp Creek and Pickerel Creek watersheds. The MWDF is located in the Pickerel Creek watershed. See Chapter 11.0.
(b) Should be located so that tailings pipelines do not cross major water courses or wetlands.	Partial Compliance	A tailings pipeline route crossing one wetland area has been determined most environmentally acceptable.

8.3 Major Design Concepts

During the study of the waste characteristics and the environmental setting, the following major design concepts were developed for the proposed MWDF:

1) Containment - the MWDF will be designed to contain the mine wastes including the mine tailings and lesser volumes of water treatment associated wastes;

2) Leachate Management - an underdrain system was included in the design to collect leachate and minimize the seepage rate through the liner;

3) Liner Compatibility - the MWDF will be lined with material that is compatible with the waste and leachate from the waste;

4) Liner Permeability - the liner used will be of low permeability to minimize seepage from the base of the facility;

5) Ground Water Separation - the base of the MWDF will be maintained well above the ground water to provide attenuation of any leachate moving through the liner;

6) Overall Area Disturbance Impacts - the facility will be designed with multiple ponds to allow phased construction, operation and reclamation thereby minimizing overall impacts;

7) Contingency Method - the design would be compatible with contingency measures and the phased development, in itself, would be considered a contingency measure;

8) Waste Rock Usage - waste rock will be used for slope protection within the disposal ponds. Although used for construction, all waste rock would be underlain by the same seepage control system used for other mine wastes;

9) Acid Generation Prevention - the proposed MWDF will be designed to maintain anaerobic conditions in the ponds to limit pyrite oxidation after reclamation. Acid generation potential will be controlled during operation of the MWDF by pH adjustment (lime addition);

10) Pond Access - access to the ponds by truck and slurry pipelines is included in the MWDF design;

11) Surface Water Drainage (Runoff) - during construction and reclamation work and until surface soils have stabilized, any

surface water drainage from the MWDF will be controlled to pass through sedimentation basins. The reclamation plan will be designed to maintain the existing drainage patterns and characteristics at the MWDF location as much as possible;

12) Final Cover - the final reclamation cover for the facility will be of low permeability materials and have an overdrain to minimize infiltration to the tailings. The cover will be the major factor limiting leachate production and seepage after closure. The drainage system would be designed to redirect precipitation to the tailing ponds perimeters where it could infiltrate outside of the tailings mass;

13) Monitoring - monitoring programs have been designed to give early warning of any potential problems (see Monitoring and Quality Assurance Plan in the Mining Permit Application);

14) Long-Term Stability - the reclamation of the MWDF will assure long-term stability and security;

15) Final Grades - for aesthetic purposes, the final grades of the facility will be limited, as much as possible, to tree top levels of the surrounding area;

16) Earthwork balance - the MWDF was designed to eliminate surface disruption and environmental effects on land outside of the facility boundary by attempting to achieve a cut and fill balance within the confines of the MWDF; however, to provide an allowance for earthwork estimating inaccuracies, a borrow area of 0.5 M yd^3, requiring about 30 acres, has been planned;

17) Constructability - all facility design components will utilize accepted construction procedures and methods; and

18) Performance Assurances - critical design features, such as the facility seepage control system, will incorporate measures of design redundancy to provide additional levels of performance confidence.

9.0 PRELIMINARY ENGINEERING

9.1 Proposed Facility Design

9.1.1 Introduction and General Description

This chapter presents the preliminary engineering design and proposed operating procedures for the MWDF. The preliminary design incorporates methods for the handling and disposal of the tailing fines and waste rock expected to be produced from the mine and mill. Alternative disposal technologies considered for this preliminary design are presented in Chapter 11 and in the Environmental Impact Report (EIR).

The goal of the preliminary design of the facility is to provide a safe, environmentally acceptable and functional system which can be constructed, operated, and reclaimed according to standards in NR 182. Several of the design concepts are influenced by the specific environment for the location of the MWDF (Area 41). These environmental features, which were discussed earlier in this report, include ecology, geology, hydrology, land use, and legal requirements. During the site selection process many of these features were addressed to identify potential waste disposal sites (Golder, 1980).

The MWDF is sized to hold the waste volumes estimated to be generated throughout the Project life. During operations the tailings will be pumped in a pipeline from the mill to the ponds as a slurry with a solids content of approximately 55 percent by weight. The excess water will pool on the tailings surface and will be pumped to one of two reclaim pond cells located north of the four tailing ponds (Plan Sheet 4). The design and operation of the water reclaim pond is outside the scope of the NR 182 Feasibility Report, but are included on many of the report figures for reference purposes only (for discussion of the reclaim pond, see the Mining Permit Application).

A portion of the slurry water is retained with the disposed tailings in the pond. Leachate from the tailings will be collected at the base of the facility from an underdrain (drain) layer above the pond liner and pumped to the reclaim ponds.

The tailing ponds will be sequentially closed and reclaimed after each pond is filled to capacity. Upon completion of all disposal activities, the fourth tailing pond will be closed, the water reclaim pond will be removed, and final closure and reclamation of the facility will be completed.

Waste Disposal Facility

The primary function of the MWDF will be to provide for environmentally compatible surface disposal of the waste generated from the mining and processing of the ore. The layout, performance and operations of the MWDF are described herein. The MWDF will consist of earthen ponds constructed primarily from site area soil materials. The ponds will be lined with a bentonite modified soil mixture with an underdrain placed over the liner. The facility will be sized to accommodate the tailings fines, reclaim pond sludge, and water treatment plant sludges. Most of the waste will be ground rock (tailing) produced during the milling of the ore.

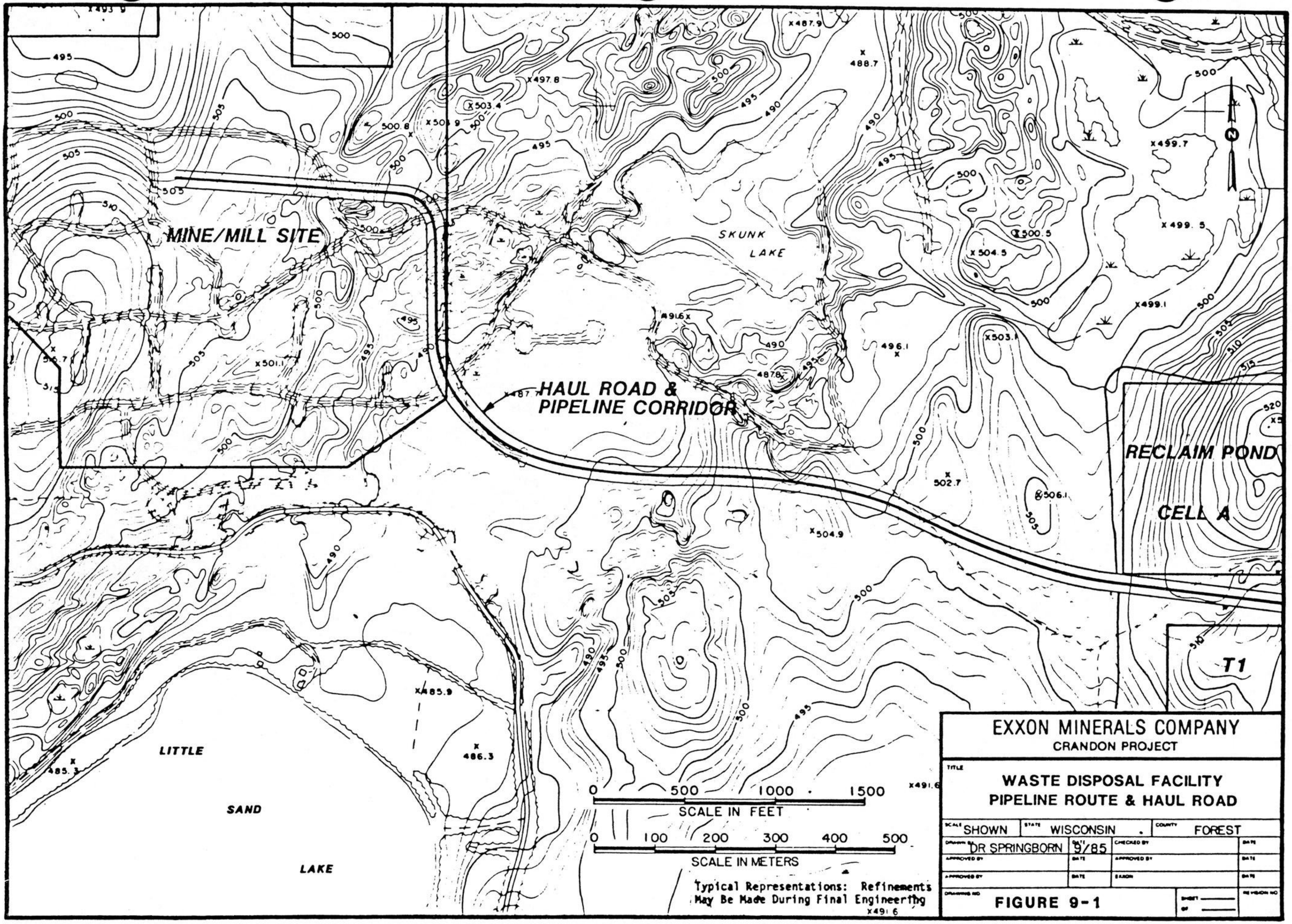
Plan Sheet 4 shows the MWDF in relation to the mine/mill site, the access road, the railroad spur, and the adjacent water reclaim pond. Four ponds with a combined surface area of 360 acres contained within the facility perimeter (outside embankment toe) will be used over the productive life of the mine. The four ponds will be similar in size and sequenced in construction, operation, and reclamation to accommodate the production of tailings from the mill.

The topography of the site area has been utilized in planning the layout of the tailing ponds and embankment locations. The topographic features affect the volume of earthwork required to construct the embankments and the soil volumes available for other uses in the facility. The existing topography is also an important aspect of the structural stability of the embankments and of the reclaimed tailing ponds. Valleys or surface depressions are desirable areas for containment because of their structural stability; they also minimize the amount of earthwork required. Naturally occurring surface depressions at the site area were used as much as possible in developing the proposed MWDF layout.

The facility has been designed to have an approximate cut/fill earthwork balance during construction, operation, and closure; that is, the majority of the soils required for facility construction can be obtained from excavations within the tailing pond areas. However, to provide an allowance for earthwork estimating inaccuracies or other earthwork imbalances that could develop over the Project life, a 0.5 M yd^3 borrow area has been planned (see Plan Sheet 2). Temporary storage of soil and other construction materials will occur and has been planned for during the MWDF construction and operations (see Plan Sheets 27 through 31).

<u>Tailings Transport and Reclaim Water Transfer</u>

The tailings transport system will transfer the fine tailings by pipeline from the mill to the MWDF as a slurry. Figure 9-1 shows the proposed route for the pipeline from the mill to the reclaim ponds at the MWDF area.


MINE/MILL SITE
SKUNK
LAKE
HAUL ROAD &
PIPELINE CORRIDOR
RECLAIM POND
CELL A
T1
LITTLE
SAND
LAKE
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
Typical Representations: Refinements
May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL FACILITY
PIPELINE ROUTE & HAUL ROAD
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 9/85
CHECKED BY
APPROVED BY
DRAWING NO
FIGURE 9-1

Pipes at the MWDF will be routed along the embankment crests (see Plan Sheet 16). The haul road from the mine/mill area to the MWDF will share a common corridor with the pipeline system. From the eastern side of the mine/mill area to the northwest corner of tailing pond T1, the pipeline length is about 0.9 miles.

Roads will be provided on the crest of the embankments and along the toe of the exterior embankments for inspection and to facilitate periodic maintenance of the facility if required. The roads will be surfaced with crushed rock or granular materials to provide an all-weather surface. The road alignments are shown on Plan Sheet 16. The embankment crests are designed to accommodate a minimum 16-feet wide road with safety berms or guard rails. In some sections of the ponds, the embankment crest is wider because the tailing and water recycle pipelines are parallel to the road. The perimeter access road at the toe of the embankments is designed to be 10 feet wide for one-way traffic. The haul road to the MWDF is 30 feet wide to permit two-way traffic; additional width is provided where necessary for pipelines. Roadway details are included on Plan Sheet 23.

From the mill to the MWDF, the pipeline system will be installed underground. There will be no need for emergency dumping of the tailings in the event of power interruption; the system has been designed to be restarted under load. Whereas NR 182.11(1)(u) directs that emergency spill areas should be included; with the proposed design, emergency spill areas are unnecessary. The tailings slurry pumps will be located at the mill site; there is no need for interim pumping along the pipeline. Pumps for returning reclaim water to the mill site will be located at the reclaim pond.

Three pump and pipeline systems will be included in the system from the mine/mill site to the MWDF area or reclaim pond. They are:

1) 6.5-inch inside diameter high density polyethylene (HDPE) tailings slurry pipeline with two operating pumps and two standby pumps. The pumps and piping system will handle approximately 555 gallons per minute of tailings slurry.

2) 15.0-inch inside diameter HDPE reclaim water return pipeline with one operating and one standby pump. The system will handle approximately 3,460 gallons per minute of water.

3) 15.0-inch inside diameter HDPE thickener overflow pipeline with one operating and one standby pump. The system will handle approximately 3,440 gallons per minute of water.

The HDPE pipe has been selected on the basis of its resistance to abrasion and corrosion. It is not affected by chemicals in the soil and it does not support the growth of, and is not affected by, algae, bacteria and fungi.

With the pipe diameter chosen and planned tailings flow rates, the expected pipeline operating pressures are well below the rated allowable pipeline pressures.

To further safeguard and protect the system, the tailings pipelines and other pipes handling process water will be buried 6-feet below ground to avoid damage by freezing or external hazards.

The trench will be over-excavated. The trench volume below the pipes will be backfilled with sand, gravel or other select material to support the pipe. Generally, the pipe bed material will be free of rock and will contain no jagged or soft rock.

After the pipe has been placed, it will be surrounded with compacted sand, gravel, or other select material and then backfilled with compacted glacial till derived from trench excavation.

Instrument cable will be buried with the pipe. The cable will be used as a metal source for pipeline locating instruments.

Because the tailing pond embankment crests are at a higher elevation than the pumping station and the discharge of tailings to the lower depths of the ponds could create a vacuum in the tailings line, a vacuum breaker will be installed at the high point of the pipeline on the tailings pond crest.

Because the pipeline is buried, it will not be vulnerable to deliberate or accidental damage from humans, vehicles or machines. The depth of burial below the maximum frost-line excludes the possibility of freezing. Rodent attack is unlikely at the 6-foot depth.

Slurry characteristics determined by laboratory penetrometer tests show that the solids are "soft-settling" (PSI, Inc., 1982). In this test procedure, a sample of tailing solids and water is prepared and allowed to settle for 24 hours. A penetrometer is placed on the solid-liquid interface. Weights are added to the penetrometer until the tip penetrates the solids and reaches the bottom of the containing vessel. The weight required to achieve penetration under standard conditions is a measure of the resistance of the settled solids to re-slurrying after a pipeline shutdown.

The results of the tests indicated that if the pipeline is shutdown during an emergency, the solids are soft-settling and can reslurry when the pipeline is restarted. During scheduled shutdowns of the pipeline, the solids will be flushed out with water prior to shutdown.

In the event of a sudden blockage of the pipeline, the slurry pumps will not be able to develop the pressure required to rupture the line. The increase in pipeline pressure and decreasing flowrate would activate alarms and the pipeline would be shutdown.

The pipe will be received in 38-feet lengths. All pipe will be inspected for damage on-site. Sections of pipe with cuts or gouges will be cut out and rejected. Each piece of pipe will be fusion butt welded to form a continuous pipeline from the pumping station in the mine/mill site to the discharge point. Butt fusion welding involves heating both ends of the pipes to be joined, making contact between the two molten ends and joining them together under pressure. The operation is performed using commercially available equipment designed for this purpose. The equipment is easily transported and may be used at any point along the pipeline during the installation of new pipe or the repair of old pipe. The joint which is formed is stronger than the pipes it joins.

A similar technique will be used to construct the reclaim water, thickener overflow water, and tailing ponds decant water pipelines. However, the decant water/underdrain water pipelines will remain on surface. Also, the tailings lines in the immediate area of the MWDF will be constructed at grade.

Buried pipelines are inherently safer than pipelines located on the surface. They are silent in operation and not visible. Typically, vegetation covers the trenched area within 2 years.

In the event of a pipeline breakage, flowrate monitoring equipment would warn the operator to shutdown the pipeline system. Such an event could be cause for a complete plant shutdown. For the case of a pipeline break at the lowest elevation in the pipeline route the contents of the pipe would drain to the low point. In the worst case the contents of about a 5,900-foot length of line could leak from the pipeline. This is equal to a volume of 10,170 gallons of slurry. However, because of the low elevation heads, the rate of leakage would be low and little solid material would escape. Also, slurry leakage could be minimized by flushing the line with water prior to excavating the break.

Clean-up would require excavation around the leak and the water and tailings would be pumped to the MWDF. Repair would involve the removal of the damaged pipe and welding in new pipe using portable butt welding equipment. The repaired pipeline would be leak tested using water before backfilling and returning the pipeline to normal service. Spare plastic pipe will be retained in storage for repair purposes.

Pipeline leaks in conventional flanged or mechanically coupled pipelines typically occur at the flanges or in areas of the pipe where sudden changes in direction are necessary. The use of welded plastic pipe eliminates the flange or other connections and reduces the possibility of leakage. Typically, HDPE pipe can be cold bent to a minimum radius of 25 times the pipe diameter. This allows gradual direction changes to be made and reduces the possibility of pipe wall erosion thus minimizing the potential for leaks.

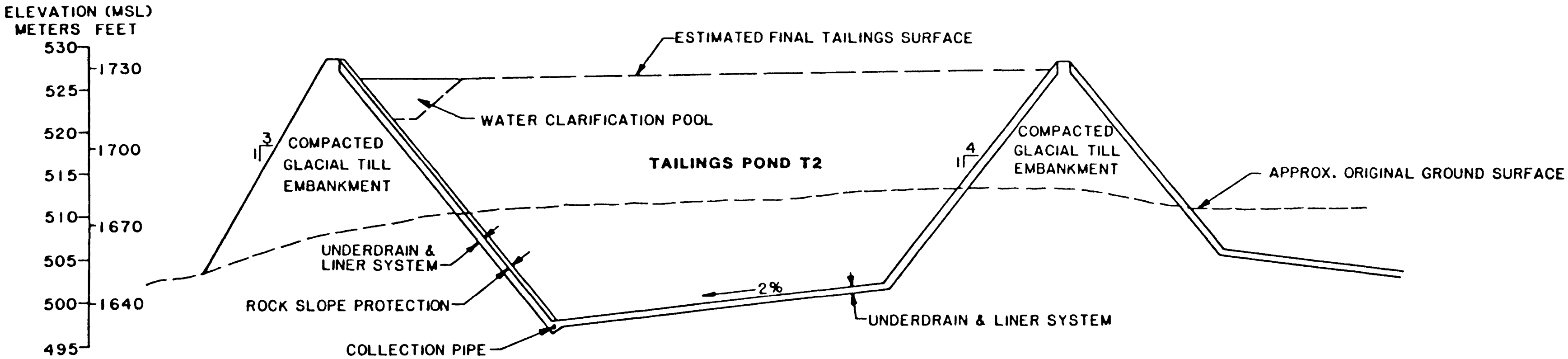
9.1.2 Tailings Disposal

Waste Volume - The size of the MWDF is based on the amount of tailings which cannot be returned to the mine. The Project orebody is currently estimated to have 67.4 million tons of mine recoverable reserves. Applying reasonable values for percentage of fine tailings to orebody of 40 percent and final tailings density of 108 pounds per cubic foot results in a fine tailings disposal volume of 11,467 acre-feet.

In addition to the fine tailings, the design has allowed for up to 200 acre-feet of volume requirement for the sludges produced from the water treatment process throughout the mine life. The proposed facility design provides a design waste storage volume of 13,388 acre-feet, thus yielding a storage volume contingency of about 15 percent.

In addition to the waste materials described above, the water treatment process produces sodium sulfate as a by-product. In all likelihood this material will be marketed and there will be no need for on-site disposal. However, provision has been made to provide capacity for all necessary storage within the MWDF. The estimated total sodium sulfate volume of 105,000 cubic yards and the volume of the associated containment dikes are adequately provided for in the facility contingency. Plan Sheet 26 shows the proposed locations within ponds T1-T4 for storage of the sodium sulfate if it becomes necessary.

Tailing pond freeboard above the normal water level when the pond is full has been designed to meet the requirements of NR 182. Calculations by Golder Associates (1982a), considering the requirements of NR 182.11(1)(q), indicated that a 3-foot freeboard was sufficient to prevent overtopping of waves for the 100-year, 24-hour rainfall event and accompanying high winds. A section through a typical tailing disposal pond is shown on Figure 9-2.

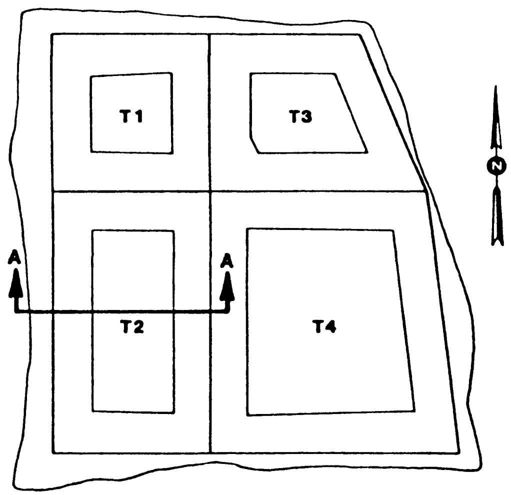


SECTION A-A

0 50 100 150
SCALE IN METERS

0 250 500
SCALE IN FEET

VERTICAL SCALE EXAGGERATED 5x



PLAN VIEW
(NOT TO SCALE)

Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY
PLAN & SECTION

SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO **FIGURE 9-2**		SHEET ___ OF ___	REVISION NO

Additional sections through other areas of the MWDF are shown in Plan Sheets 18, 19, 20, and 21.

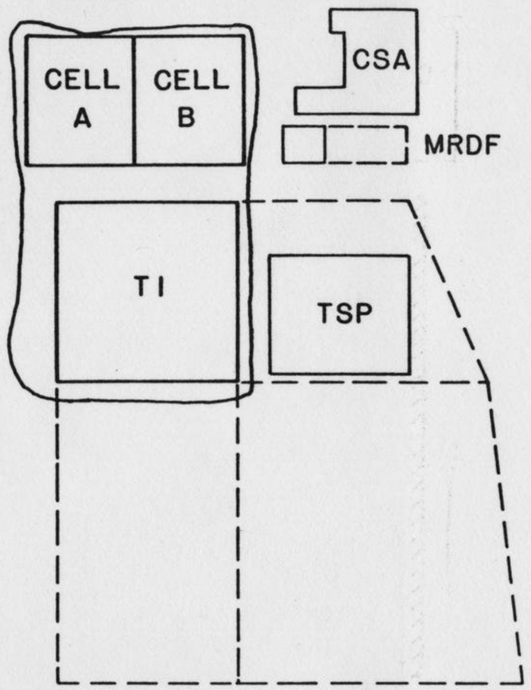
Mine Waste Disposal Facility Location and Design - An area approximately 1.5 miles southeast of the mine/mill site will be used for the MWDF. This area primarily lies in Section 32, T35N, R13E in Forest County (see Plan Sheet 3).

The major characteristics of this area (designated Area 41) are: an extensive upper soil layer of relatively low permeability till; low ground water gradients; the depth from the existing ground level to the main ground water table averages approximately 100 feet; and no current domestic use of ground water within the compliance boundary area of the MWDF. In addition, with the distance from pond bottom to ground water of approximately 45 feet, any pond seepage from this area will have to pass through a large volume of soil that will provide considerable attenuation. Soil attenuation is specifically addressed in the Soil Attenuation Study - Final Report (D'Appolonia, 1982b). This report includes information on the attenuation of chemical constituents in tailings leachate with Crandon site till and drift soils.

The design layout for the MWDF, designated as 41-114C, is shown on Plan Sheet 5. The facility will consist of four ponds that are constructed, operated, and reclaimed sequentially. The phased development of the entire MWDF is shown in Figure 9-3.

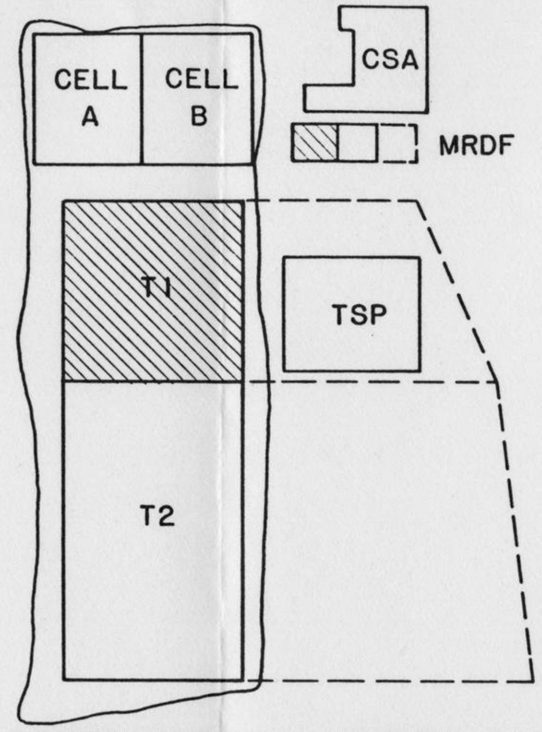
The detailed configuration of the MWDF and the interface area with the water reclaim pond for each of the main development phases is presented in Plan Sheets 27 through 31. The phased development of the MWDF has been

PHASE 1 - YEARS 1-4



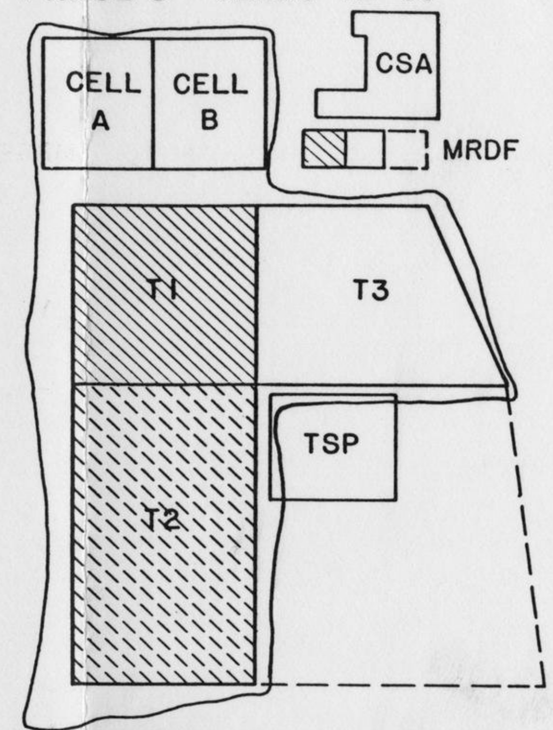
**CONSTRUCTION OF TAILING POND T1,
WATER RECLAIM POND, MRDF CELL 1 & CSA**

PHASE 2 - YEARS 5-11



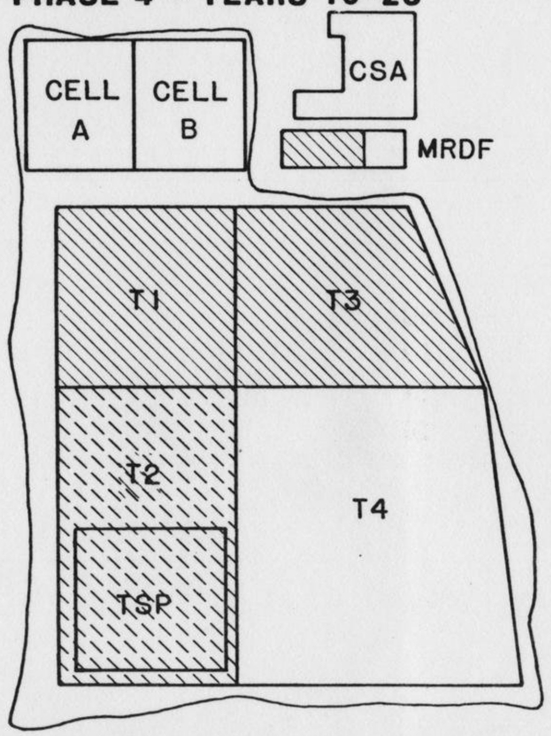
**CONSTRUCTION OF TAILING POND T2
& MRDF CELL 2
RECLAMATION OF TAILING POND T1 &
MRDF CELL 1**

PHASE 3 - YEARS 12-16



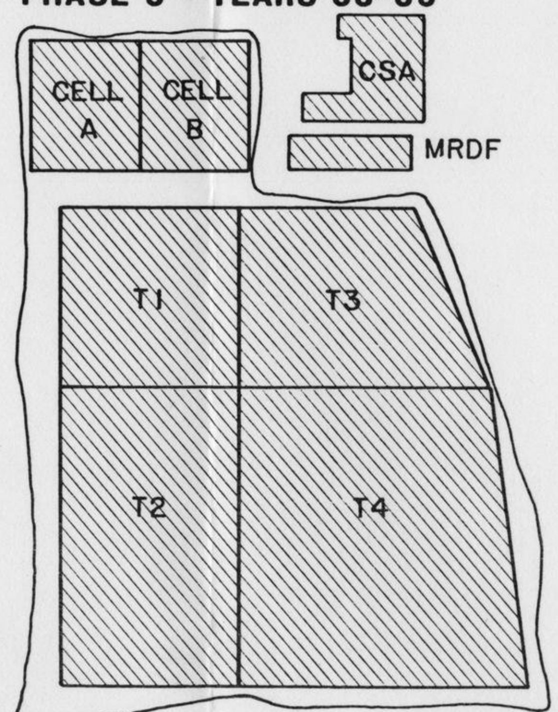
**CONSTRUCTION OF TAILING POND T3
PARTIAL RECLAMATION OF TAILING POND T2**

PHASE 4 - YEARS 19-23



**CONSTRUCTION OF TAILING POND T4 &
MRDF CELL 3
RECLAMATION OF TAILING POND T3 &
MRDF CELL 2**

PHASE 5 - YEARS 33-36



**RECLAMATION OF TAILING POND T2 & T4,
WATER RECLAIM POND, MRDF CELL 3 & CSA**

LEGEND:
- CSA – CONSTRUCTION SUPPORT AREA
- TSP – TILL STOCKPILE
- MRDF – MINE REFUSE DISPOSAL FACILITY

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **WASTE DISPOSAL AREA FACILITIES CONSTRUCTION & RECLAMATION PHASES**

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	11/13/85
APPROVED BY	DATE	EXXON	11/19/85
DRAWING NO **FIGURE 9-3**		SHEET ___ OF ___	REVISION NO

considered a key aspect of the overall MWDF design. Developing the ponds in this fashion minimizes many impacts associated with or related to overall facility size and also it allows for continuing refinement of design and operation as experience is gained and/or technology advances. Phasing, itself, amounts to a form of contingency planning. There are also some worthwhile economic benefits attributable to phasing as a result of deferred capital costs; however, these are somewhat offset by the forward movement of the reclamation work. The net benefit of phasing is an integration of both economically and environmentally sound project objectives.

The inside slopes of the pond embankments will be 4 horizontal to 1 vertical (4H:1V) to accommodate placement of the pond lining system. The outside slopes will be 3H:1V. The 3H:1V outside slopes of the MWDF are conservatively flat for stability and for maintainability. The glacial till soils to be used in the embankments are excellent construction soils and could be placed at steeper slopes if desired. The 3H:1V outside slopes were chosen with aesthetic consideration for the reclaimed facility allowing blending into the surrounding topography. The 4H:1V inside slopes have been chosen primarily to facilitate construction of the bentonite-modified soil liner and other seepage control system layers. With these flat slopes, conventional equipment can be used to construct the seepage control system readily and meet required quality control objectives.

An analysis has been performed to assess the safety of the embankment design. The technical studies have evaluated the stability of the embankment slopes under both static and seismic conditions and the design freeboard which is influenced by precipitation, wind velocity, and process shutdown (Golder, 1982a).

The stability analysis of the design slopes with respect to major slope failure indicates that the minimum factors of safety for static and seismic conditions are 2.1 and 1.8, respectively. The stability analysis was conducted with conservative assumptions about the conditions of the embankment system. The major assumptions were: the entire depth of the tailing within the ponds is in a liquid state with no shear strength; seepage from the tailing ponds will saturate large portions of the embankment and induce steady-state seepage forces; and pseudo-static seismic loadings based on horizontal acceleration of 0.06g were applied (Golder, 1982a). Using these assumptions, in conjunction with the design section and assumed physical properties for the embankment materials, a simplified Bishop's method of analysis was used to assess stability (Golder, 1982a). As previously described, the safety factors against both deep or shallow slope failure exceeded 1.8 in all cases (even under seismic loading) for the proposed embankment design, indicating that the slopes are stable.

The effects of local seepage developing at the perimeter of the reclamation cover from the proposed infiltration trench at the embankment crest was evaluated with regard to slope stability by Ayres Associates (1984). For these analyses the direction of seepage was varied from horizontal to parallel to the embankment face. The results of these analyses indicate that the embankment surface will be stable under the most severe seepage conditions provided that an earthquake producing a 0.06 g site acceleration does not simultaneously impact the site. The likelihood of either condition occurring is minimal; consequently, the probability of a simultaneous occurrence is negligible (Ayres Associates, 1984).

Specific individual pond design data are included below and additional data are presented in Plan Sheet 5:

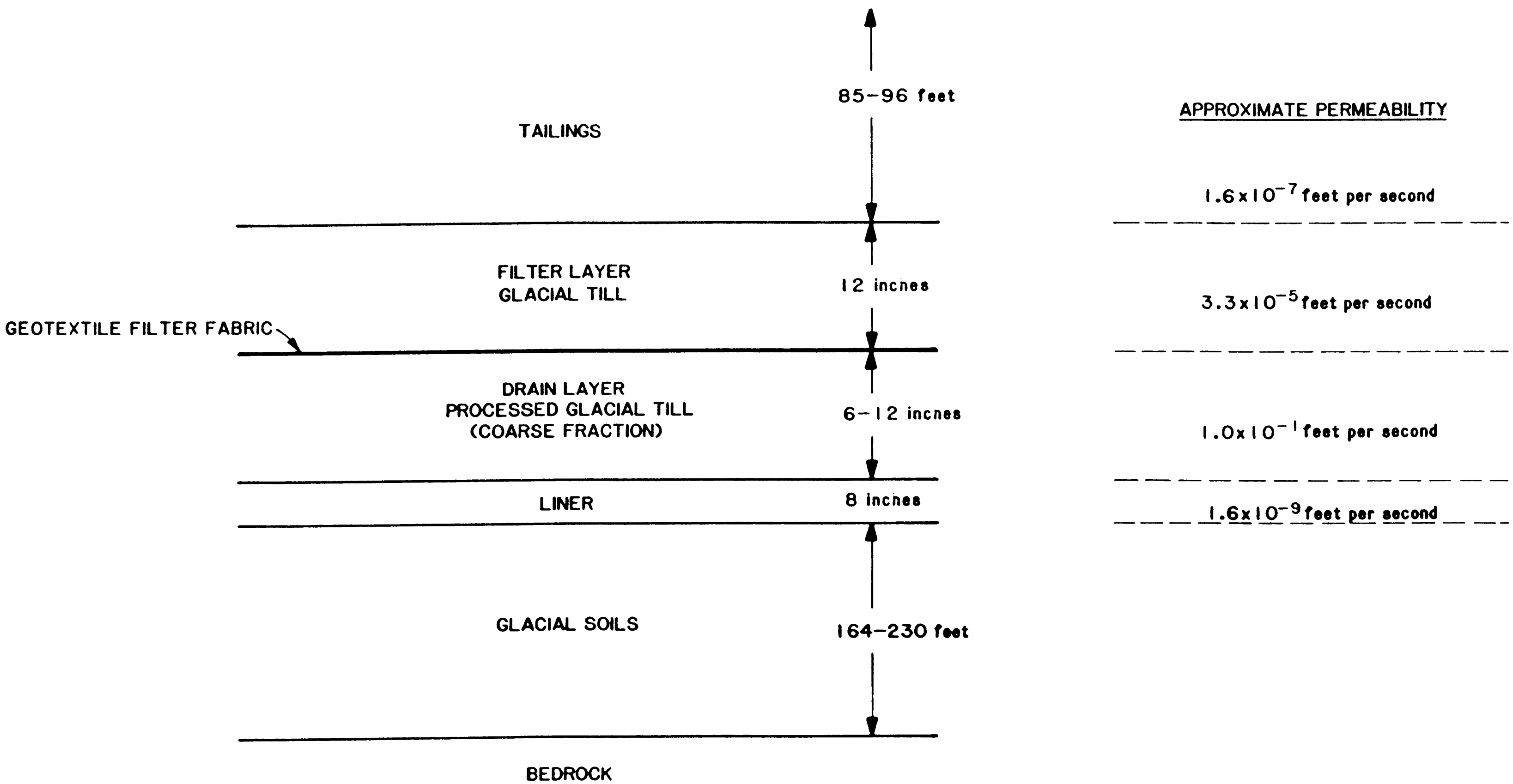
MWDF INDIVIDUAL POND DATA

Pond Data/Pond Number	Tailing Ponds T1	T2	T3	T4	T1-T4
Area Inside Crest (acres)	43	71	50	107	271
Bottom Area (acres)	9	22	12	39	82
Lined Slope Area (acres)	35	50	39	70	194
Maximum Interior Depth (feet)	99	99	99	99	--
Maximum Exterior Fill Height(feet)	110	107	36	77	--
Crest Elevation (feet)	1,732	1,732	1,732	1,732	--
Lowest Bottom Elevation (feet)	1,633	1,633	1,633	1,633	--
Struck Storage Volume ($x\ 10^6\ yd^3$)	3.56	6.59	4.25	10.46	24.86
Tailings Storage Volume ($x\ 10^6\ yd^3$)	3.1	5.7	3.7	9.1	21.6

9.1.3 Leachate Management

One of the major design concepts incorporated in the preliminary engineering of the MWDF is the selection of a liner and leachate collection (underdrain) system along the base areas of the ponds and upstream slopes of confining embankments. The purpose of the liner and the underdrain system is to minimize the volume of seepage that enters the glacial till soils from the MWDF.

Analyses performed for the MWDF leachate management system indicate that the most feasible design is a liner and two layer blanket underdrain of prepared local soil materials (Golder, 1982b). Figure 9-4 presents the conceptual design selected for the MWDF liner and underdrain system. The



Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: **DIAGRAM OF LINER & UNDERDRAIN SYSTEM**

SCALE: NONE	STATE: WISCONSIN	COUNTY: FOREST
DRAWN BY: DR SPRINGBORN	DATE: 9/84	CHECKED BY: H.S. — DATE: 10-15-84
APPROVED BY:	DATE:	APPROVED BY: C.C. — DATE: 10-15-84
APPROVED BY:	DATE:	EXXON: D.E. — DATE: 1/13/85

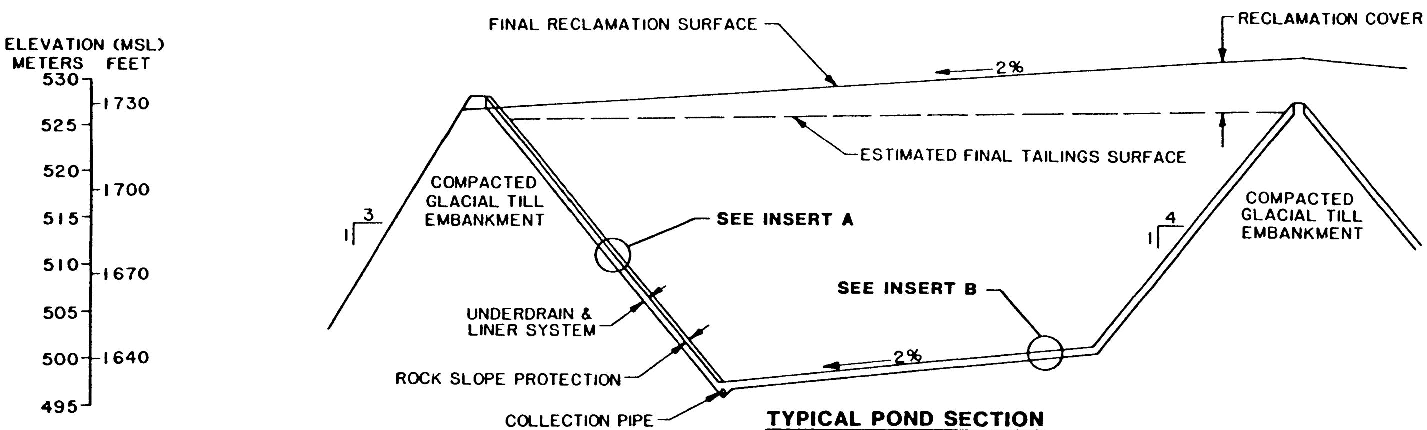
DRAWING NO: **FIGURE 9-4**

underdrain system consists of an upper filter layer, a geotextile filter, a drain layer, a liner and perimeter leachate collection pipes. The filter layer has been designed to transmit leachate to the drain layer and also to inhibit migration of tailing into the drain layer. The geotextile will similarly act to prohibit migration of fines from the filter layer into the drain. The drain layer has been selected to provide sufficient hydraulic capacity to accommodate estimated leachate volumes from the filter layer.

All of the ponds will utilize a full underdrain system below the entire tailings area to collect and remove seepage water. The underdrain system will be underlain by a bentonite modified soil liner. A typical full pond configuration of the underdrain system with a filter layer, geotextile, a drain layer, and the bentonite modified soil liner is presented in Figure 9-5.

The seepage control system will be continuous over the pond bottom, and inside slopes of the embankments. Sloping of the pond bottom will allow water movement in the underdrain layer to a perforated collection pipeline.

The design thicknesses and estimated permeabilities of the components of the seepage control system design are presented in Figure 9-4. The average liner permeability would be equal to or be less than 1.6×10^{-9} feet per second, which will be confirmed by rigorous quality control and a field and laboratory testing program conducted during construction. The liner will be constructed from on-site glacial till materials processed with bentonite (bentonite/modified soil liner or liner) as necessary to achieve the design permeability. The 6 to 12 inch drain layer soil material will be processed from glacial till and will consist of

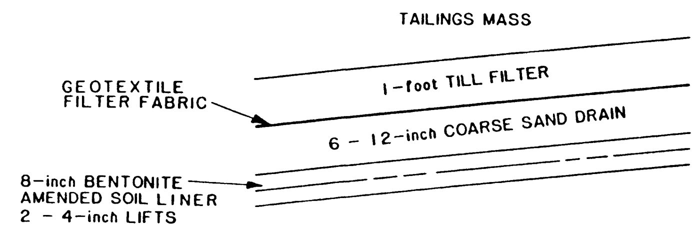


TYPICAL POND SECTION

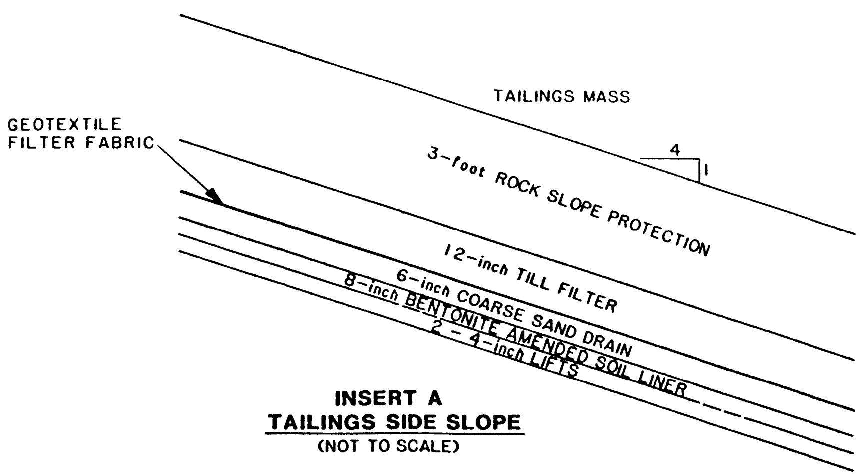
0 50 100 150
SCALE IN METERS

0 250 500
SCALE IN FEET

VERTICAL SCALE EXAGGERATED 5x



INSERT B
TAILINGS POND BOTTOM
(NOT TO SCALE)



INSERT A
TAILINGS SIDE SLOPE
(NOT TO SCALE)

Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY SEEPAGE CONTROL SYSTEM

SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/13/85
APPROVED BY	DATE	EXXON D.S. [illegible]	DATE 11/13/85
DRAWING NO FIGURE 9-5	SHEET ___ OF ___	REVISION NO

particles smaller than 2-inches and larger than 0.017-inch. The permeability (0.1 feet per second) of the drain layer soil material has been measured in the laboratory on prepared material having the design grain size distribution (Exxon, February 19, 1985 letter by J. F. Wallace).

The thickness of the filter layer soil material on the sides of the embankments will also be 12 inches because of construction considerations. By Hazen's approximation (Golder, 1982b), the permeability of this filter layer is estimated at 3×10^{-5} feet per second. With the exception of limited compaction occurring from operating traffic during material placement and grading the filter and drain soil materials will not be compacted during placement. Waste rock will be used for protection of the filter layer along those embankments of the ponds where water is expected to pool (i.e., the sides opposite the tailings input) as shown by Plan Sheet 24. Design details of the liner, drain and filter layers for the pond bottom and sides of the embankments are shown on Plan Sheets 22 and 23.

A bentonite modified soil liner has been determined to be the most acceptable liner for the facility (see Chapter 11.0-Alternatives). Studies have indicated compatibility of the bentonite modified soil liner in the MWDF environment (D'Appolonia, 1982b). A design permeability of 1.6×10^{-9} feet per second appears readily achievable through the addition of 2 percent or less bentonite by weight (STS Consultants Ltd., 1984b). In addition to the studies directed specifically toward the development of the proposed liner system, information has been compiled for other facilities that have been built and are operating with similar liners (see Black and Veatch, 1984; Knight and Piesold Ltd., 1984).

The estimated total facility maximum seepage rate through the liner and underdrain system, as proposed in this design, is less than 15 gallons per minute. This occurs approximately at the time of pond T4 closure. The estimated maximum seepage rate for each individual pond during operation is less than 5 gallons per minute. The seepage rates for the liner and underdrain system throughout the operating life of the MWDF and after closure are discussed in more detail in Section 9.5.

Quality control and quality assurance procedures will be implemented during construction of the liner and underdrain system to ensure the system will be installed in accordance with the final design material and performance specifications. The liner and underdrain system provides assurance that the impact of any MWDF seepage will comply with the ground water quality standards in NR 182.075.

The base of the tailing disposal ponds and the bentonite modified soil liner has been designed at a 2 percent slope from the inside of each tailing pond toward the inside toe of the exterior embankments on the east and west sides of the MWDF. The underdrain collection pipelines are located along the inside toe of the exterior tailing pond embankments on the east and west sides of the MWDF. This system also provides for collection of drainage from the embankment drain layer (see Plan Sheets 16, 22, and 23). The 8-inch diameter perforated collection pipes provide greater hydraulic capacity than required based on the estimated leachate collection rate for each tailing pond.

The underdrain collection pipe system has been designed to eliminate the need for pipe cleanouts. The criteria for backfill material sizing to prevent silting of the underdrain collector pipe are well established (U.S.

Army Corps of Engineers, 1955; Bureau of Reclamation, 1973). With the criteria employed, the addition of cleanouts to the system are not necessary.

With the proposed design of the pond reclamation cap, a functional underdrain system is only required for the pond operating period and a few years thereafter. Each pond has an operating life of 3 to 10 years after which the pond is closed with the construction of the reclamation cap. The underdrain will be pumped for the appropriate time after pond closure to collect remaining water draining from the tailings. When draining is complete, there is no longer any need for the underdrain system.

Leachate will be removed from each of the four tailing ponds by pumping from one of the two underdrain discharge pipelines constructed in each tailing pond along the embankments on the east and west sides of the MWDF. This is an important design feature of the leachate collection pipe system in that pond drainage water can be pumped from either of the two pipelines in the event portions of the system become inoperative. The location of these pipelines is shown on Plan Sheet 16 and detailed design drawings are shown on Plan Sheets 22 and 23.

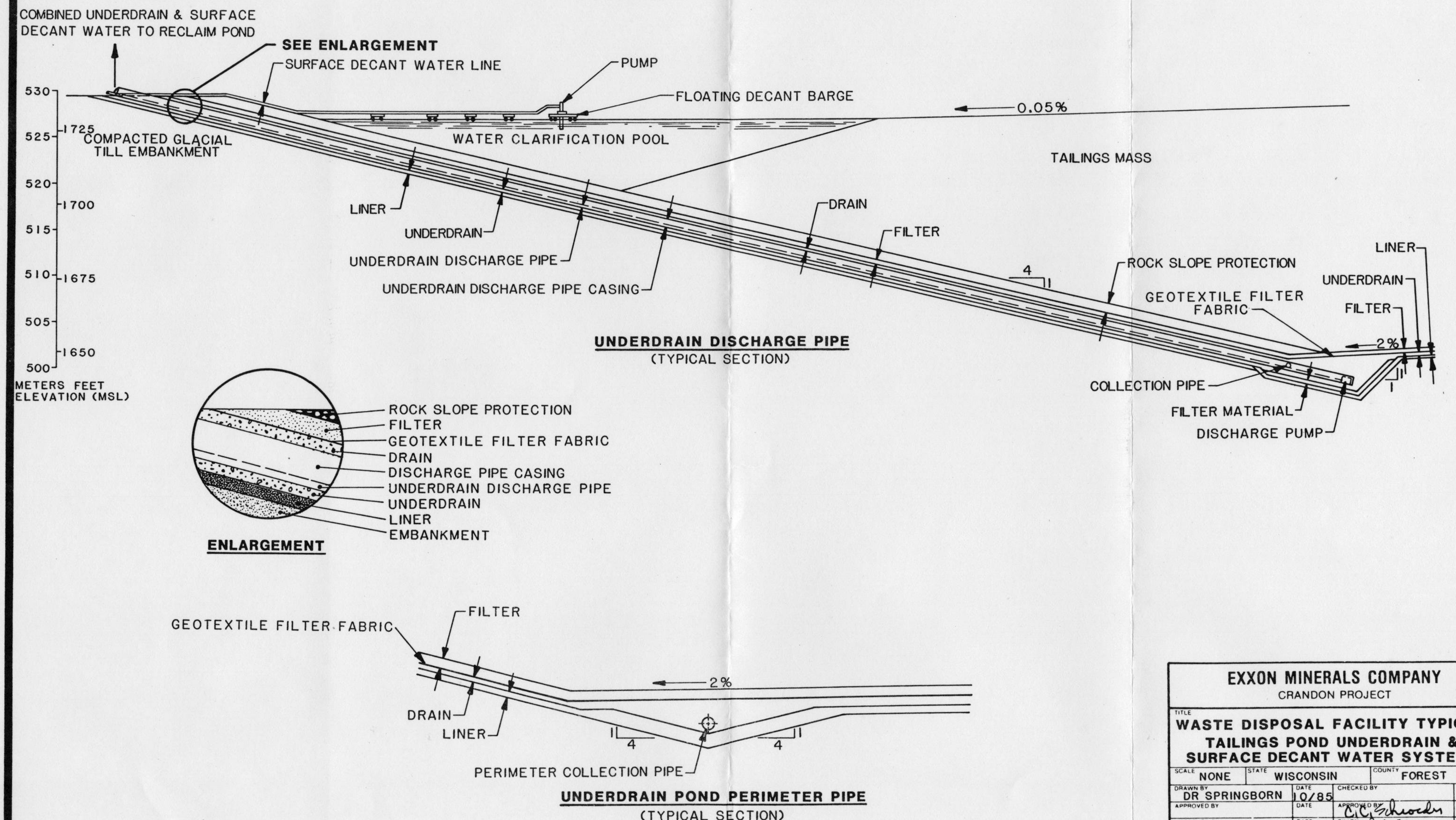
Each underdrain pump will have the capacity to handle the entire flow expected to pass through the tailing to the underdrain system. Because the tailing permeability is low (1.6×10^{-7} feet per second) and the overall water used to transport the tailings is reduced in the tailing thickening step, underdrain pumping demands are small. Based on an estimated pumping rate of 300 gallons per minute and a nominal head of 150 feet, pumping power requirements would be less than 20 horsepower.

Pump operation will be controlled by level sensing or pressure sensing devices as drainage water flows to the sump area surrounding the bottom of the discharge pipe casing. The underdrain pump and discharge pipe installation is similar to a deep well submersible pump installation. It will be serviced and maintained in a similar fashion although roller guides will be utilized to ensure easy pump and discharge pipe removal and replacement on the embankment incline.

The thickness for the filter and drain layers has been conservatively designed to satisfy all design requirements and to provide a substantial protective cover thickness for the liner. The construction procedures (see Section 9.2) have been developed to assure a minimum (8 inches) liner thickness is provided and to afford a measure of redundancy to the liner performance. Additional details of the Seepage Control System and the Leachate Removal System are presented in Plan sheets 22 and 23.

Water will be allowed to pond to a convenient operating depth at the tailings surface at the low end of the tailing beaches before transfer to the reclaim pond system. The details of this transfer or decant system are presented in Figure 9-6. Discharge pipes will be placed in each pond and used to pump water from the underdrain perimeter collection pipeline to the top of the embankment crest. At the pond crest, collected seepage will be combined with the decant water in a common pipe for transfer to the reclaim pond system.

Tailing Pond Surge Capacity - The surge capacity in each of the tailing ponds, above highest normal water levels, is in all cases greater than required for storm and wave run-up. In an emergency, if the surge capacity in



Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE **WASTE DISPOSAL FACILITY TYPICAL TAILINGS POND UNDERDRAIN & SURFACE DECANT WATER SYSTEMS**			
SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/85
APPROVED BY	DATE	EXXON E. M.	DATE 11/13/85
DRAWING NO **FIGURE 9-6**	SHEET ___ OF ___		REVISION NO

the reclaim ponds was not sufficient, the tailings ponds could be used to store water.

To use the tailings ponds storage capacity and maintain low seepage rates, pumping of the underdrains would continue with underdrain water recirculated to the tailing pond. Then, depending upon the rate of decant water pumping, water level in a tailings pond could be increased to accommodate surge storage requirements. As the ponded water depth is increased, there would be an increase in the underdrain flow rate which can be accommodated in the design of the underdrain pumping system. If the underdrains were not pumped, they would flood; while this would temporarily increase seepage, it would not affect the integrity of the facility, nor reduce the stability of the embankments.

Tailings deposited underwater would have approximately a 10 percent lower density than the tailings deposited under normal operating conditions. However, the overall tailings volume change within the pond would be negligible.

Tailing ponds T1 and T3 have approximately equal surge capacity and they are the smallest of the four ponds. Their minimum surge capacity (at completion of tailings deposition and without utilizing any of the design freeboard of the pond) is approximately 160 acre feet from the tailings surface to a level surface 3 feet below the pond crest. At an inflow or filling rate of 2,500 gallons per minute, this volume represents 1.5 days of surge capacity. The total minimum surge capacity (i.e., either tailings pond T1 or T3 and reclaim pond surge capacity) would be approximately 14 days at a 2,500 gallons per minute flow rate. This minimum surge capacity would only be used in an emergency and would not infringe upon the normal freeboard required in the pond for the 100 year - 24 hour storm plus wave run-up. Also, this minimum condition would exist only at the point in time when the tailings pond has just been completely filled with tailings (to the design level) and no other storage exists. In actual practice the next tailings pond would be completed before this point in time and would also be available for storage.

Water Treatment Plant Waste Disposal

The water treatment process will produce two waste products. The first, a sludge resulting from lime and sulfide precipitation processes and the lime/soda ash softening process, will be mostly calcium carbonate. This sludge will be added to the tailings and pumped to the MWDF for disposal.

The other solid product will consist primarily of crystalline sodium sulfate. The production of crystallized sodium sulfate from the water treatment plant will range from 0 to 11 tons per day depending on the percentage of water being treated by the reverse osmosis/vapor compression evaporation (RO/VCE) units.

Prior to sodium sulfate crystallization (removal of soluble impurities), the nearly saturated sulfate solution exiting the VCE unit will be lime neutralized and then clarified to remove insoluble impurities (heavy metals). This post treatment of the VCE brine ensures a marketable salt cake or a non-hazardous secure landfill disposal option. Although the sodium sulfate by-product is expected to be marketed, a provision has been planned to allow approximately 30,000 cubic yards of storage in each tailings pond. Preliminary design for these storage areas, should they ever be necessary, is shown in Plan Sheet 26.

Reclaim Pond Sludge

Throughout operation, sludge will accumulate in the water reclaim ponds. This sludge will consist of fine sediments and particulate precipitates that settle during retention of the water. During final Project reclamation the sludge will be collected and disposed in the MWDF.

A conservative reclaim pond sludge projection of 140,000 cubic yards has been made for the life of the Project. This estimate is based on the water flow rate passing through the two pond system, the suspended solids in the water, the total Project time, and a sludge density. This projection also makes allowance for the volume of water treatment sludge that will be produced during the construction period when mine water will be treated. This volume of sludge can be held in the system with no effect on the reclaim ponds. Overall, it will occupy approximately 16 percent of the total operating volume. Divided evenly between the two ponds, it would amount to less than 4 feet of sediment on the reclaim pond bottom.

There will be some difference in the sludges between the two ponds. Reclaim pond cell B, the first pond to receive the tailings pond decant and underdrain water, will have sludge consisting predominately of very fine suspended tailings and calcium carbonate precipitates, while reclaim pond cell A will have a predominance of gypsum precipitates from the pH adjustment step between the two ponds. There may also be some metal hydroxide precipitates in pond cell A from pH adjustment.

In addition to the conservative sludge estimates, operation of the tailings pond decant system offers a degree of control on the clarity of the water returned to the reclaim pond. Some additional ponding with increased retention time in the tailings ponds could reduce suspended solids in the decant water.

If it would ever be necessary, there are suitable sludge removal methods that would not damage the reclaim pond liner while still allowing continued pond operation. A small floating suction dredge with depth control on the suction head could be used. In practice, a small depth of sludge (i.e., 1 foot) would not be removed as a precaution to protect the liner. If the estimated 140,000 cubic yards of sludge were distributed evenly over the final tailings surface of pond T4, the depth of sludge would be approximately one foot. Since there are no crucial timing constraints on reclamation of pond T4, there would be ample time for proper management of the sludge through drying or blending with tailings or cover soil. The sludge could also be incorporated into the thick till grading layer planned as the first step in reclamation of the tailings pond.

9.1.4 Final Grades

The final ground surface grades after reclamation of the MWDF are designed for a minimum top slope of between 1 and 2 percent. An evaluation of the settling characteristics (beaching) of the tailings indicates that the final surface of the disposed tailings is estimated to be approximately 0.5 percent (CSMRI, 1982). The design of the final surface contours includes a layer of glacial till to develop the final grade of each tailing pond. The reclamation cover design will consist of a six layer system (i.e., till grading layer, bentonite modified soil seal, synthetic membrane, overdrain, geotextile filter and till soil including an upper topsoil layer) which is discussed further in subsection 9.4.1. The final contour plan for the reclamation cover is designed to distribute surface water runoff outward from higher topographic areas in the center of each pond. The exterior slopes of each ponds embankments are designed with an outside slope of 3.0 horizontal to 1.0 vertical (3H:1V) and will remain intact and require no excavation or revegetation with the reclamation cover work.

The final grades and configuration of the facility are designed to be compatible with the topography in the surrounding site area. The highest elevation of the facility after reclamation is 1,750 feet MSL.

An initial vegetative cover will be included with the reclamation work but the cover is planned to eventually become a forest ecosystem developed by invasion and indigenous species succession.

The proposed final uses for the MWDF area are forestry and recreation. A more complete discussion of these uses is included in the Reclamation Plan.

9.1.5 Surface Water Control

Precipitation on the tailing ponds during active operations will either infiltrate the disposed tailings or pool on the exposed tailing surface. Because of the method of operation and design of the MWDF, all surface waters within the ponds are recycled during operation.

During construction periods (initial pond construction and reclamation) and as necessary during operation of the MWDF, off-site surface water drainage will be diverted around the outside embankments or will be collected in a series of perimeter drainage swales. Surface water collected in drainage swales will be routed through sedimentation control devices as necessary. The sedimentation control mechanisms will discharge to existing surface water drainage features to maintain hydrologic conditions in the site area similar to conditions before MWDF construction. In the general Project area, rainfall runoff coefficients are low and corresponding runoff volumes are low. This site characteristic, coupled with the location of the MWDF at the upper limits of the local watersheds, results in only minor requirements for surface water control. The surface drainage/erosion control plans that will be utilized during construction, operation (if necessary) and the reclamation construction period for the MWDF are presented in Section 10. The surface water drainage control structures associated with these drainage control plans will be designed to control a 100-year, 24-hour storm. After a tailings pond has been reclaimed and all surface areas stabilized, there is no longer any need for erosion control and the drainage structures will be removed.

The reclamation plan for the MWDF has been developed to eliminate the need for drainage control structures or other devices that would require continuing maintenance. The bentonite modified soil seal, synthetic membrane, overdrain and minimum 5-foot thick soil protective cover will reduce infiltration to the tailings and promote drainage of infiltrating precipitation to the perimeter and internal embankments of the facility. The final cover design is discussed in detail in subsection 9.4.1. Surface water runoff after reclamation will be routed from the higher elevations in the center of each pond outward eventually being distributed to the perimeter of the MWDF. The final grades and preliminary surface water drainage patterns are shown on Plan Sheet 17. Surface water flows from the MWDF are anticipated to be minor. However, the drainage patterns of the final reclamation surface are designed to maintain overland water flow to lakes and wetlands similar to present conditions in the site area (Ayres Associates, 1984, 1985).

9.1.6 Revegetation Aspects of the Reclamation Cap

Following topsoil placement and final grading of the reclamation cap of each tailings pond, herbaceous vegetation will be established to stabilize the soil surface and to minimize erosion. The long-term goal of the revegetation program will be to allow ecological succession to occur in all reclaimed areas. Plant communities will be allowed to develop that are compatible with adjacent undisturbed communities. To ensure establishment of a variety of woody plant species in the MWDF area, selected planting will be proposed, if necessary, at various locations on each of the reclaimed tailings ponds. This will ensure establishment of diverse plant communities.

The proposed reclamation cap design includes a minimum 5 feet of glacial till (including an upper 9-12 inch topsoil layer) over the drain and seal layers which will provide a growth medium for plants. Based on the rooting depths of tree species that are expected to invade the reclaimed MWDF (e.g., sugar maple, aspen, birch and red oak), the majority of the roots would be located within 36 inches of the ground surface (Ayres Associates, 1984). The potential for root penetration through the drain and/or seal layers or damage to these layers from windthrow of trees is considered negligible for the proposed design.

9.2 CONSTRUCTION

9.2.1 General

This section presents a discussion of general construction methods, special construction details and activities proposed for the MWDF. The facility has been designed for construction and reclamation using soils excavated from within the tailing ponds. No soil from outside the site area, with the exception of powdered bentonite for use in the bottom liner and top seal, will be used for construction of the facility. However, a 500,000 yd^3 borrow area is included on the north side of the MWDF site, if an earthwork imbalance should occur during the Project life. Waste rock will be used as slope protection on portions of the interior embankment surfaces for all the tailing ponds.

9.2.2 Embankments

Embankment construction will be a major activity for each of the four tailing ponds. The embankments are designed to contain pooled water in addition to the disposed tailings using a balanced cut and fill approach. The layout of the embankments to be constructed for the facility is shown on Plan Sheet 15. Drawings of the embankment design are shown on Plan Sheets 18, 19, 20, and 21.

The embankments will be constructed by placement and compaction of glacial till soils excavated from within the reclaim pond and tailing ponds. The glacial till soils in the site area provide an excellent source of structurally stable and workable materials for constructing the embankments.

The embankments will be designed for surface erosion control, maintenance and other considerations in addition to providing adequate structural stability (Golder, 1982c). For aesthetic purposes, erosion control and maintenance concerns, 3.0 horizontal to 1.0 vertical (3H:1V) slopes have been selected for the embankment exteriors (downstream). Vegetation can be easily established on these slopes and the slopes and vegetation can be readily maintained. The interior (upstream) slopes of the embankments have been designed at 4.0 horizontal to 1.0 vertical (4H:1V). This slope is sufficiently flat to facilitate construction of the liner, underdrain system and slope protection. Refer to Plan Sheets 18, 19, 20, 21, and 25 for details of the embankment design.

As required by NR 182, the design height (freeboard) of the proposed embankments has also been evaluated for the MWDF. The design storm precipitation for a 100-year, 24-hour occurrence in the site area is 5.1 inches. A 100-year, 1-hour wind velocity of 90 miles per hour was also selected for this design. The design wind direction was selected as the maximum possible fetch of the ponds, and the water and storm water level increases were computed for each of the tailing ponds (Golder, 1982d). The range of freeboard for the system of ponds above the normal maximum operating water level has been designed to range from about 7 to 12 feet. These freeboard heights exceed that required to contain the estimated water level increases of the 100-year storm water event and projected maximum wave height conditions. This design is in conformance with freeboard requirements included in NR 182.

Roads will be provided on the crest of the embankments and along the toe of the exterior embankments for inspection and to facilitate periodic maintenance of the facility if required. The roads along the crest of the embankments will also be used by trucks hauling waste rock to the facility for slope protection during construction. The roads will be surfaced with crushed rock or granular material to provide an all-weather surface. The road alignments are shown on Plan Sheet 16 and detail drawings are provided on Plan Sheet 23.

Temporary ramps will be constructed down the upstream slopes of each pond to facilitate equipment access during the construction process. These ramps will be removed near the completion of earthwork activities to facilitate final liner and seepage collection system construction in these areas.

The embankment crests are designed to accommodate a minimum 16-foot wide access road with safety berms or guard rails. In some sections of the ponds, the embankment crest is wider because the tailings and water recycle pipelines are parallel to the access road. The perimeter access road at the toe of the embankments is designed to be 10 feet wide for one-way traffic. The haul road to the MWDF is 30 feet wide to permit two-way traffic; additional width is provided where necessary for pipelines.

9.2.3 Earthwork Balances

Construction of the MWDF will occur in five phases to accomplish systematic facility development, operation and reclamation corresponding to anticipated mill production. The length of construction in each phase will vary from 2 to 4 years, with several years between phases. Table 9.1 presents the five construction phases, their activities, and their relative time frame.

The first major phase in construction of the MWDF will include construction of the contractor's support area for development of the MWDF and construction of the first tailing pond. This work will be completed before tailing production begins. A three season period is envisioned in which site preparation and a majority of the earthwork required to excavate the pond interior and form the exterior embankments will be performed the first two seasons. The third season activities will be the completion of the pond excavation and the construction of the liner and seepage collection system as well as tailings distribution and monitoring system construction.

The second, third, and fourth major phases of construction occur for tailing ponds T2, T3, and T4, respectively. Construction schedules will be established so each tailing pond is completed before tailing disposal begins. The general sequence of major construction activities described for pond T1 would be executed for ponds T2, T3 and T4 over a similar 2 to 3 year construction period.

Glacial till from within the MWDF will be processed for liner and underdrain construction material and for use in pond reclamation. The volume of glacial till to be excavated is estimated to be 15 million cubic yards. Of this volume, approximately 8 million cubic yards will be used for embankment construction, 1.3 million cubic yards as processed materials, and 6.2 million cubic yards for the reclamation seal (cap) and cover. Approximately 0.5 million cubic yards will be developed from an outside borrow source for final

TABLE 9.1
CONSTRUCTION PHASES

Phase	Year	Construction Activities
1	1-5	Construct Construction Support Area (CSA) Construct Reclaim Pond Cell A Construct Tailing Pond T1 Construct Reclaim Pond Cell B Construct MRDF Cell 1
2	6-11	Construct Tailing Pond T2 Tailing Pond T1 Reclamation Construct MRDF Cell 2 MRDF Cell 1 Reclamation
3	13-16	Construct Tailing Pond T3 Tailing Pond T2 Reclamation (Partial - Construct Traffic Mat on Tailing Pond T2)
4	19-23	Construct Tailing Pond T4 Tailing Pond T3 Reclamation Construct MRDF Cell 3 MRDF Cell 2 Reclamation
5	33-36	Tailing Pond T4 Reclamation Tailing Pond T2 Reclamation (Complete) Reclaim Pond Cell A and B MRDF Cell 3 Reclamation CSA Reclamation

reclamation of pond T4. These totals include the volumes required for construction of the reclaim pond although it is not considered a part of the MWDF. A detailed listing of the earthwork volumes for each pond is included in Tables 9.2, 9.3, 9.4 and 9.5.

9.2.4 Site Construction Methods

General - Site construction methods will be similar to those for any large conventional earthmoving operation. Even those activities associated with liner construction including till processing, bentonite amending and liner placement use standard industry technology and equipment. Some modifications will be made to equipment to accommodate higher degrees of quality control. Specifically, the bentonite/till mixing plant will be automated to monitor feed quantities of till, bentonite and water to assure an accurate and consistent mix. As indicated in subsection 9.2.5, a rigorous quality assurance and quality control program will be employed during all phases and facets of construction and reclamation activities at the MWDF.

Site Preparation - MWDF site preparation is required in the first four phases of facility construction. In Phase 1, preparation is required to: (1) construct the haul road from the mill to the tailing ponds; (2) install a fence around the perimeter of the MWDF site; and (3) construct a contractor's support area.

Clearing and grubbing of vegetation and debris and topsoil stripping and salvage will be completed in each phase, as required, affecting only the acreage actually needed for immediate earthwork operations. An estimated 9-12 inches of topsoil will be recovered and transferred to the long-term stockpile

TABLE 9.2

PRELIMINARY ESTIMATED TAILING POND SOIL MATERIAL CONSTRUCTION QUANTITIES

Tailing Pond T1

ITEM	QUANTITY
Tailing Pond Areas	
Inside Crest	43 acres
Bottom	9 acres
Interior Embankment	35 acres
Pond Elevations (above MSL)	
Crest	1732 feet
Bottom	1633 feet
Till Excavation	1.21×10^6 cubic yards
Construction Quantities	
Till Embankment	2.25×10^6 cubic yards
Liner	0.047×10^6 cubic yards
Underdrain Material	0.039×10^6 cubic yards
Filter Material	0.071×10^6 cubic yards
Waste Rock Slope Protection	0.047×10^6 cubic yards
Pipe Lengths	
Underdrain Collection Pipeline	590 feet
Reclamation Quantities	
Seal	0.046×10^6 cubic yards
Overdrain Material	0.046×10^6 cubic yards
Final Cover Material	1.03×10^6 cubic yards

TABLE 9.3

PRELIMINARY ESTIMATED TAILING POND SOIL MATERIAL CONSTRUCTION QUANTITIES

Tailing Pond T2

ITEM	QUANTITY
Tailing Pond Areas	
Inside Crest	71 acres
Bottom	22 acres
Interior Embankment	50 acres
Pond Elevations (above MSL)	
Crest	1732 feet
Bottom	1633 feet
Till Excavation	2.35×10^6 cubic yards
Construction Quantities	
Till Embankment	2.81×10^6 cubic yards
Liner	0.077×10^6 cubic yards
Underdrain Material	0.067×10^6 cubic yards
Filter Material	0.116×10^6 cubic yards
Waste Rock Slope Protection	0.093×10^6 cubic yards
Pipe Lengths	
Underdrain Collection Pipeline	1500 feet
Reclamation Quantities	
Seal	0.076×10^6 cubic yards
Overdrain Material	0.076×10^6 cubic yards
Final Cover Material	1.64×10^6 cubic yards

TABLE 9.4

PRELIMINARY ESTIMATED TAILING POND SOIL MATERIAL CONSTRUCTION QUANTITIES

Tailing Pond T3

ITEM	QUANTITY
Tailing Pond Areas	
Inside Crest	50 acres
Bottom	12 acres
Interior Embankment	39 acres
Pond Elevations (above MSL)	
Crest	1732 feet
Bottom	1633 feet
Till Excavation	2.44×10^6 cubic yards
Construction Quantities	
Till Embankment	0.69×10^6 cubic yards
Liner	0.055×10^6 cubic yards
Underdrain Material	0.046×10^6 cubic yards
Filter Material	0.082×10^6 cubic yards
Waste Rock Slope Protection	0.053×10^6 cubic yards
Pipe Lengths	
Underdrain Collection Pipeline	660 feet
Reclamation Quantities	
Seal	0.054×10^6 cubic yards
Overdrain Material	0.054×10^6 cubic yards
Final Cover Material	0.90×10^6 cubic yards

TABLE 9.5

PRELIMINARY ESTIMATED TAILING POND SOIL MATERIAL CONSTRUCTION QUANTITIES

Tailing Pond T4

ITEM	QUANTITY
Tailing Pond Areas	
Inside Crest	107 acres
Bottom	39 acres
Interior Embankment	70 acres
Pond Elevations (above MSL)	
Crest	1732 feet
Bottom	1633 feet
Till Excavation	5.17×10^6 cubic yards
Construction Quantities	
Till Embankment	1.84×10^6 cubic yards
Liner	0.117×10^6 cubic yards
Underdrain Material	0.104×10^6 cubic yards
Filter Material	0.176×10^6 cubic yards
Waste Rock Slope Protection	0.094×10^6 cubic yards
Pipe Lengths	
Underdrain Collection Pipeline	1510 feet
Reclamation Quantities	
Seal	0.115×10^6 cubic yards
Overdrain Material	0.115×10^6 cubic yards
Final Cover Material	2.03×10^6 cubic yards

area. The salvaged topsoil will be stored for eventual reuse in the various reclamation phases of the MWDF. Additional description of the topsoil stripping, salvage and storage procedures is included in the reclamation plan. In Phases 2 through 4, required MWDF site preparation is generally limited to clearing, grubbing and topsoil salvage. The remaining areas of the MWDF site will be disturbed as little as possible. In Phase 5, no major MWDF site preparation is required.

Site Access Road - The haul road from the mill to the tailing ponds will be a permanent feature for the life of the mine and will be watered as needed to control dust. The haul road will be the primary road to the ponds for all construction equipment and personnel, as well as the haul route to the adjacent Mine Refuse Disposal Facility (MRDF).

Construction Support - During Phase 1, a construction support area will be constructed north of the MRDF site. The support area will be used as a base of operations for the earthwork contractor during construction of the MWDF and will remain through reclamation of pond T4. Any needed support equipment will be erected to process the glacial till, bentonite, and water for the liner and seal. Most equipment required to process drain and liner materials will remain in place between construction and reclamation periods. Some processed soil material stockpiles may remain between phases. The long-term stockpile (glacial till) will be located in the pond T3 and T4 areas and in the later phases of MWDF development will be located on pond T2 (Figure 9-3).

The limited construction season in the site area requires the mobilization of equipment and a work force in each phase to meet the schedule.

In all phases of construction, the earthwork operations will start as early as possible in the spring. The layout of the construction support area is presented in Plan Sheet 36.

Excavation of Soil Materials - Excavation will be conducted with scrapers and the soils will be hauled directly to the embankment for placement and compaction or stockpiled in the construction support area for use in processing liner and drain material and later use as filter blanket fill. The height of the long-term stockpile will be approximately 50 feet. The storage area required to stockpile 2,000,000 cubic yards at this height is approximately 25 acres.

Processing of Drain Material - Drain layer material will be developed by screening and washing till using standard processing technology (INDECO, 1982). Till will be screened to remove oversize material greater than 2 inches in size and again screened to remove the fine fraction, that portion passing a standard 40 mesh screen. The screened product will than be washed to produce a free-draining clean coarse sand and gravel to be used as the drain in the seepage collection system.

Processing of Liner Material - The liner will be constructed of bentonite amended till mixed in designed proportions and properly moisture conditioned such that when it is placed and properly compacted, a design performance criteria (minimum permeability) will be obtained. The development of this blended till will start with the removal of oversize material (greater than $^3/4$ inch) using a conventional screening process. The till will then be placed in a temporary stockpile.

Stockpiled screened till will then be loaded via a conventional front-end loader to a hopper feeding a shredder unit to breakup any clods or clumps of soil in preparation for transport to the mixing plant. Shredded till will then be conveyed to a hopper feeding the main conveyer to the mixer. Discharge from the hopper will form a relatively uniform width and thickness of till on the feed belt where at about its mid-point a controlled rate screw feed auger will deposit crushed bentonite atop the till. Flow rate and weight of till will be continuously monitored and fed into a control center computer which in turn will regulate the screw auger feed rate of bentonite to the conveyor for a controlled blend. Both bentonite and till will travel up the conveyor to be deposited in a mixing chamber ("pugmill") consisting of two counter-rotating, horizontal paddle augers. The paddles on each auger are pitched to both mix and transport the mixture down the axis of the mixing chamber.

A regulated flow of water will be added to the traveling bentonite/till mix as it passes the third point moving through the mixing chamber. Water conditioning will be controlled as a measured function of the tills moisture content measured before mixing begins and adjusted as moisture conditions change to achieve the design target moisture of 3 percent wet of optimum (for compaction purposes) plus or minus one percent ($3 \pm 1\%$).

Finally, at the end of the mixing box the moisture conditioned bentonite amended till will be discharged into a dump truck for direct haulage to the tailing pond for liner construction. Photographs of a mixing plant similar to that proposed and recently in operation at the Bristol Hill Landfill in Oswego County, New York are presented as Figures 9.7 and 9.8.

FIGURE 9-7
MIXING PLANT - VIEW 1

FIGURE 9-8
MIXING PLANT - VIEW 2

To accommodate the volume of liner processing required in the proposed single construction season and to provide a degree of redundancy both in terms of excess system capacity and continued operation during either scheduled or unscheduled maintenance, a system comprised of four identical plants will be utilized. Each plant will be designed such that a 25 percent excess system capacity will be provided when all plants are in operation. The overall layout of the contractor support and staging area is presented on Plan sheet 37. A schematic flow diagram of the liner processing plant is also presented on Plan Sheet 36.

Liner Construction - After excavation of the glacial till soils is completed to designed subgrade levels and upstream embankment slopes are shaped, proof rolling will be performed to detect any soft areas before beginning liner placement. Upon approval of the subgrade, liner placement will begin first with a single 4-inch compacted lift to be followed shortly thereafter by a second layer of bentonite modified till resulting in a total 8-inch thickness of compacted liner. Liner layers will be generally placed parallel to one another but offset laterally such that "seams" or joints in overlying layers do not coincide.

Placement of loose liner material will be via a paving machine similar to that shown in Figure 9-9. Dump trucks will empty into the paver hopper and move along with the track mounted spreader as it delivers a uniform loose lift thickness of liner soil atop the subgrade or underlying liner lift. The compacted liner material will provide a suitable surface for vehicular traffic without being damaged. Surface stability will be similar to that of subbase and base course layers in typical highway construction.

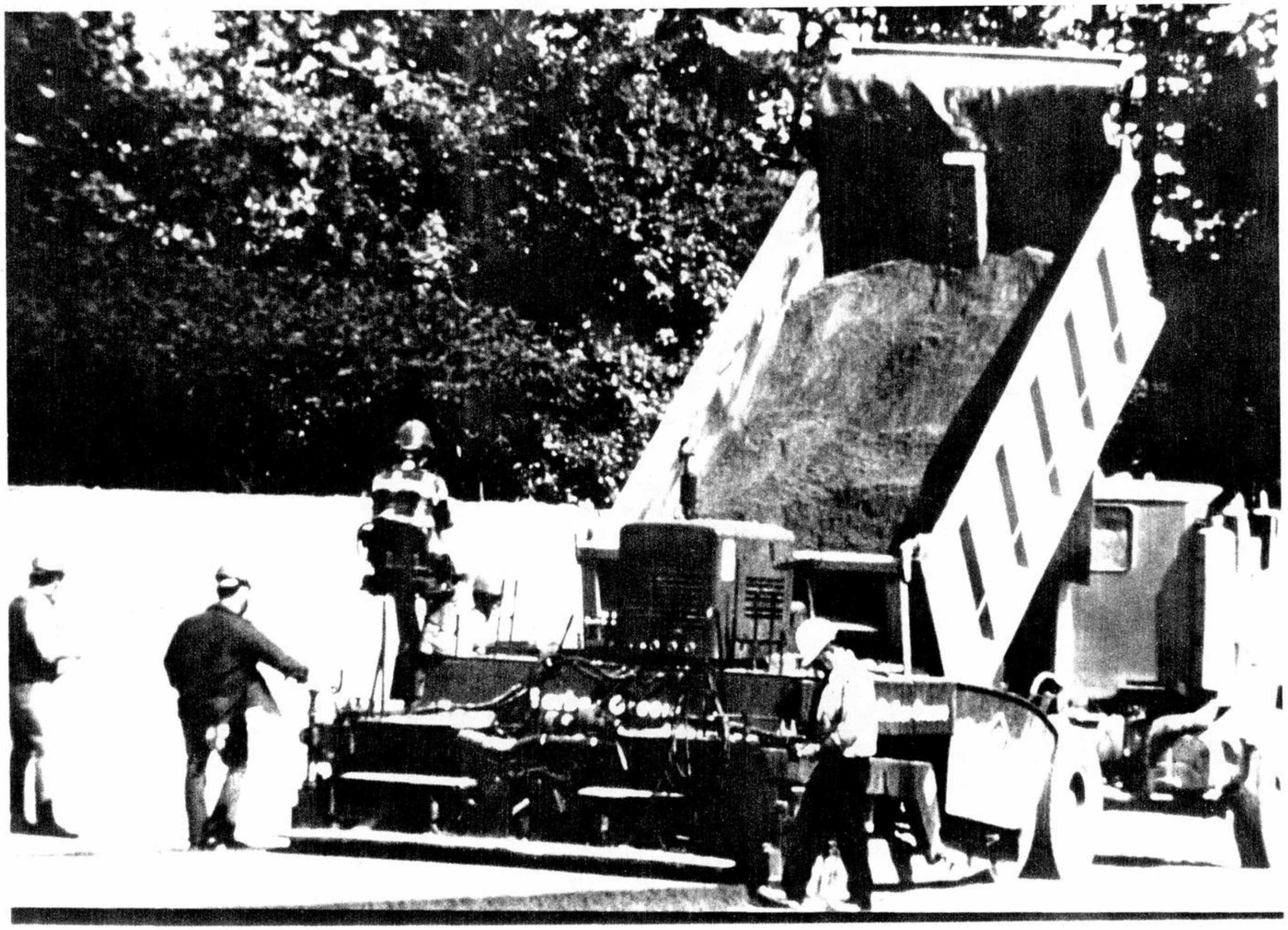


FIGURE 9-9
LINER PLACEMENT

The loose lift of liner fill will then be compacted with several passes of a vibratory smooth drum roller. The paver system will similarly be employed on the internal 4:1 side slopes; however, liner material will be fed by traveling conveyor system from the base or crest of the pond. Compaction will be performed by self propelled smooth drum vibratory rollers.

In confined areas, where instrumentation is installed, at corners, or other significant grade changes that prohibit the use of the relatively large equipment to be employed as in the majority of the liner construction, special procedures utilizing smaller self propelled or hand operated equipment will be employed. The details for these conditions and specialized procedures will be developed for the plan of operation or final design. After successful installation of the liner, as confirmed by field quality assurance testing, the drain and filter soil layers will be constructed to protect the liner from potential damage.

The drain and filter layers will be constructed by end dumping from trucks and grading the soil material over the liner. A geotextile filter will be placed on top of the drain gravel prior to placement of the filter soil. Installation of the underdrain pipeline system will occur during placement of the drain layer.

Reclamation Cover - Stockpiled soils and the upper portions of the MWDF perimeter embankments will be used to first establish the proper reclamation grades across the MWDF area. After the grading layer is complete and acceptable, glacial till soil material from the long-term stockpile will be used to construct the seal and drain layers which will comprise the seepage control portion of the reclamation cover. The bentonite amended top seal will be constructed and placed in the same manner as described for the liner. As portions of the bentonite amended soil seal are completed the 40 mil synthetic membrane will be installed. Then, as portions of the composite seal are completed, the 8-inch drain layer, the geotextile filter, and a 5-feet thick cover layer (including a final layer of approximately 9-12 inches of topsoil) will be constructed. A detailed drawing of the reclamation cover is shown on Plan Sheet 25. A vegetative cover of grasses and legumes will be established by hydroseeding and planting (see Reclamation Plan).

Well Abandonment and Closure - Existing wells and any future wells to be installed within the confines of the MWDF "footprint" that will not be used for permanent ground water quality monitoring will be closed and abandoned in accordance with existing DNR and other State Regulations prior to commencement of construction activity in the affected pond area.

Dust and Water Control - Control of dust during the earthwork operations will be accomplished by sprinkling as necessary. Control of surface water drainage, particularly when major portions of the excavation and embankments have been completed, will require temporary sumps. Excess water will be pumped from the interior of the pond to the perimeter water drainage system (INDECO, 1982). Water will be available to the construction support area from a well to be constructed at the beginning of Phase I. A 600 gallons per minute pump will be installed in this well.

9.2.5 Construction Quality Control and Documentation

General - All facets of construction of the MWDF will be inspected and tested to assure conformance of material and performance specifications.

In most instances, the specifications will be industry standards such as for piping, pumps, and general earth work activities and will be developed in conjunction with final engineering.

The use of bentonite modified soil to construct both the liner and top seal will require a comprehensive quality control/assurance program. The following presents a preliminary quality control and documentation program proposed to monitor liner and top seal construction to assure that design objectives and performance specifications are achieved.

Bentonite-Soil Mix Plant Testing and Documentation - Quality control in the mixing plant is important to assure that a uniform and consistent product is produced with specific characteristics to achieve low design permeability characteristics for the liner and top seal. Two main aspects of the mix are important in this regard: the bentonite content and moisture content. Moisture content of till after processing to remove oversize material will be periodically measured to permit adjustment of mix water. A belt scale will be incorporated into the conveyor system to continuously measure the till feed weight. This weight coupled with moisture content data will permit a continuous monitoring of the dry weight of till by the automated computer control system to regulate the bentonite screw feed auger allowing a controlled and accurate mix to be prepared. The data collected from monitoring of material moisture content will be input into an automated control system that will adjust the amount of water added during mixing, thereby allowing both a correct and consistent moisture conditioned bentonite/soil mix to be prepared. Plan Sheet 36 includes a flow diagram depicting processing steps to prepare the liner and top seal.

Automated control systems proposed for the mix plant will also allow continuous automated data acquisition and provide a continuous monitoring record of mixing throughout the construction process. These data will permit additional verification of total material amounts processed, average uniform bentonite content of the mix, and moisture conditioning of the material on a daily or hourly basis as necessary.

A comprehensive laboratory testing program was performed to evaluate various mixtures of bentonite and site till and their associated behavioral characteristics (STS Consultants Ltd., 1984b). The results of this testing indicate that the liquid limit test may be a relatively simple and dependable indicator of relative bentonite percentage. Atterberg limits measurements as well as grain size analyses will be performed on random samples of the prepared bentonite/till mixture to confirm both its consistency and as an indicator to bentonite content and inferred permeability characteristics.

Periodic samples of moisture conditioned soils will be obtained and tested for moisture content verification. These tests can easily and readily be performed in a matter of minutes using simple yet accurate microwave oven drying techniques.

A field quality control lab will be established at the mixing plant site to facilitate both the testing of liner and seal materials as they are prepared, as well as augment other field testing to be conducted in conjunction with actual liner and seal construction.

<u>Bottom Liner/Reclamation Seal Construction Testing and Documentation</u> - Construction control testing will be performed to confirm that design specifications are being met as the liner and reclamation seal are

constructed. As in most earthwork construction, compacted density as well as moisture content of the liner/reclamation seal will be measured. Primary moisture-density testing will be performed using a nuclear gauge in accordance with ASTM-D-3017. Supplemental testing will be performed using sand cone techniques (ASTM-D-1556) and conventional moisture content determinations (ASTM-D-2216) or a well developed microwave moisture content methodology. Moisture-density data will be used with correlations previously established for permeability versus density relationships to infer field permeability.

Supplemental field laboratory permeability testing on either undisturbed or remolded liner/reclamation seal samples or possibly in situ measurements of permeability will be performed to verify the validity of density inferred field performance. A majority of the field liner performance testing will occur in Phase I construction associated with cell A of the reclaim pond and the first cell of the MRDF. Potential methods for rapid field laboratory measurement of permeability are suggested by Van Zyl (1983).

Alternatives for in situ determination of liner/top seal permeability are available (Knight Piesold, 1984; Day, Daniel, & Boynton, 1984). Further study is required to assess the merits of such available field performance testing techniques before establishing a final program.

Documentation of all field testing and construction observations will be in a written form and be maintained during construction for continuous review as required.

9.3 Operation

9.3.1 General

The proposed operating procedures for the MWDF are based on the data and analysis from the waste characterization studies and determination of acceptable operating conditions at the facility. Daily operations and construction has been planned to ensure that safe and environmentally compatible conditions are maintained at the MWDF.

9.3.2 Facility Sequencing

The proposed MWDF will be developed through the construction and filling of four tailing ponds. Plan Sheet 5 displays the location of the four ponds and their relationship to each other. Table 9.6 shows the expected years of use and the disposal capacity of each tailing pond. Figure 9-3 depicts the sequencing and phased development, operation, and reclamation of the MWDF.

9.3.3 Operating Procedures

Most waste products from the mill will be transported to the MWDF by pipeline. The tailings will be pumped at approximately 55 percent solids concentration, by weight, from the mill to the disposal ponds. The water treatment plant sludge will be transported as a pumpable slurry to the tailings thickener and from there with the tailings in the pipeline. The waste rock, reclaim pond sludge and water treatment plant by-product sodium sulfate sludge will be transported by truck to the MWDF.

TABLE 9.6

PRELIMINARY ESTIMATED TAILING POND DISPOSAL CAPACITIES AND ESTIMATED YEARS OF USE

TAILING POND NUMBER	ESTIMATED TAILINGS POND DISPOSAL CAPACITY CUBIC YARDS
T1	3.1×10^6
T2	5.7×10^6
T3	3.7×10^6
T4	9.1×10^6
	21.6×10^6

TAILING POND NUMBER	ESTIMATED YEARS OF USE DURING MINE/MILL OPERATION
T1	4 (Years 3[1] - 7)
T2	7 (Years 7 - 14)
T3	7 (Years 14 - 21)
T4	11 (Years 21 - 32)[2]

[1] End of construction phase.

[2] Based on utilization of full MWDF capacity.

The pipeline alignments for the entire MWDF system are shown on Plan Sheet 16. Although the alignments for all pipelines are shown, they will be constructed only as needed, depending on which ponds are in operation. The tailing and return water pipelines will be constructed along the embankment crests within the MWDF only. The embankment crest widths will vary depending on the number of pipelines as shown on the detail drawings on Plan Sheet 23. The pipelines for the facility will be buried from the mill to the MWDF.

The tailings will be deposited from the common inner embankment of the ponds. The estimated surface of the tailings when the ponds are filled reflects the tailings input locations. From the tailings discharge locations there will be an estimated 0.5 percent slope to the tailings surface, and an estimated pool water surface of approximately 20 percent of the tailing pond area with a water depth of approximately 20 feet. Water will be pumped from the surface pool by a floating barge mounted pump system and from the underdrains by submersible pumps. At the embankment crests the two streams will be combined for transfer to the reclaim pond.

9.3.4 Dust and Noise Control

Control of noise and dust was considered in the location, design, and operation of the MWDF. Aesthetic considerations have also been incorporated in the construction, operation, and reclamation of the facility. A separate report "Tailings Surface Dusting from Wind Erosion", (Exxon 1983a) provides information on procedures planned to control tailings dusting. Also, refer to the Noise Abatement Plan for further discussion of dust and noise control measures for the MWDF, and to the Reclamation Plan for aesthetic concerns.

9.3.5 Environmental Monitoring Program

9.3.5.1 General

The ground water monitoring program for the MWDF has been developed to include background and operations monitoring near the compliance boundary and at intermediate points between the facility and the compliance boundary. The program also includes monitoring above and below both the liner and top seal such that performance of the liner and top seal can be evaluated.

Other monitoring associated with the MWDF for surface water and dust is also included in the program.

9.3.5.2 Liner Performance Monitoring

Two collection lysimeters measuring 50.0 feet x 50.0 feet will be constructed immediately beneath the liner covering the pond bottom in each of the four ponds proposed. The purpose of these devices will be to collect seepage through the liner and monitor quality and quantity. Plan Sheet No. 32 shows the location of these devices in all four tailing ponds.

Liquids that may collect in these lysimeters will flow by gravity to sumps located either at the internal perimeter of the pond basin or at the outside toe of the pond embankment in the case of one lysimeter to be located in Pond T1. Seepage collected in this Pond T1 lysimeter will be directed to the exterior of the pond to facilitate gravity removal and manual collection of samples. Access to the remainder of the sumps will be through an access pipe constructed beneath the liner of the earth embankment. A water level sensor will be installed in each sump along with a replaceable submersible pump for sample collection. The access pipe will be large enough to allow servicing of the level sensor and pump, and if required, replacement of either. Preliminary details of the collection lysimeters and sumps are presented on Plan Sheet 35.

9.3.5.3 Piezometric Head Monitoring Within Tailing Ponds

Piezometric observation and sample collection wells will be installed in conjunction with the lysimeters in each of the tailing ponds. The purpose of these wells is to provide data to be used in comparison to hydraulic head estimates that were assumed during design. These wells will be constructed in pairs to monitor both leachate head in the tailings and head developed in the drainage area immediately above the liner overlying a lysimeter. These wells will be constructed of high strength plastic pipe and be of sufficient diameter to facilitate pump extraction of collected leachate for leachate quality evaluation.

These wells will extend laterally and parallel to the pond liner bottom sloping at approximately 2 percent and then elbow up at the edge of the pond bottom and advance up the 4H:1V side slopes of the tailings pond. The replaceable submersible pumps will be installed in these wells for sampling of leachate. Water level sensors will be installed in each well. Locations of these wells are shown on Plan Sheet 32. Preliminary details of the system are depicted on Plan Sheet 35.

The data gathered from these wells will be available for evaluation by the DNR but will not be reported as part of the overall monitoring reporting requirements. These wells will primarily be used to evaluate the design and efficiency of the drain system in pond T1. Depending upon the results, design changes in subsequent ponds may be considered.

9.3.5.4 Reclamation Top Seal Performance Monitoring

It is recognized that overall facility performance in the long-term will primarily be governed by the performance of the reclamation cap and primarily by the performance of the reclamation top seal. For this evaluation moisture sensing systems are utilized above and below the reclamation seal. This instrumentation will determine a moisture profile through the cover depth and provide data to evaluate the performance of the MWDF reclamation cover. Proposed locations of the moisture sensing systems are shown on Plan Sheet 33. Actual locations and specific instrumentation will be chosen at the time of Reclamation.

9.3.5.5 Ground Water Monitoring Wells

Ground water monitoring will utilize the following types of wells:

1) Background wells to monitor ground water quality and levels in the MWDF area and maintain a continuing record of data.

2) Intermediate wells to monitor ground water quality and levels (potentiometric surface) within the compliance boundary; and

3) Compliance boundary wells to monitor ground water quality and levels at or near the compliance boundary.

4) Performance wells to monitor ground water quality and levels in the embankment areas of the MWDF at Tailings Pond T1.

The locations of these wells are shown on Plan Sheet 34. Table 9-7 provides a summary list of these wells and includes either existing or proposed screening intervals for the wells. The background (Subprogram I) monitoring is for a minimum of 12 months prior to start of waste deposition in the MWDF. Subprogram I includes monthly sampling and testing of 31 wells or piezometers.

Operations (Subprogram II) monitorng includes all monitoring from start of first construction for the MWDF through operations, reclamation and the long-term care period. Subprogram II includes quarterly sampling and testing of a total of 52 wells or piezometers over the entire monitoring period.

The performance wells located within the MWDF embankments will be monitored as a means to supplement facility monitoring data from the system of collection lysimeters beneath the pond bottom and the moisture sensing system in the pond cap.

The intermediate wells are located within the compliance boundary nearer to the MWDF and provide relatively uniform coverage around the MWDF perimeter, offering an additional measure of monitoring coverage.

Compliance boundary wells have been planned to provide a relative uniform distribution of sampling points located along the entire compliance boundary perimeter. In this regard, these wells are planned so that one or more of them will serve or are capable of being used as background wells (upgradient to ground water flow direction).

The typical construction detail for the proposed new wells is shown on Plan Sheet 35.

TABLE 9.7

MONITORING WELL LIST

Sampling Location	Type[c]	Screen Depth Interval[a]	Sampling Frequency	Project Years	Parameters Measured
Background (Subprogram I) ground water monitoring program for the Project indicating wells, parameters measured, and sampling intervals.					
DMB-6	I	485-482 (T)[d]	Monthly	-1[g]	2
EX-9AL	I	437-436 (BR)	Monthly	-1	2
EX-9AU	I	447-446 (FSD)	Monthly	-1	2
EX-9BL	I	464-463 (CSD)	Monthly	-1	2
EX-9BU	I	486-480 (T)	Monthly	-1	2
EX-10AU	B	451-450 (FSD)	Monthly	-1	2
EX-12AL	I	426-425 (LAC)	Monthly	-1	2
EX-12AU	I	444-443 (T)	Monthly	-1	2
EX-12BL	I	459-458 (CSD)	Monthly	-1	2
EX-12BU	I	482-477 (T)	Monthly	-1	2
EX-13BU	I	462-461 (CSD)	Monthly	-1	2
EX-14AU	C	452-451 (CSD)	Monthly	-1	2 and 3
EX-14BU	C	482-478 (CSD)	Monthly	-1	2 and 3
EX-14BL	C	465-464 (T)	Monthly	-1	2 and 3
EX-14AL	C	432-431 (LAC)	Monthly	-1	2 and 3
EX-16AL	B	450-449 (FSD)	Monthly	-1	2
EX-16BL	B	476-471 (T)	Monthly	-1	2
EX-16AU	B	460-459 (CSD)	Monthly	-1	2
G41-E17	I	436-433 (BT)	Monthly	-1	2
G41-E19A	C	467-464 (CSD)	Monthly	-1	2
G41-H18B	I	468-465 (CSD)	Monthly	-1	2
G41-K13	I	439-436 (CSD)	Monthly	-1	2
MW1-C[b]	C	(CSD)[f]	Monthly	-1	2 and 3
MW1-F[b]	C	(FSD)[f]	Monthly	-1	2 and 3
MW1-T[b]	C	(T)[f]	Monthly	-1	2 and 3
MW2-C[b]	C	(CSD)[f]	Monthly	-1	2 and 3
MW2-F[b]	C	(FSD)[f]	Monthly	-1	2 and 3
MW2-T[b]	C	(T)[f]	Monthly	-1	2 and 3
MW3-C[b]	C	(CSD)[f]	Monthly	-1	2 and 3
MW3-F[b]	C	(FSD)[f]	Monthly	-1	2 and 3
MW3-T[b]	C	(T)[f]	Monthly	-1	2 and 3

TABLE 9.7 (continued)

MONITORING WELL LIST

Sampling Location	Type[c]	Screen Depth Interval[a]	Sampling Frequency	Project Years	Parameters Measured
Operations (Subprogram II - Construction, Operation, Reclamation and Long-Term Care) ground water monitoring program for the Crandon Project indicating wells, lysimeters, other sampling points, parameters measured, and sampling intervals.					
CW1-D[b]	P	(CSD)[f]	Quarterly	4-66	2
CW1-T[b]	P	(T)[f]	Quarterly	4-66	2
CW2-D[b]	P	(CSD)[f]	Quarterly	4-66	2
CW2-T[b]	P	(T)[f]	Quarterly	4-66	2
CW3-D[b]	P	(CSD)[f]	Quarterly	4-66	2
CW3-T[b]	P	(T)[f]	Quarterly	4-66	2
CW4-D[b]	P	(CSD)[f]	Quarterly	4-66	2
CW4-T[b]	P	(T)[f]	Quarterly	4-66	2
DMB-6	I	485-482 (T)	Quarterly	1-66	2
EX-9AL	I	437-436 (BR)	Quarterly	1-32	2
EX-9AU	I	447-446 (FSD)	Quarterly	1-32	2
EX-9BL	I	464-463 (CSD)	Quarterly	1-32	2
EX-9BU	I	486-480 (T)	Quarterly	1-32	2
EX-12AL	I	426-425 (LAC)	Quarterly	1-12	2
EX-12AU	I	444-443 (T)	Quarterly	1-12	2
EX-12BL	I	459-458 (CSD)	Quarterly	1-12	2
EX-12BU	I	482-477 (T)	Quarterly	1-12	2
EX-14AL	C	432-431 (LAC)	Quarterly	1-66[e]	2[e]
EX-14AU	C	452-451 (FSD)	Quarterly	1-66[e]	2[e]
EX-14BL	C	465-464 (T)	Quarterly	1-66[e]	2[e]
EX-14BU	C	482-478 (CSD)	Quarterly	1-66[e]	2[e]
EX-16AL	B	450-449 (FSD)	Quarterly	1-66	2
EX-16BL	B	476-471 (T)	Quarterly	1-66	2
EX-16AU	B	460-459 (CSD)	Quarterly	1-66	2
G41-E17	I	436-433 (BT)	Quarterly	1-66	2
G41-E19A	C	467-464 (CSD)	Quarterly	1-66	2
G41-H9	B	449-446 (CSD)	Quarterly	4-66	2

TABLE 9.7 (continued)

MONITORING WELL LIST

Sampling Location	Type[c]	Screen Depth Interval[a]	Sampling Frequency	Project Years	Parameters Measured
G41-H18B	I	468-465 (CSD)	Quarterly	22-66	2
G41-K13	I	439-436 (CSD)	Quarterly	1-11	2
IW1-D[b]	I	(CSD)[f]	Quarterly	8-66	2
IW1-T[b]	I	(T)[f]	Quarterly	8-66	2
IW2-D[b]	I	(CSD)[f]	Quarterly	8-66	2
IW2-T[b]	I	(T)[f]	Quarterly	8-66	2
IW3-D[b]	I	(CSD)[f]	Quarterly	15-66	2
IW3-T[b]	I	(T)[f]	Quarterly	15-66	2
IW4-D[b]	I	(CSD)[f]	Quarterly	15-66	2
IW4-T[b]	I	(T)[f]	Quarterly	15-66	2
IW5-D[b]	I	(CSD)[f]	Quarterly	22-66	2
IW5-T[b]	I	(T)[f]	Quarterly	22-66	2
IW6-D[b]	I	(CSD)[f]	Quarterly	22-66	2
IW6-T[b]	I	(T)[f]	Quarterly	22-66	2
IW7-D[b]	I	(CSD)[f]	Quarterly	22-66	2
IW7-T[b]	I	(T)[f]	Quarterly	22-66	2
MW1-C[b]	C	(CSD)[f]	Quarterly	1-66	2[e]
MW1-F[b]	C	(FSD)[f]	Quarterly	1-66	2[e]
MW1-T[b]	C	(T)[f]	Quarterly	1-66	2[e]
MW2-C[b]	C	(CSD)[f]	Quarterly	1-66	2[e]
MW2-F[b]	C	(FSD)[f]	Quarterly	1-66	2[e]
MW2-T[b]	C	(T)[f]	Quarterly	1-66	2[e]
MW3-C[b]	C	(CSD)[f]	Quarterly	1-66	2
MW3-F[b]	C	(FSD)[f]	Quarterly	1-66	2
MW3-T[b]	C	(T)[f]	Quarterly	1-66	2

TABLE 9.7 (continued)

MONITORING WELL LIST

Sampling Location	Type[c]	Screen Depth Interval[a]	Sampling Frequency	Project Years	Parameters Measured
Cap Moisture Content		Above and Beneath Top Seal	Quarterly	10-66	4
Liner Lysimeters		Beneath Liner	Quarterly	4-66	2
Leachate		Underdrain	Quarterly; Annual	4-34	2;3

a. Elevation in meters above mean sea level (MSL).
b. Proposed new well.
c. B = background; C = compliance; I = intermediate; P = performance.
d. T = till; BR = bedrock; CSD = coarse strtified drift; FSD = fine stratified drift; LAC = lacustrine; BT = basal till.
e. Parameter lists 2 and 3 will be measured in the year following reclamation cap completion and the final year of closure.
f. Screen interval for new well will be set at time of installation; based on samples and specific stratigraphy.
g. -1 indicates a minimum of 12 months of monitoring prior to start of waste deposition.

1. Water level only.
2. Alkalinity, chemical oxygen demand, copper, hardness, iron, manganese, pH, sodium, specific conductance, sulfate, total dissolved solids, total organic carbon, water level, zinc.
3. Arsenic, barium, cadmium, chloride, chromium, cyanide, fluoride, gross alpha radiation, gross beta radiation, lead, mercury, nitrate, radium-226, radium-228, selenium, silver, sulfide.
4. Moisture content only.

Monitoring Program Parameters and Schedules - The purpose of this section is to discuss:

1) Parameters to be monitored for the lysimeters and monitoring wells; and

2) Monitoring schedules.

Table 9-7 lists the parameters to be monitored for the lysimeters and wells. Discussion providing the basis for establishing these parameters for monitoring is provided in the Monitoring and Quality Assurance Plan presented as part of the Mining Permit Application. These parameters are based primarily on characterizations and analyses of the wastes to be disposed in the MWDF. The moisture sensing devices within the reclamation cap will be monitored for moisture levels only, and no water quality parameters will be monitored. Data from the ground water monitoring program will be reported to the DNR quarterly except for ground water table and quality monitoring wells. These wells will be reported annually for the following reasons:

1) The monitoring program emphasizes liner and reclamation top seal performance to detect potential effects on ground water; and

2) Monitoring data for the liner and reclamation cover will be reported to DNR quarterly; and

3) Flow times in both the unsaturated and saturated zones at the MWDF are very slow. Annually will be sufficient to detect ground water changes at intermediate wells to allow sufficient time for action. The intermediate wells will detect changes early so any problems can be addressed at that time.

In addition to monitoring the facility performance through the system of wells and collection lysimeters proposed, additional sampling including that of the leachate water pumped from the underdrain layer will be performed to evaluate the parameters indicated in Table 9-7.

9.3.5.6. Surface Water

Surface water monitoring will be conducted during construction and operation of the MWDF (see Monitoring and Quality Assurance Plan). The monitoring stations will be determined for the Plan of Operation (NR 182.09) but will include the sedimentation basins (see Figures 10-1 through 10-6). Because these basins will not receive water that has been in contact with waste, the parameters include specific conductance, pH, temperature and TDS. The basin will be monitored after major storms, and at least four times per year.

9.3.5.7 Tailings Dusting

Monitoring for potential MWDF tailings dusting impacts on surrounding soils and vegetation is provided for in the Monitoring and Quality Assurance Plan. The monitoring includes periodic sampling to establish baseline conditions and to determine cumulative dusting impact during operations.

9.3.6 Contingency Plan

The Contingency Plan prepared for the MWDF is designed to comply with NR182.08 (2)(i), NR182.075 (1)(c), NR182.17. The Contingency Plan provides an emphasis on ground water quality protection with action steps included for implementation if warranted. However, the basic program is designed to rely heavily on facility performance monitoring and to provide a systematic evaluation of data as they are collected. The Contingency Plan consists of a sequence of appropriate actions as required if data indicate that a potential problem is developing. The major input to the Contingency Plan is data gathered during the environmental monitoring program.

9.3.6.1 Objectives

Several objectives have been established for the MWDF Contingency Plan. Presented below are the objectives and summaries of how they are met in the Contingency Plan:

1. Comply with NR182.08(2)(i) - The requirement of NR182.08(2)(i) is addressed by inclusion of the Contingency Plan.

2. Respond to the DNR's April 10, 1984 letter on MWDF feasibility - The requirements of the DNR letter that pertain to additional detail for the Contingency Plan are addressed in this Contingency Plan.

3. Respond to DNR's September 11, 1985 letter on contingency plans for dust control - Specific contingency actions are included for control of potential tailings dusting.

4. Provide for contingency action at an early time should liner or reclamation cap monitoring show deviations from planned or anticipated conditions - The Contingency Plan calls for action if potential problems are detected in liner and reclamation cap monitoring. This will allow time for problem definition and early followup action to reduce or eliminate potential ground water effects. An important input for the Contingency Plan is data from monitoring the liner and cap performance program.

5. Address a variety of situations - A systematic methodology or sequence is provided in the Contingency Plan to address the wide variety of situations that could occur. Should problems be confirmed using this methodology, the response involves a

problem definition approach to identify possible cause(s) and solutions.

6. Take advantage of the redundancy in the monitoring program to help define problems if they are detected in one portion of the monitoring system - The monitoring program includes substantial redundancy in terms of what is monitored (cover, liner & ground water), types of monitoring instruments (wells, lysimeters and moisture sensing devices), and numbers of instruments. This redundancy in the monitoring program can play an important role in defining and isolating problems if they are detected. For example, if a problem is detected in a collection lysimeter beneath the bentonite amended soil liner, the data from the moisture sensing system in the reclamation seal can be reviewed to determine if a faulty seal is the cause of the problem.

7. Include practical and realistic measures for remedial action that are constructible, durable and reliable - Several remedial measures are available and are discussed in this section.

The design for the reclamation cap and liner incorporates substantial redundancy into the MWDF seepage control system. The projections for infiltration through the cap (Ayres, 1984, 1985) indicate that the MWDF design is highly conservative with respect to potential ground water impacts. The MWDF design, in combination with the proposed monitoring sytem, has been used in the development of the Contingency Plan.

The intent of a Contingency Plan is to address those actions that could be taken if a change is detected from planned or anticipated facility performance. This plan is structured along those lines. Information obtained in the systematic evaluation of in-field conditions will determine the appropriate remedial action. A situation can have a number of possible causes, solutions and remedial action alternatives. Redundancy in the monitoring plan (cover, liner and ground water monitoring) allows the early detection of potential problems, their evaluation and early action to address or correct them as required.

No Contingency Plan can address all circumstances. Therefore, the remedial actions described in the following sections should be considered a starting point based on presently available construction technology and not the only feasible solutions that may exist at some future time in the event a problem may occur. Depending on the circumstances of a situation, these remedial measures could be implemented as short-term or long-term control measures. Also, a combination of the remedial measures may be desirable to control a detrimental situation.

9.3.6.2 Systematic Program for Evaluating Differences Between Planned and Actual Conditions

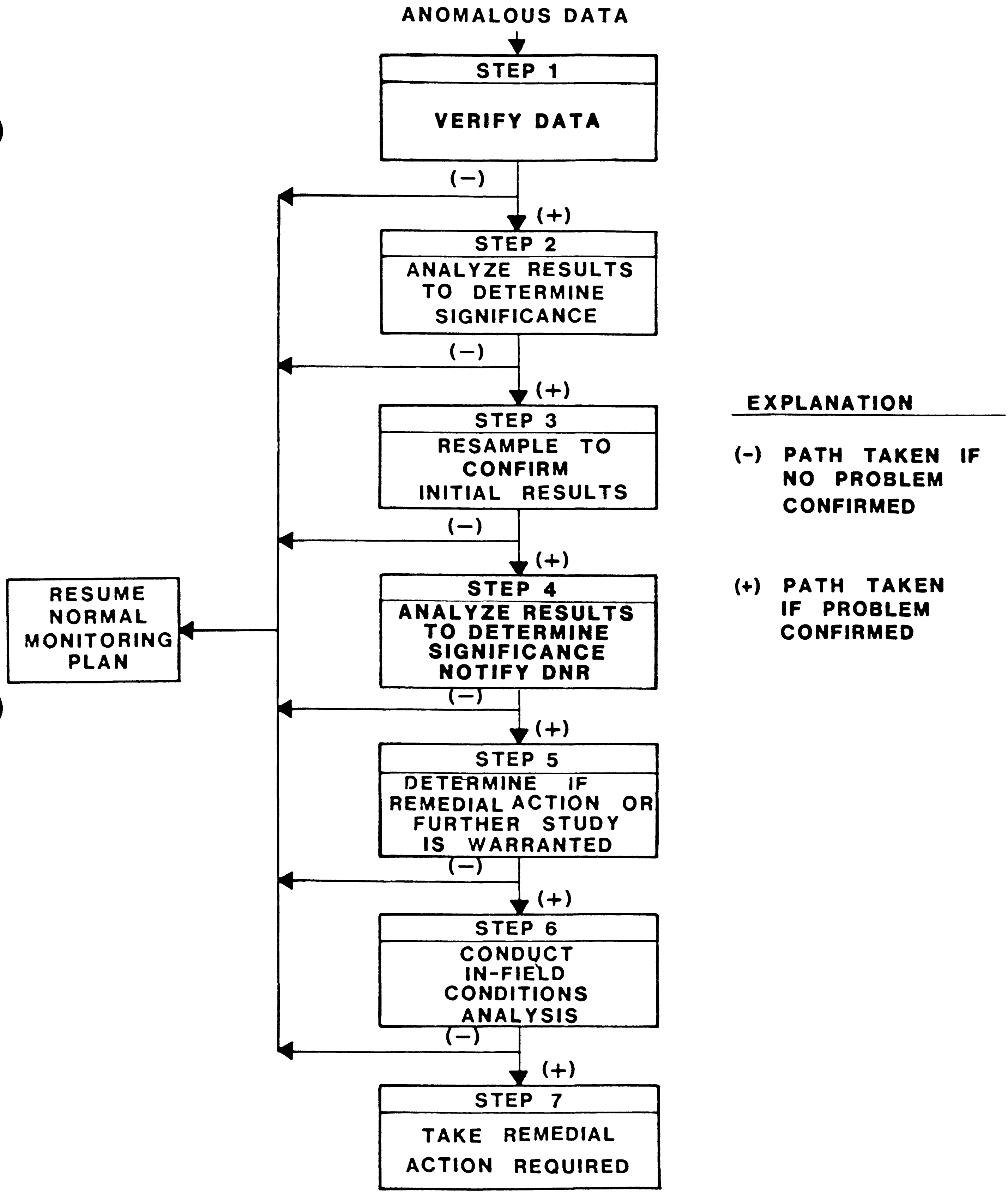
The following generalized procedure, shown in Figure 9-10, is a step-by-step approach to be implemented if the monitoring program suggests a potential problem:

Step 1: If a statistically significant variation in facility performance or ground water quality is observed, the following will occur. Data on all sample collection, sample handling, and analytical procedures used in the monitoring program will be checked to determine if the proper procedures were used.

Step 2: Following data verification, sampling results will be analyzed to determine the significance of the data.

Step 3: Resample to confirm results. If the occurrence appears to be localized, only monitoring locations in that immediate area may need to be resampled.

Step 4: If similar results are obtained, determine the significance of the elevated values, the cause (if possible), and the potential effect on the environment. The new data could be



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SYSTEMATIC EVALUATION FOR CONTINGENCY PLAN

JMM

FIGURE 9-10

used in the contaminant flow computer models to determine a new set of predicted impacts.

Step 5: Based on the relative significance of the elevated values and on the predictions from the adjusted model, determine if remedial action is required or if continued monitoring is sufficient.

Step 6: If it is concluded that a problem is occurring warranting action, an in-field conditions analysis will be conducted to determine the vertical and horizontal extent of the problem and the effect of the elevated values on the environment. It will also include an analysis of potential sources for the problem. If required, mitigation or repair alternatives would be developed to correct the situation as defined. An in-field conditions report summarizing the findings, conclusions and recommendations will then be prepared and submitted to the DNR for review.

Step 7: - Implement remedial action.

9.3.6.3 Detection of Changes from Planned Conditions

Reclamation Cap Infiltration - A detailed water budget has been prepared for the revised reclamation cap design (Ayres, 1984, 1985). The budget indicates that with the use of a drain layer and synthetic membrane liner in conjunction with a two-layer bentonite amended soil liner, no infiltration of precipitation should occur. A reclamation cap monitoring system has been designed to permit reclamation seal performance evaluation.

A moisture sensing system will be installed above and below the reclamation seal to provide data to determine a moisture profile through the reclamation cover system. If data from these instruments indicate significant infiltration through the reclamation cap is occurring, several actions will be taken:

1. The time rate of infiltration will be quantified.

2. The evaluated time rate of infiltration will be compared to that assumed for design impact predictions.

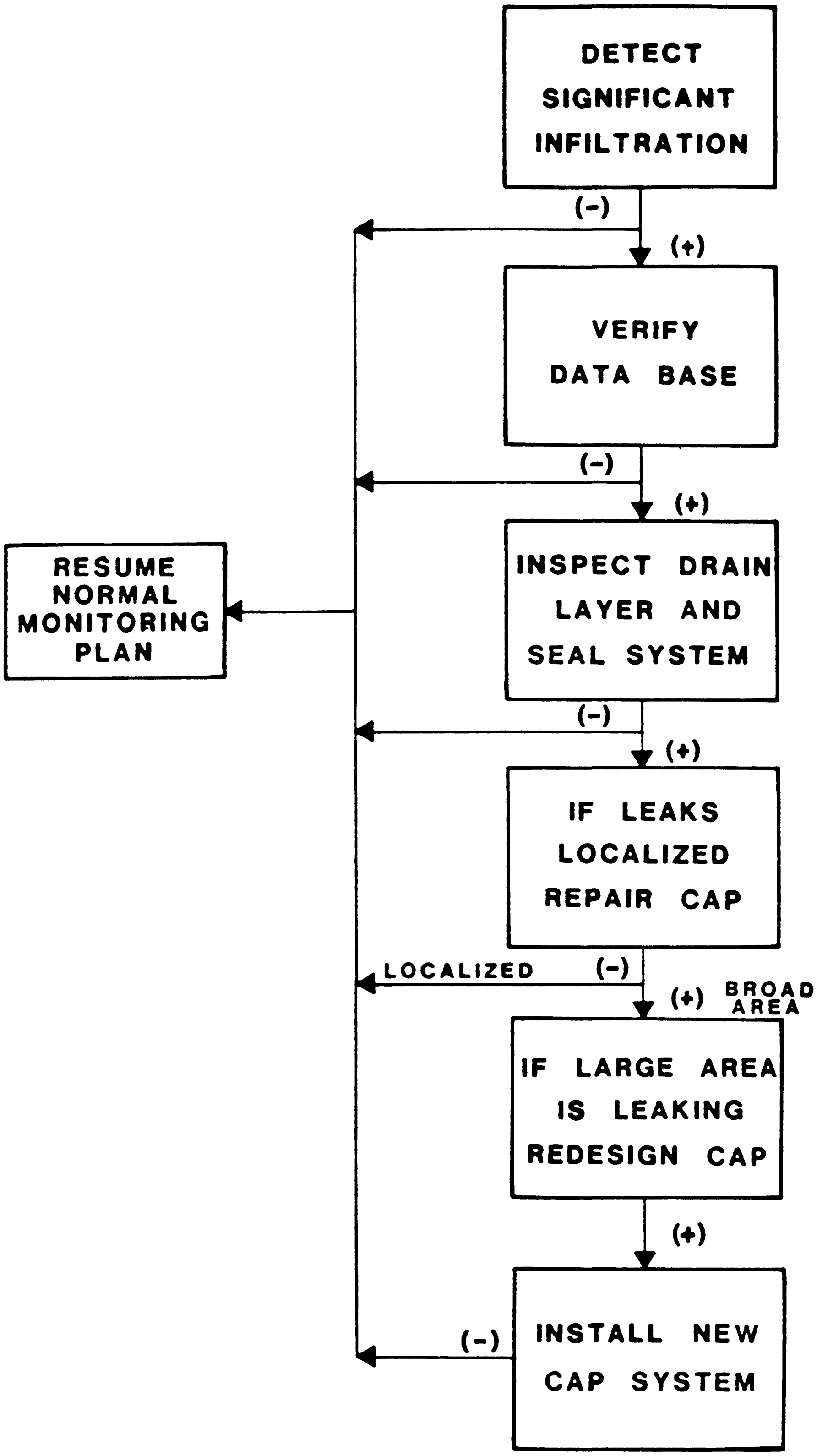
3. If measured rates of infiltration exceed the assumed design rates, an assessment will be made using available unsaturated and saturated flow transport models to determine the effect of this infiltration on the overall facility design and performance.

4. If results from Item 3 above indicate that the infiltration could create the potential for adverse effects on the facility's performance, excavations to the double-liner system in the area of leakage will be made, if possible. Visual inspection of the liner systems will be made to ascertain the reasons for the infiltration. If data are gathered that indicates the leakage is localized to a small area, a patch of the liner system will be made and monitoring data will be carefully evaluated to determine if the leakage has been corrected.

If monitoring data indicated that the leakage is likely occurring over a much broader area (e.g., if all of the measurements are showing unacceptable rates of infiltration) that might suggest a general failure of the synthetic or bentonite amended soil seal, then other action will be taken. Figure 9-11 is a diagram showing the Contingency Plan for the reclamation cap.

Liner Performance - A monitoring system has been developed for liner performance that will allow collection of water samples so that comparisons between actual and planned concentrations and flow rates can be made.

If data from the liner performance monitoring system show that significant deviations from planned conditions are occurring, a number of actions will be taken:



EXPLANATION

(-) PATH TAKEN IF NO PROBLEM CONFIRMED OR IF NO ADDITIONAL ACTION NEEDED

(+) PATH TAKEN IF PROBLEM CONFIRMED

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RECLAMATION CAP CONTINGENCY PLAN

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FIGURE 9-11

1. The data will be rechecked and additional data will be collected and analyzed to verify that a significant deviation has actually occurred both in terms of quantity and quality.

2. Available flow and transport models will be used to assess the effect of this leakage on overall facility performance and potential ground water quality changes.

3. If the results from Item 2 above indicate that leakage could result in a violation of the ground water quality standard in effect for the facility at the time, then further investigations will begin. These investigations could include:

   a) Evaluation of the flow and transport models to ensure that the models have properly represented the physical and chemical conditions in the unsaturated zone.

   b) Evaluation of the extent of leakage to determine from the monitoring data if leakage is localized to a small portion of the total base area of the MWDF or if the data suggest an overall failure of the liner system.

Potential remedial actions for a localized failure of the leachate collection system include:

1. <u>In Early Stages Of Use</u>

   a) Removing waste and repairing faulty liner.

   b) Repairing the leachate collection system.

   c) Altering the MWDF design and/or the manner of filling so that portions of the site are brought to final grade and reclaimed at a faster rate.

   d) Grouting the drain layer of the leachate collection system in an area of liner failure.

2. <u>Closed Pond Or Substantially Completed Pond</u>

   a) Closing the facility and placing final cover before final grades are reached.

   b) Injecting chemicals into waste to stabilize generated leachate.

c) Pumping from underdrain collection wells. The pumped leachate would have to be treated; however, the design of any leachate treatment system would depend on the quantity and quality of leachate produced. The specifics of such a treatment system, discharges and sludge disposal cannot be defined now. However, physical, chemical and biological treatment technology exists today to handle such a situation.

d) Installing a well through the waste to intersect the leachate collection system and pump leachate from the site. (Note: above discussion on leachate treatment applies here also.)

e) Grouting the drain layer of the leachate collection system.

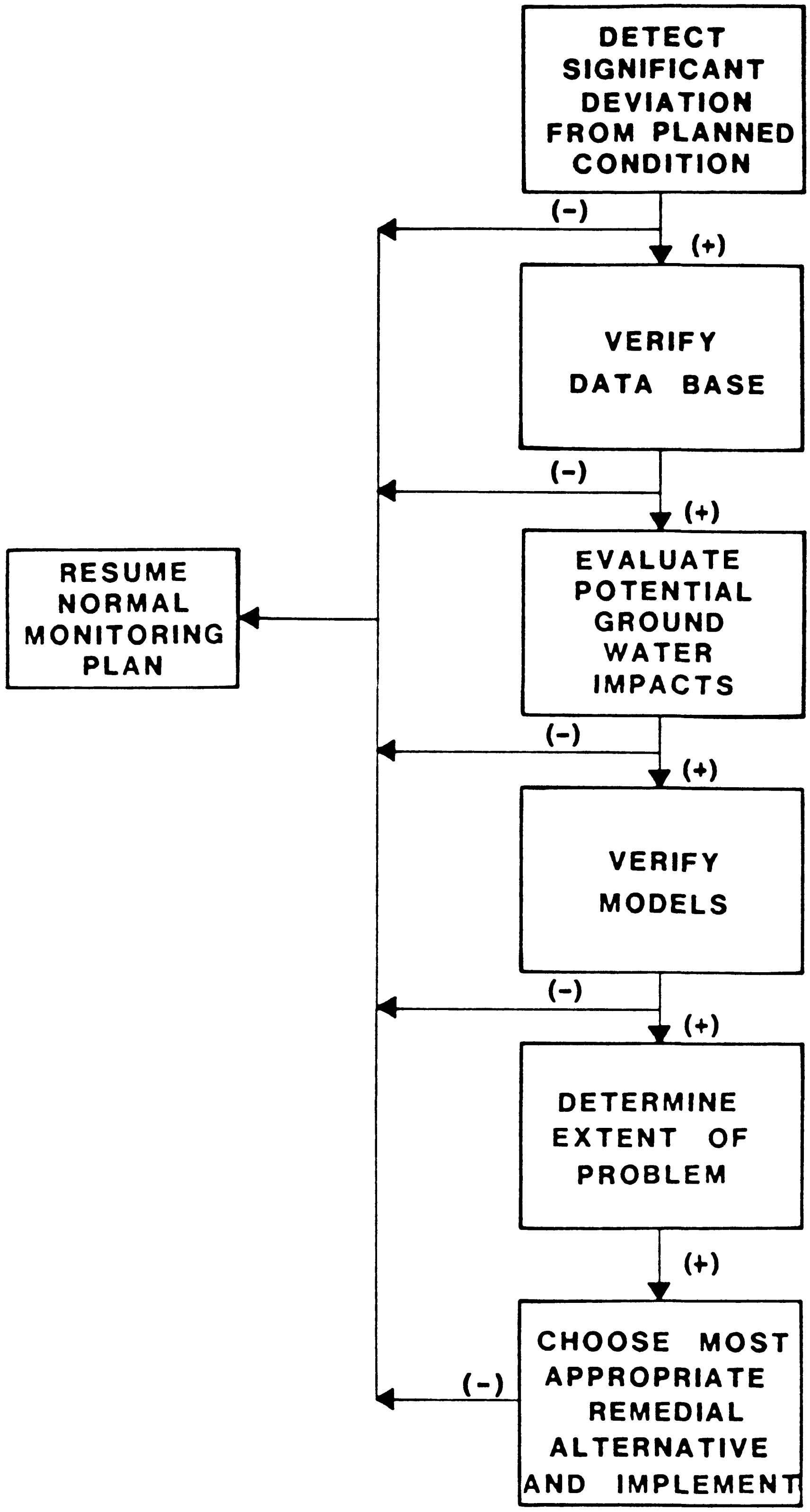
Figure 9-12 shows the Contingency Plan for liner failure.

Ground Water Monitoring and Remedial Action - A ground water transport model has been developed that estimates the concentrations of parameters at a specified location in the ground water flow system through time (D'Appolonia, 1985). The ground water monitoring system has been developed to allow comparisons between actual and projected conditions. If data from the monitoring system indicate significant differences between projected and actual concentrations, the following action will be taken:

1. The data will be rechecked and additional samples will be collected and analyzed to verify that the original data are accurate.

2. The available flow and transport model will be used to assess the information and evaluate overall facility performance and ground water quality.

3. If results from Item 2 above indicate that the change could ultimately result in a violation of the water quality standard in effect for the facility at that time, then further investigation will begin. These investigations include:



EXPLANATION

(-) PATH TAKEN IF NO PROBLEM CONFIRMED OR IF NO ADDITIONAL ACTION NEEDED

(+) PATH TAKEN IF PROBLEM CONFIRMED

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LINER CONTINGENCY PLAN

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FIGURE 9-12

a) Evaluation of the flow and transport models to ensure that models have properly represented the physical and chemical conditions in the saturated zone.

b) Evaluation of the areal extent of the change. Also, it will be determined whether the intermediate well monitoring data are localized to a small portion of the ground water flow system, or if the entire flow system is being affected.

Potential remedial measures for ground water problems include:

1. <u>During Facility Operation</u>

   a) Applying those steps listed in the Liner Contingency Plan.

   b) Installation of barrier or interceptor wells to control migration of affected ground water.

The number of wells, locations and construction would be determined by using the flow and transport models. Additional monitoring would be conducted using new wells in the appropriate area to ensure that the barrier or interceptor wells are performing as designed.

The comments made in the previous section regarding treating pumped leachate from leachate pumping wells apply to treatment of ground water extracted during remedial action. Quantity and quality of contaminated ground water would have to be defined before a treatment method could be devised. Also, discharge of treated ground water and disposal of any sludge generated would have to be dependent on the treatment system. Again, technology is available to treat ground water, especially for the contaminants that might be expected from the MWDF.

2. <u>After Closure</u>

   a) The same remedial measures for the During Facility Operation category would apply after closure.

Figure 9-13 shows the Contingency Plan for ground water quality degradations.

9.3.6.4 Tailings Dusting Contingency Plan

If the tailings dusting monitoring determines any significant deviations from baseline conditions have occurred, or if a pattern is developing which indicates tailings dusting is occurring, then the following steps will be taken:

1. Additional field monitoring and study will be conducted immediately to determine the extent of the problem and the basis for its occurrence.

2. A plan to eliminate the problem will be developed from the following alternatives:

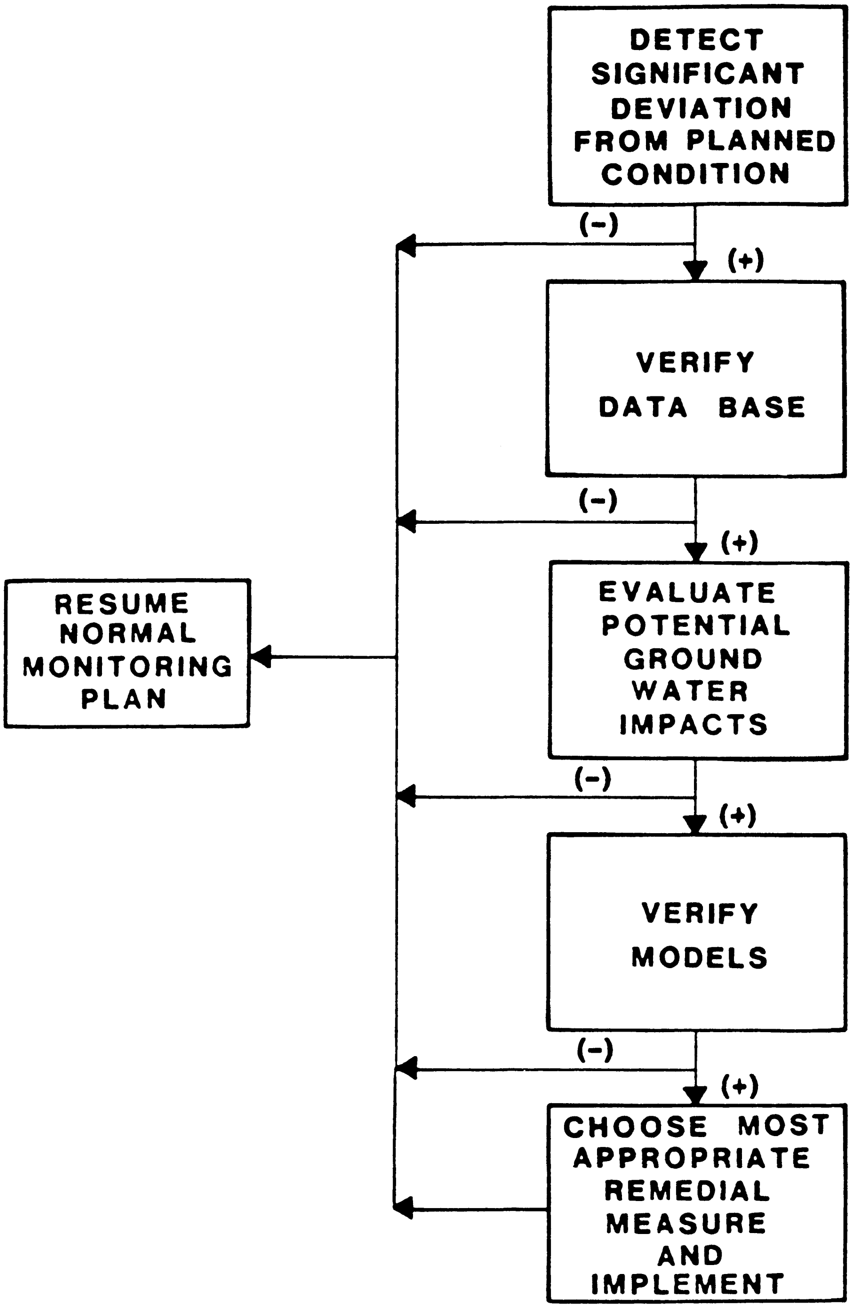
   a) Revision of operating procedures for the tailings disposal to maintain moist conditions over a larger expanse of the tails surface.

   b) Addition of water spraying systems to provide moisture for the tailings surface.

   c) Application of a chemical binder to the tailings surface.

   d) Use of an interim protective cover.

The above alternatives would be utilized in the plan in a progressive fashion to satisfactorily resolve the problem. Use of alternative (d) is not anticipated unless the tailings pond were to be shut down for some unexpected reason.



EXPLANATION

(-) PATH TAKEN IF NO PROBLEM CONFIRMED OR IF NO ADDITIONAL ACTION NEEDED

(+) PATH TAKEN IF PROBLEM CONFIRMED

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GROUND WATER CONTINGENCY PLAN

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FIGURE 9-13

9.4 CLOSURE AND LONG-TERM CARE

9.4.1 Closure

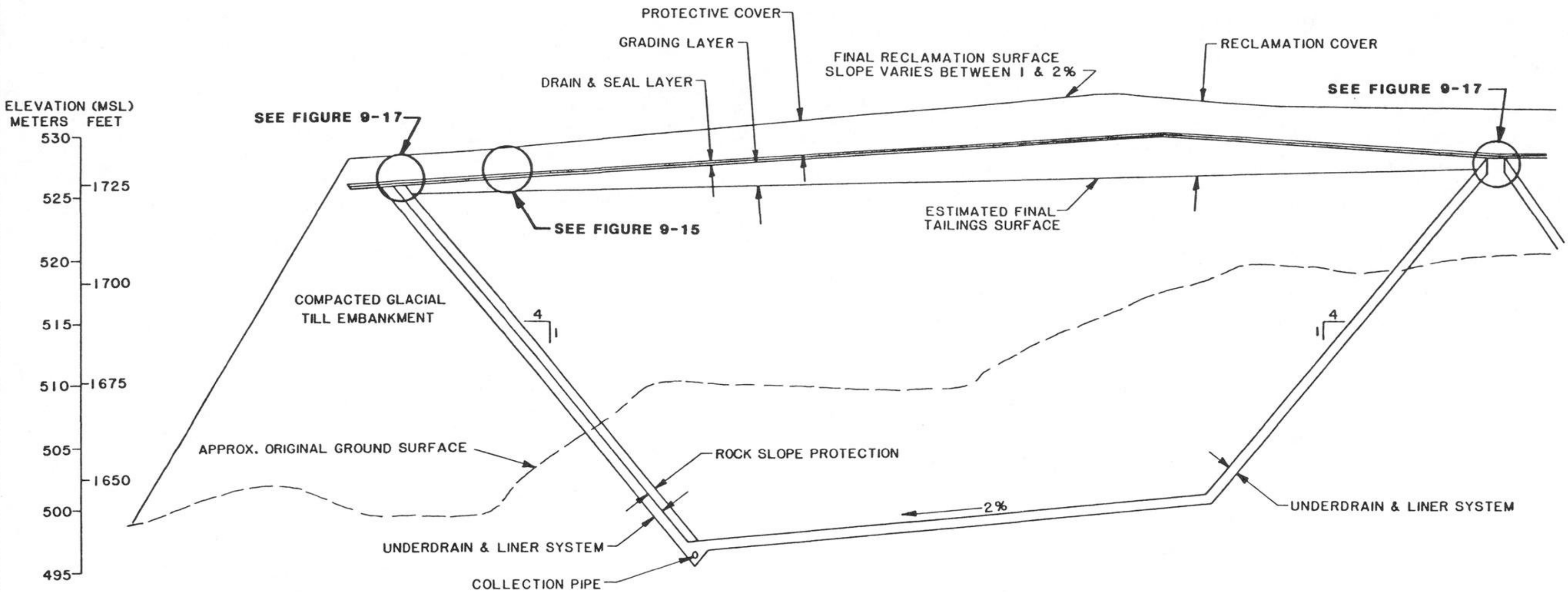
The Reclamation Plan for the MWDF has been designed for compatibility with the biological and physical characteristics of the disposal area and the adjacent undisturbed environment. The main elements of the Reclamation Plan will address landform design of the topcover, surface water hydrology, soil management, and revegetation. Reclamation of the area will be sequenced to coincide with the schedule for development, use, and closure of each of the four tailing ponds. The reclamation cover has been designed to provide a stable, secure soil cover for the MWDF and a suitable layer for vegetation, and to limit infiltration through the cover to the deposited tailings. In the final analysis of MWDF performance, with respect to seepage control, the reclamation cover plays a most important role. After the establishment of steady-state seepage through the closed MWDF, the reclamation cover infiltration rates become the final or steady-state MWDF seepage rates. These final rates, because of the extended time periods, are more significant in evaluating overall MWDF performance than the slightly higher seepage rates predicted for relatively short periods during operations.

Tailings Ponds Precipitation Infiltration Control Measures

At the end of operation the surface of a tailings pond will be covered with a cap composed of six layers. The lower most (or first) layer, composed of glacial till, will be used to grade the final pond surface to between a 1 and 2 percent slope. The second layer will be composed of a bentonite modified soil seal to prevent surface water from percolating through the tailings. The seal will be an overall 8-inch minimum thickness consisting of two 4-inch thick lifts of liner placed in a manner similar to that described for the pond liner in Section 9.2.4. The upper lift will be placed so that seams between construction passes are offset; the third layer, placed atop the bentonite modified soil seal will be a 40 mil thick polyethylene membrane. Fourth, an 8-inch coarse sand and gravel overdrain layer will be placed above the membrane to promote drainage of the final layer and to minimize hydrostatic head across the seal. Atop the drain layer a geotextile filter will be placed to minimize migration of silt and fine sand into the drain layer from the final cover soils. The final layer will be formed by spreading a layer of glacial till 5 feet thick to provide a protective cover for the seal and drain layer and to provide a plant growth medium. The top 9-12 inches of the 5 foot thick cover will be replacement topsoil originally stripped and salvaged from the MWDF area.

A typical tailings pond cross-section showing the relationship between the initial pond configuration, the final tailings surface at completion of pond operation and the final reclamation cover is shown on Figure 9-14. Additional detail of the typical reclamation cap section is shown on Figure 9-15.

The final tailings surface slope is estimated to be 0.5 percent based on an evaluation of the settling and drainage characteristics of the slurried tailings. Construction of the glacial till and reclamation cover will result in a final surface slope ranging between 0.5 and 2 percent. Soil material, some of which will come from the upper regions of the confining embankments, will be used to construct the glacial till cover layer. The remaining soil requirements will be met from stockpile volumes developed



0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

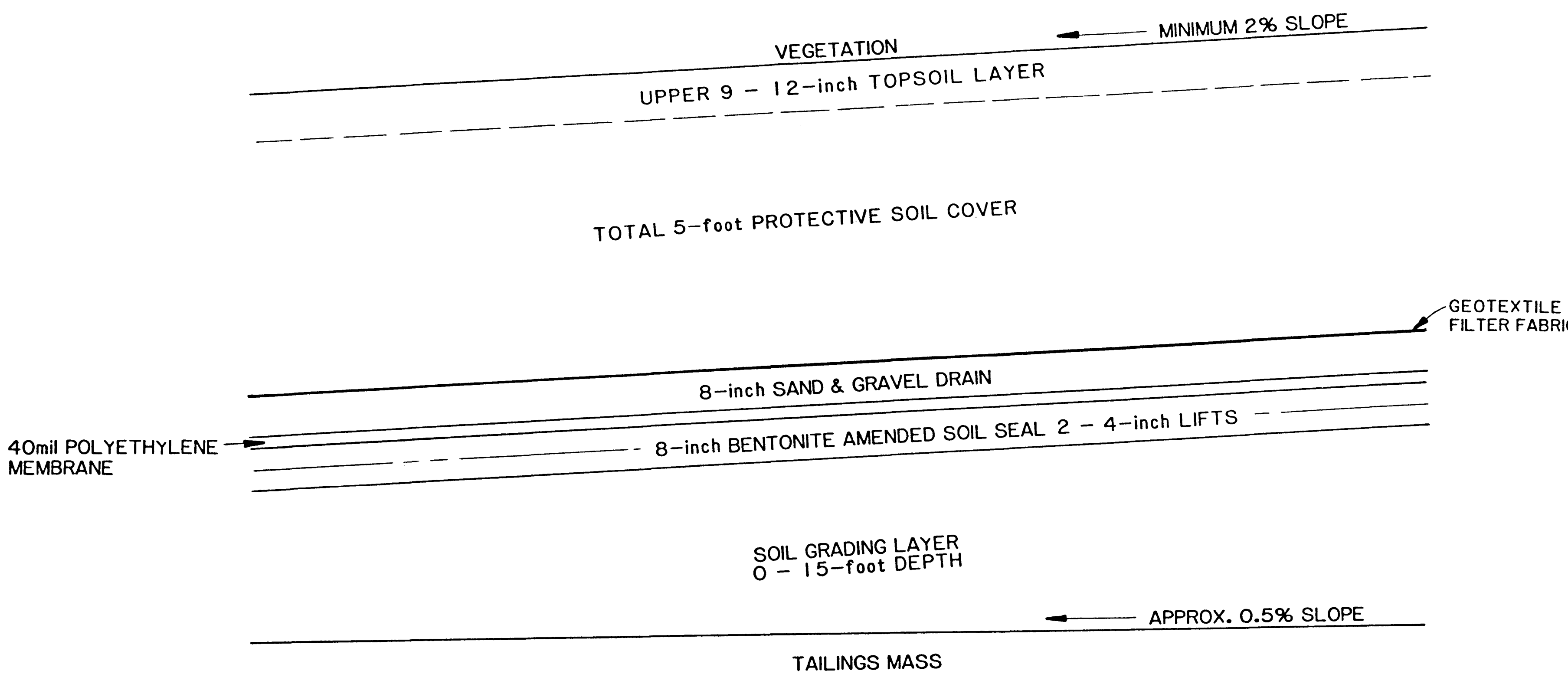
VERTICAL SCALE EXAGGERATED 5x

Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY
TYPICAL RECLAMATION CAP

SCALE NONE	STATE WISCONSIN	COUNTY FOREST
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY / DATE
APPROVED BY / DATE	APPROVED BY	DATE 11/13/85
APPROVED BY / DATE	EXXON	DATE
DRAWING NO FIGURE 9-14	SHEET OF	REVISION NO



Typical Representation: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY
RECLAMATION SEAL DETAIL

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 7/84	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11/13/85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE	
DRAWING NO FIGURE 9-15			SHEET ___ OF ___	REVISION NO	

during the previous construction phase. The overdrain layer will be prepared and constructed as described for the drain layer of the seepage collection system. A detail drawing of the final cover design is shown on Plan Sheet 25.

The surface area of each pond to be covered, and the quantity of soil materials required for the seal and the abandonment cover layer is included in Tables 9.3 through 9.6.

A settlement analysis for the reclamation cover has been made as part of the feasibility report design work (Golder, 1982e). The analysis indicated that the surcharge of the working mat, grading layer, and reclamation cap (total 16.4 feet of cover in the pond center) could produce settlement of as much as 2 feet. However with the high coefficient of consolidation of the tailing, settlement will be relatively fast. The rapid consolidation and planned time frame (staged over two construction seasons) for construction of a pond reclamation cap will allow a final adjustment of the grading layer, if necessary, prior to installation of the seal, drain layer, and vegetative cover layer. These tailing and construction conditions will eliminate the possibility of settlement affecting the integrity of the reclamation cap. While studies indicate settlement amounts will be minor, actual field settlement monitoring data will provide the final indication of acceptable conditions for installation of the seal and upper reclamation cap layers. After the grading layer is in place it will be monitored for settlement to determine if or when all settlement is complete. After an acceptable condition has been reached, the final cap layers will be installed. If significant settlement had occurred during the grading layer surcharge period, the final reclamation grade would be reestablished prior to installing the final cap layers.

If the field data indicated that substantially more time would be required for complete settlement, which would delay completion of the reclamation cap, then additional compensating measures would be undertaken to complete reclamation. Assuming the field data indicated an additional longer term ultimate settlement would occur, the grading layer would be supplemented with additional material to ultimately form the desired final grades. The predictability of the uniformity of the settlements throughout the tailings mass is very high because of the homogenity of the tailing and no problems are anticipated.

Preparation of Final Reclamation Surfaces

The MWDF is designed so that reclamation will be done in stages. After each tailings pond is filled and removed from service, the ponded water will be pumped to the reclaim pond, or in the case of the last tailing pond, to the wastewater treatment facility for treatment prior to discharge.

On completion of milling, the water in the reclaim pond will be treated for discharge and the pond basin reclaimed. The reclaim pond liner, rock slope protection materials and water treatment sludge contained therein will be placed in tailings pond T4 before it is reclaimed. The reclaim pond area will be regraded with the glacial till soils that formed the reclaim pond embankments.

Construction of the reclamation cover system will involve placing a working mat of till soil over the tailings surface. The till will be used to develop approximate 0.5 to 2 percent grades over the tailings pond area surface below the bottom of the seal. A bentonite modified soil seal, a synthetic membrane, an overdrain, a geotextile filter, and a soil cover (including an upper topsoil layer) will be placed uniformly over this subgrade. The pond embankments above the tailings will also be used in this grading operation. After the reclamation cap subgrade has been prepared, the composite seal, overdrain, a geotextile filter, and soil cover will be installed. Final reclaimed MWDF surface grades are shown on Figure 9.16 with additional detail presented on Plan Sheet 17.

Based on the final reclamation cap grading slopes and surface runoff routing, riprap slope facing materials will be placed on the four outside embankment faces where the reclamation cap drainage swales route surface runoff down the embankments. Based on the anticipated flows, analysis has indicated provision for permanent erosion control is necessary at these four locations (Ayres Associates, 1985). Figure 9.16 indicates the locations of these slope protection features.

MWDF Overall Reclamation Cap Performance

The drain layer and composite seal work effectively to reduce final seepage through the seal to a practically negligible amount. However, for purposes of analyzing overall MWDF performance a seepage rate has been assumed. This final assumed seepage through the composite seal and hence through the tailings mass and pond bottom has been used in evaluating overall MWDF seepage characteristics and performance through the use of ground water models as described in Chapter 4 of the EIR.

The coarse drain layer and membrane above and the till grading layer below the soil-bentonite seal act as capillary breaks and prevent the

LEGEND

AREAS POTENTIALLY REQUIRING SPECIAL EROSION CONTROL

DIRECTION OF SURFACE WATER RUN-OFF

NOTES:

1) SEE DETAIL B, FOR TYPICAL RECLAMATION COVER PLAN SHEET 25.

2) SEE PLAN SHEET 25 FOR CROSS-SECTION THROUGH ENTIRE FACILITY.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/ TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER HOUSTON TX

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MWDF FINAL GRADE PLAN

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST
DRAWN BY J.J.T.	DATE 10-7-85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY JKWallace	DATE 11/27/85
APPROVED BY	DATE	EXXON D.E. Moe	DATE 12/4/85
DRAWING NO **FIGURE 9-16**		SHEET 17 OF 36	REVISION NO 0

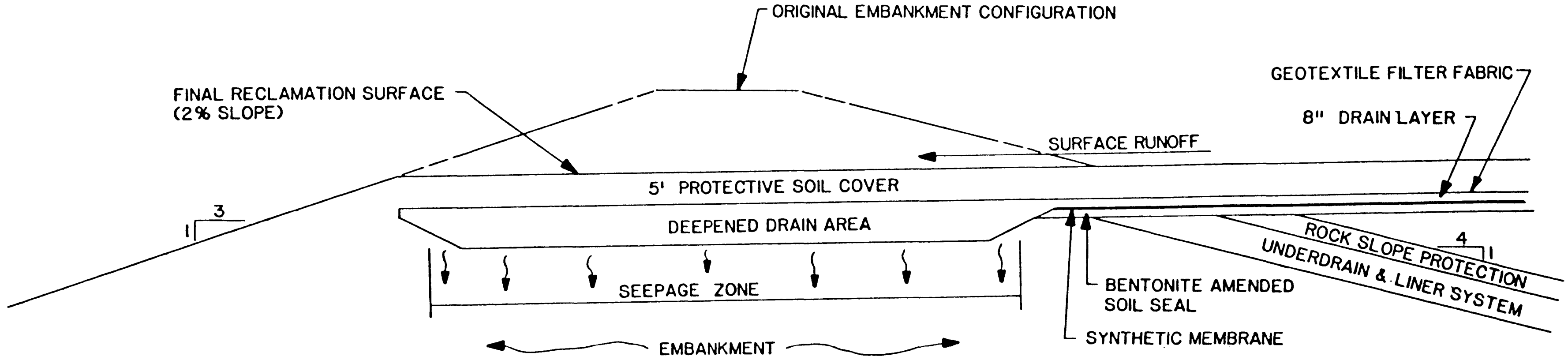
DESIGN PRODUCTS CO —

development of suction pressures which might draw water from the bentonite soil seal. The water balance analysis by Ayres Associates (1984, 1985) showed that sufficient moisture would be retained in the 5.0 feet of till cover to support the vegetation.

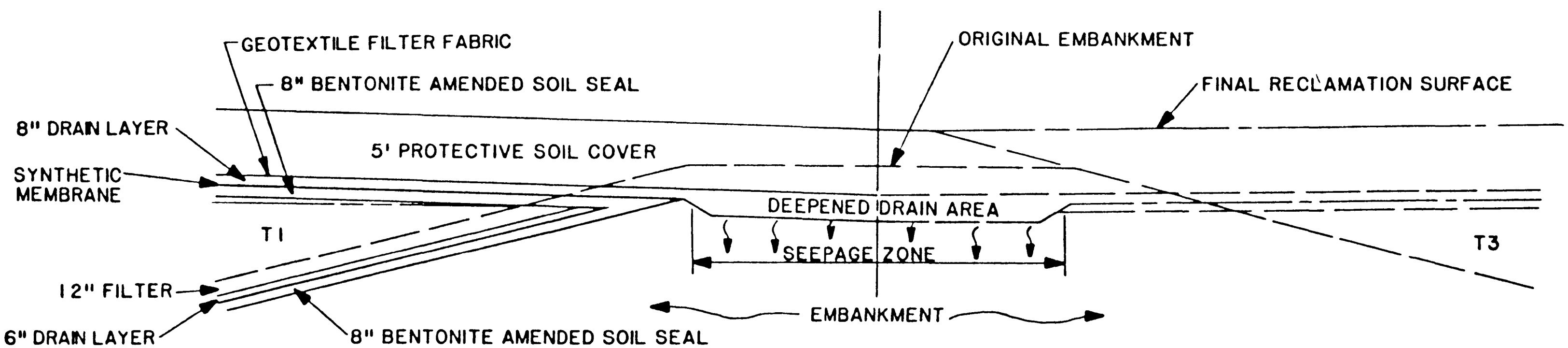
Bentonite modified soil is similar to glacial till soils except for permeability reduction. The soil structure mix is less susceptible to shrinkage and swelling than a high clay content soil.

The drain layer will channel nearly all infiltration through the reclamation cap to the perimeter and internal embankment crests of the MWDF where it will infiltrate downward. Figure 9-17 presents the configuration of the drain layer as it terminates in the embankment area. Plan Sheet 25 presents additional detail for this system. This system approaches, as nearly as possible, the restoration of initial site hydrologic patterns upon completion of the final reclamation in the MWDF area. Surface runoff, which originally occurred throughout the area occupied by the MWDF, still can occur although probably to a lesser degree since final reclamation grades are low. Infiltration which occurred prior to development of the MWDF will still occur; however, its pattern will be changed slightly since the cap drain system redirects infiltration to the MWDF perimeter and internal embankments where it infiltrates. Outside the MWDF embankments there should be relatively little change in infiltration quantities or patterns.

An evaluation by Ayres Associates (1984, 1985) indicates the proposed design will ensure the long-term integrity of the cover system. A water balance analysis performed as part of this same study indicated the cap



MWDF PERIMETER EMBANKMENT



MWDF INTERIOR EMBANKMENT

Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY TYPICAL RECLAMATION CAP EMBANKMENT DRAIN DETAIL

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 9/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO **FIGURE 9-17**		SHEET ___ OF ___	REVISION NO

design will maintain comparable overall ground water infiltration quantities within the MWDF compliance boundary area.

In their analysis, Ayres Associates (1984) assumed zero seepage through the proposed reclamation seal considering the essentially impervious nature of the synthetic membrane. However, for modeling study and analysis a final steady-state seepage rate of 0.066 inch per year, defined as Case I, has been assumed through the composite seal. This assumed rate is based on an order of magnitude reduction in seepage from a case where only the bentonite amended till top seal would be employed. The leakage rate for that condition was determined by Ayres Associates (1984) to be 0.66 inch per year.

For an average annual precipitation, overall infiltration into the cover system ranges from 4.74 to 4.99 inches per year depending upon whether or not the membrane is included in the analysis (Ayres Associates, 1984). The excess infiltrating water (that portion that does not seep through the seal) will travel laterally through the drain layer to infiltrate the MWDF perimeter and internal embankments.

Additional analysis (Ayres Associates, 1985) for the 41-114C facility produced similar results to the previous study. For the typical, slightly shorter reclamation cap slope, overall infiltration ranged from 4.68 to 4.78 inches per year depending on whether or not the membrane is included or not. Also, the leakage rate for the condition where only the bentonite amended till top seal is employed decreased to 0.61 inch per year.

For the proposed design (41-114C), the reclamation cap water balance for a normal year indicates that approximately 4.2 to 4.7 inches of precipitation per year will move laterally through the drain layer depending on whether or not the membrane is included (Ayres Associates, 1985). For other hydrological analysis this value has been assumed to be approximately 4.3 inches per year and the 0.066 and 0.66 inch per year seepage values initially chosen for long-term MWDF seepage analysis have been continued.

The purpose of the drain is to reduce infiltration through the seal and to transport water to the external and internal embankments of the MWDF. Grading of the reclamation cap (and drain layer) has been planned to approximately distribute this water as uniformly as possible around the MWDF. For the normal year, the 4.3 inches of infiltrating precipitation being carried into the drain layer will be distributed approximately uniformly around the 20,900-foot length of the MWDF pond embankment perimeters. On the average this equates to a water flow rate of 0.003 gallons per minute per foot of MWDF embankment. In the reclamation cap, the drain layer is designed to allow this water to infiltrate into the MWDF embankments. The infiltrating water will percolate through the embankment soils as it leaves the underdrain and recharge to ground water.

The analysis by Ayres Associates (1984) shows that for all but wettest years, all of the water moving laterally through the drain would infiltrate within the embankment area through the seepage zone as described above. Additional details for the water budget analysis work, including cover performance during wet and dry years, sensitivity studies, and overall water budget analyses within the compliance boundary area are included in the Ayres Associates' (1984, 1985) reports.

9.4.2 Preliminary Cost Estimates for Closure and Long-Term Care

The preliminary engineering cost estimates are based on the preliminary engineering design, staged closure, and equipment, materials and personnel required to complete the closure and long-term care (reclamation) activities. The estimated closure costs are listed in Table 9.8. All cost estimates were based on 1983 dollars and do not account for inflation or interest.

9.4.3 Long-Term Care

NR 182.17 specifies that the owner of an MWDF shall be responsible for the long-term care of the facility for 30 years after closure unless released after petition at 10 years. A more detailed description of the proposed reclamation and long-term care activities for this facility is provided in the Reclamation Plan prepared according to NR 132.08 of the Wisconsin Administrative Code. Activities planned and estimated costs for the long-term care period and as specified in the Reclamation Plan are outlined in Table 9.9.

TABLE 9.8

ESTIMATED CLOSURE COSTS[a]

TAILING POND TO BE CLOSED	CONSTRUCTION[b] PHASE	CLOSURE COVER TO REACH FINAL GRADES	COVER[c] LAYER	SEED, FERTILIZE, AND MULCH	TOTAL ESTIMATED COST
T1	2	$ 754,000	$3,203,000	$ 73,000	$4,030,000
T2	3	1,211,000	5,227,000	120,000	6,558,000
T3	4	692,000	3,441,000	85,000	4,218,000
T4	5	1,544,000	7,452,000	181,000	9,177,000

[a]Estimated costs are based on 1985 dollars and do not include contingency.

[b]See Table 9.2 for timing of planned construction phases and Tables 9.3 through 9.6 for estimated soil material volumes.

[c]The reclamation final cover consists of a 8 inch thick seal, a 40 mil polyethylene membrane, a 8 inch thick drain layer, a geotextile filter, and a 5 foot thick glacial till layer.

TABLE 9.9

LONG-TERM CARE ACTIVITIES AND ESTIMATED COSTS

LONG-TERM CARE ACTIVITY	DURATION OF ACTIVITY IN LONG-TERM CARE PERIOD[a] (YEARS)	ESTIMATED ANNUAL COST (1985 DOLLARS)
LAND SURFACE CARE		
Vegetation Maintenance	3	$ 54,000
Erosion Control, including Regrading and Stabilizing Reclamation Surfaces	3	27,000
Maintenance of Temporary Drainage Structures	3	5,000
INSPECTIONS		
MWDF Physical Conditions Monitoring (e.g., berm stability, settlement)	30	13,000
ENVIRONMENTAL MONITORING PROGRAM		
Ground Water Monitoring	30	35,000
Lysimeter and Moisture Sensing Monitoring	30	13,000
Surface Water Monitoring	30	5,000
Maintenance of Monitoring Systems	30	12,000
LEACHATE MANAGEMENT		
Pumping of Leachate to Water Treatment Plant	2	10,000
Leachate Quality Monitoring	2	6,000
Water Treatment	2	217,000
ADMINISTRATION	30	15,000
CONTINGENCY	30	15,000

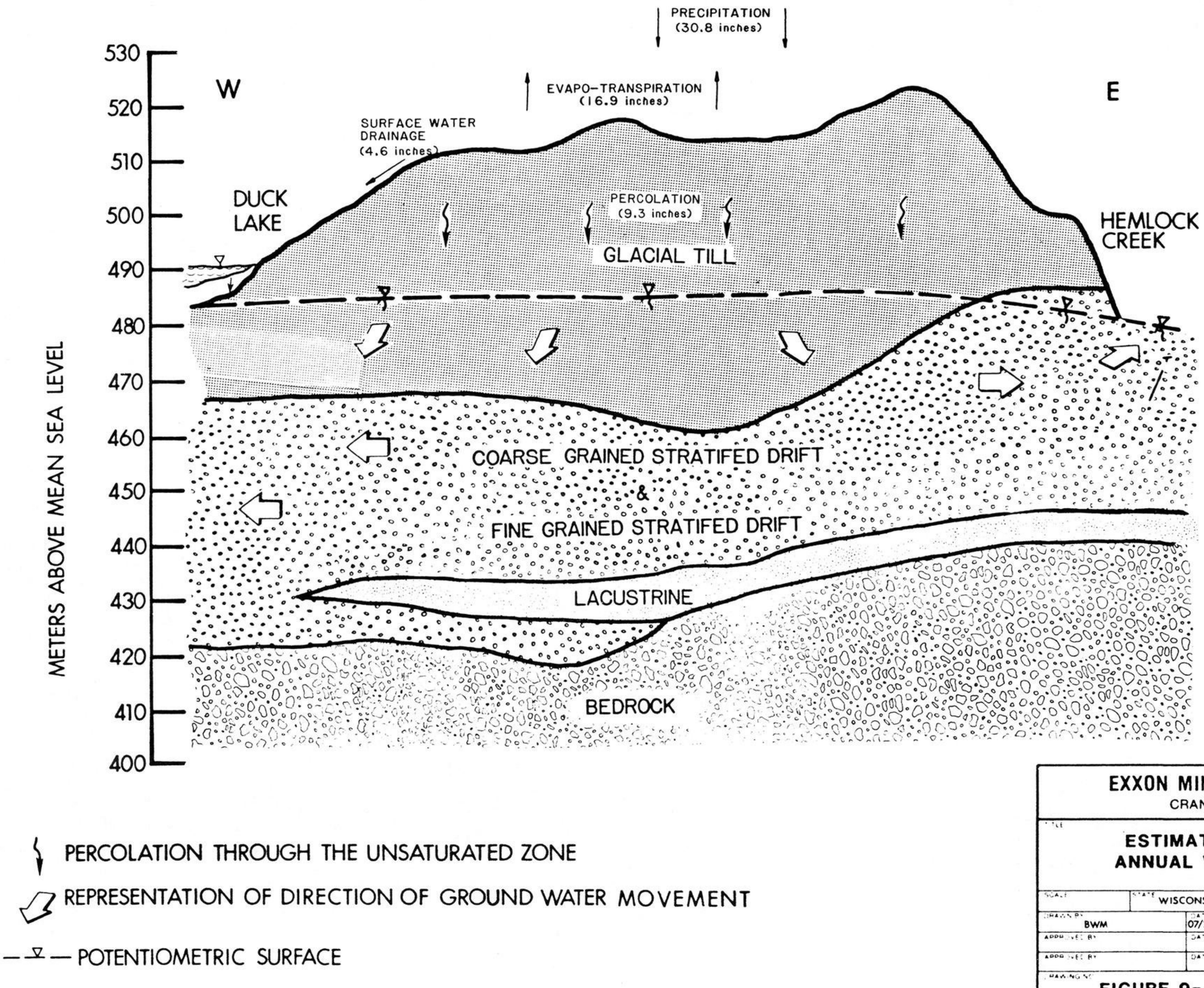
[a]Long-term care period begins after closure of Tailings Pond T4.

9.5 Water Budget

The water budget for the MWDF summarizes the distribution of water at the site area before, during, and after operation. The water budget analysis has been confined to average conditions because the water flow rates through the tailings, underdrain and filter layers and the liner are not sensitive to changes in climatological conditions. The volume of water in the ponds is controlled by the design and operation of the MWDF rather than the amount of precipitation on the facility. The hydrologic effects of extreme dry and wet conditions will be the same after reclamation as they are now.

The hydrologic studies for the MWDF reclamation cover (Ayres Associates, 1984, 1985) and overall performance of the MWDF (EIR Appendix 4.1A) included analyses of wet and dry conditions and additional detail is presented in those reports. The study by Ayres Associates indicates that regardless of the actual precipitation (within the range evaluated), the rate of seepage through the reclamation seal (for the case without the synthetic membrane-Case II) remained fairly constant. However, their work did indicate the excess cover water (that water moving in the drain layer to the MWDF pond perimeters) did vary according to the precipitation level. For the overall ground water modeling study an infiltration rate ranging from 6 to 11 inches per year was analyzed.

The average water budget for the site area before construction of the MWDF is displayed on Figure 9-18 and has been divided into four basic components: precipitation, evapotranspiration, surface water drainage (runoff), and percolation to ground water. The estimated annual precipitation (30.8 inches) is based on a 70-year average (1907-1977) for the regional study



EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE: ESTIMATED SITE AREA ANNUAL WATER BUDGET			
SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/26/82	CHECKED BY R P Hextall	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON D. E. Moe	DATE 1/12/85
DRAWING NO. FIGURE 9-18		SHEET ___ OF ___	REVISION NO. 0

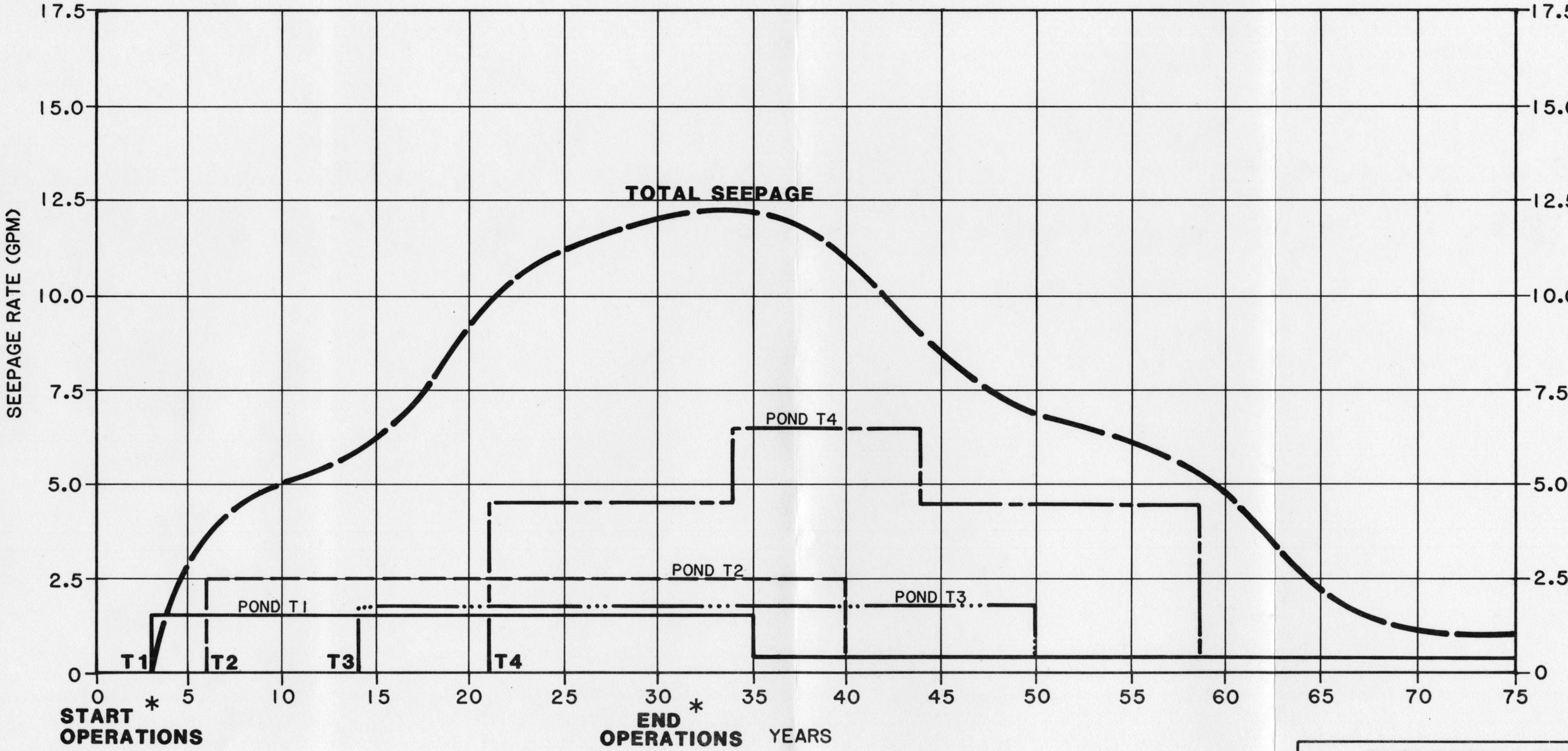
area. Evapotranspiration of approximately 16.9 inches is based on the northern Wolf River drainage basin average reported by the USGS for 1965-1979 D'Appolonia, 1982a). The basin average surface water drainage was 4.6 inches estimated from stream gage records for Swamp Creek in 1978-1980 (D'Appolonia, 1982a). With these annual basin averages, percolation to ground water can be calculated from the following formula:

Precipitation - (Evapotranspiration + Runoff) = Percolation

The calculation with this data yields an average annual percolation to the ground water table of 9.3 inches.

The results of other studies substantiate the 6 to 11 inch range of infiltration rates indicated above and used for analysis of the MWDF. The evaluation by Ayres Associates (1984) indicates recharge values near the low end of the range when upland areas are included; however, as more wetland areas or lakes with higher seepages are added into the analysis area, the average recharge rate increases. Also, the ground water modeling study by D'Appolonia (1985), when comparing model area ground water discharges to area prorated creek base flows, indicates a ground water recharge rate near the low end of the range selected for modeling purposes.

During construction and operation of the facility, surface water drainage patterns will be altered. As filling of the tailing ponds proceeds, there will be a reduction in percolation to ground water because seepage from the base of the ponds will be less than the existing infiltration in the site area. The estimated seepage projections for the ponds (including the assumed final steady-state seepage explained in Section 9.4) is presented in Figure 9-19 as the Case I seepage rate history. The seepage rate from each of the



MWDF SYSTEM 41-114C
RECLAMATION CAP INFILTRATION 0.066 inches/yr

EXXON MINERALS COMPANY
CRANDON PROJECT

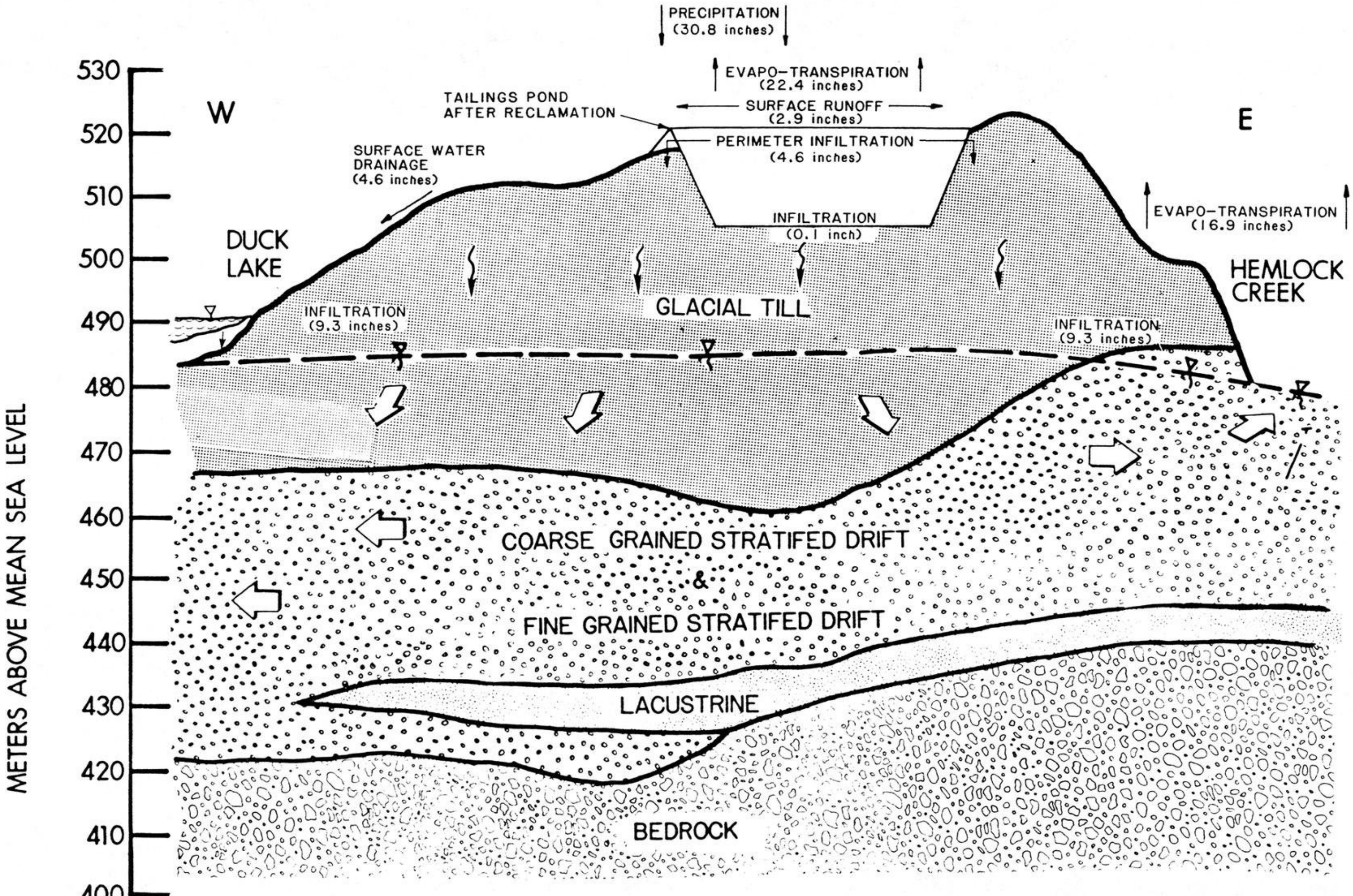
TITLE
CASE I
SEEPAGE RATE HISTORY

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 11/85	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11/85	
APPROVED BY	DATE	EXXON D.E. [illegible]		DATE 11/85	
DRAWING NO FIGURE 9-19			SHEET ___ OF ___		REVISION NO

ponds is plotted over time and a composite total rate for the facility is also shown. The seepages during operations are based on a Q = KiA relationship with $K = 1.6 \times 10^{-9}$ feet per second for the liner, i = 1.1, and A as the pond area. Based on the largest pond (T4) the gradient i is determined by the average depth of flow in the underdrain. For simplicity and to add conservatism to the ground water modeling work, the flows are approximated by the maximum seepage, constant flow blocks. Also, for additional conservatism, the seepage was determined as if the entire pond was filled at the start of its operation as opposed to building up slowly over its whole life. The seepage rate from each pond is indicated for two major phases: during operation, and after the pond is closed and the underdrain pumping has stopped. During operation, when the underdrain collection system is being pumped, the seepage rate from the base of the ponds is very low. For example, the estimated seepage rate for pond T1 at year 10 is approximately 3 gallons per minute or 0.7 inch per year over the area of Pond T1. This flow rate is substantially less than the 9.3 inches per year percolation rate average before facility construction. After the tailing ponds are closed, pumping will continue as required until 2 years after closure of tailing pond T4.

For the Case I seepage rate history, the maximum seepage rate for the entire facility, which will occur approximately 35 years after beginning Project construction, is estimated to be less than 20 gallons per minute and then decrease to an equilibrium condition at steady-state of less than 2 gallons per minute or 0.066 inch per year over the MWDF area after approximately 75 years from start of Project construction. This equilibrium condition represents the long-term tailing ponds seepage rate (assumed for modeling purposes) where infiltration through the seal of the facility is equal to seepage from the base. For the Case I seepage rate history, for the average year, total cover infiltration is approximately 4.7 inches per year. The excess of this water, over the 0.066 inches per year, assumed seeping through the seal travels in the drain layer to the tailing pond perimeters where it infiltrates into the MWDF embankments. The estimated unit seepage rates along the total 20,900-foot perimeter length of the MWDF ponds are based on the reclamation cover watershed areas as shown in Plan Sheet 17 and the perimeter lengths of the watersheds. For the overall MWDF area, including the reduced seepage area in the middle of the tailings ponds and the increased seepage areas along the facility embankments, the hydrologic studies by Ayres Associates indicate the water budgets for areas outside the MWDF will not be noticeably changed by the MWDF. The final seepage rate condition will approximate existing infiltration in the site area. Figure 9-20 indicates the typical water budget for the Case I equilibrium conditions for a tailings pond after reclamation.

As a sensitivity analysis of the cover seepage value, water balance and modeling work was completed for the condition where the synthetic membrane was omitted from the reclamation cap composite seal. This water balance, noted as Case II seepage rate history, is basically unchanged through the operating life of the tailing ponds, but after reclamation ultimate steady state seepages are based on unit area infiltration and seepage rates equal to 0.66 inches per year (Ayres Associates, 1984). The time history seepage curve for this condition is shown on Figure 9-21.



PERCOLATION THROUGH THE UNSATURATED ZONE

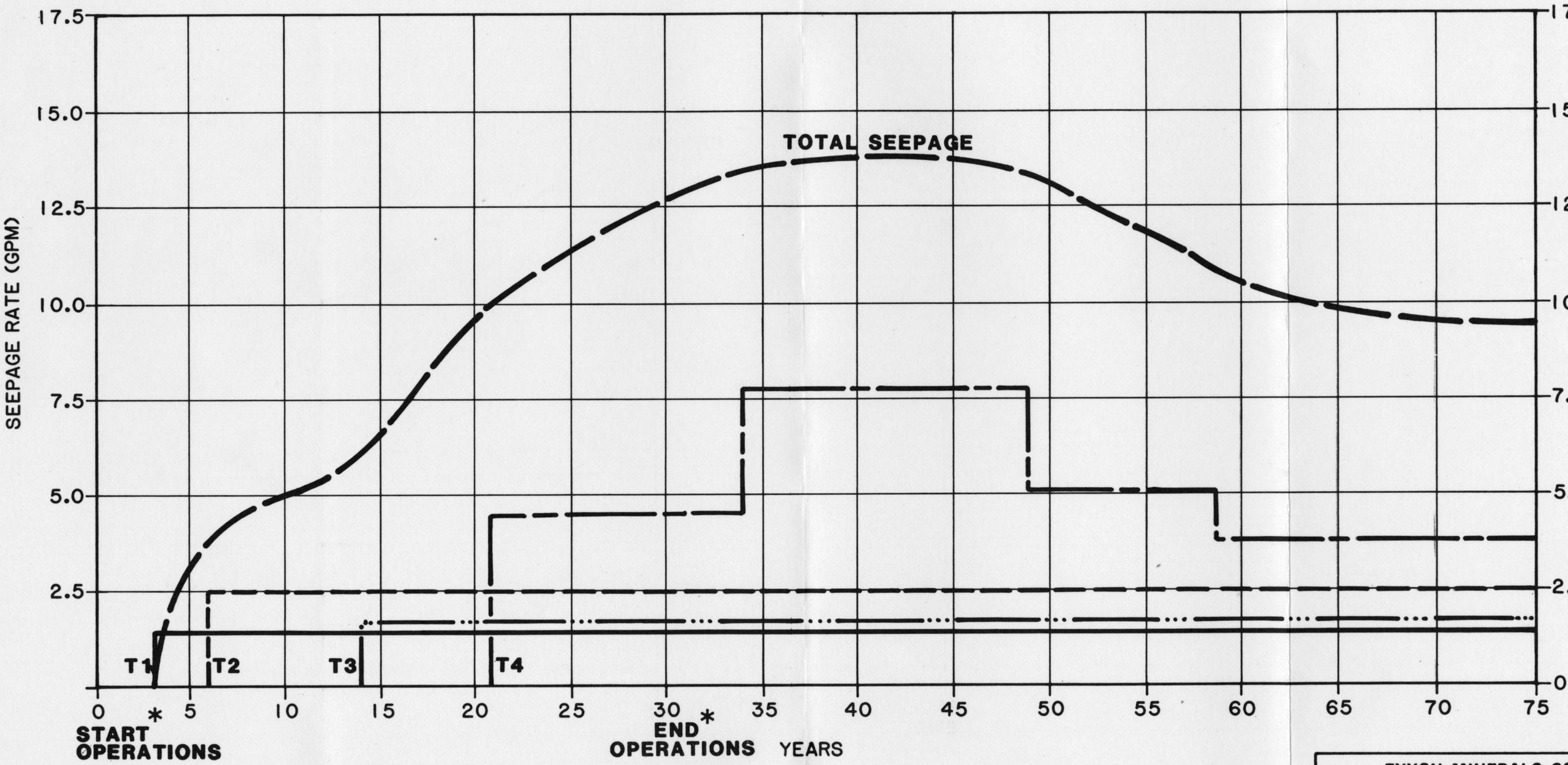
REPRESENTATION OF DIRECTION OF GROUND WATER MOVEMENT

POTENTIOMETRIC SURFACE

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
ESTIMATED MWDF AREA ANNUAL WATER BUDGET AFTER RECLAMATION

SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/26/82	CHECKED BY R P Herbst	DATE 12-82
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12-82
APPROVED BY	DATE		
DRAWING NO. **FIGURE 9-20**		SHEET OF	REVISION NO. 0



MWDF SYSTEM 41-114C
RECLAMATION CAP INFILTRATION 0.66 inches/yr
(ASSUMING NO CREDIT FOR SYNTHETIC MEMBRANE)

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE CASE II SEEPAGE RATE HISTORY			
SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/85
APPROVED BY	DATE	EXXON D. E. Mc	DATE 11/85
DRAWING NO FIGURE 9-21		SHEET ___ OF ___	REVISION NO.

For both the Case I water balance MWDF seepage condition (Figure 9-20) and the Case II conditions the following procedures have been used in developing the seepage histories:

1) The expected operating time periods (based on the full MWDF capacity) for each pond are:

   T1 - years 3-6
   T2 - years 6-14
   T3 - years 14-21
   T4 - years 21-32

2) All underdrain pumps are operated until year 34 (one year prior to completion of reclamation following the full capacity MWDF related schedule).

3) From the point a pond is put in operation until the underdrain pumps are shut down the pond seepage is constant. Seepage is computed by $Q = KiA$ with $K = 1.6 \times 10^{-9}$ feet per second, $i = 1.1$ (reflecting the fact that the underdrain essentially eliminates head on the liner), and A = total pond bottom and slope area within the crest.

4) Final pond steady-state seepage is equivalent to the reclamation cap infiltration rate of either 0.066 inches/year for the Case I rate or 0.66 inches/year for the Case II rate again applied over the inside crest area of each pond.

5) An additional quantity of seepage is computed for the period of time from shut down of the underdrain pumps until an approximate steady-state rate is reached. This seepage is computed on a month-by-month water balance basis taking into account all waters entering and leaving the pond.

6) The seepage from the tailings is sensitive to the drainable porosity of the tailings. Exxon's latest studies indicate a value of 10 percent is probably conservatively high. Porosity of the tailings is estimated at 45 percent.

7) For simplicity and conservatism in modeling, these flows are simplified to the constant flow blocks superimposed on Figures 9-19 and 9-21.

8) The reclamation cap drain water carried to the tailings ponds perimeters will begin on a pond-by-pond basis 2 years after the end of operations for each pond.

10.0 ENVIRONMENTAL EVALUATION OF THE FACILITY

This chapter evaluates the proposed MWDF design in relation to its environmental compatibility with NR 132 and NR 182 location and siting criteria for wetland, ground water, and surface water protection standards. Potential effects are summarized here and are discussed in more detail in Chapter 4 of the Environmental Impact Report (EIR), since the environmental consequences of the MWDF must be considered in conjunction with the overall Crandon Project development.

10.1 Wetland Criteria

The MWDF siting process is summarized in Chapter 11. All of the factors required by NR 132.06(4) have been addressed, including environmental, technical, economic, recreational, and aesthetic. One major conclusion of the siting process is that it is not technically and economically feasible to develop a viable site for the MWDF of the size needed for the Crandon Project in the regional study area that does not affect some wetlands.

The primary objective of the wetland assessment was to map the study area wetlands, evaluate and compare their functional values, and relate these data to Crandon Project siting activities (NAI and IEP, 1982). Each wetland of the study area was identified and mapped. Semi-quantitative numerical evaluation models for wetland functions were developed utilizing an inventory list of resource elements (NAI and IEP, 1982). Field studies were also conducted to identify, inventory, and map 158 wetlands that were larger than 0.25 acre. Data from the inventory list were entered into each numerical model and a score was generated for each wetland function; then these individual model scores were totaled for each wetland. In addition, qualitative descriptions were also provided for the wetlands.

The NAI and IEP (1982) report summarizes the wetland evaluations which considered all wetland functions and values as specified in the Code:

1) Biological functions;

2) Watershed functions:

   a. hydrologic support functions;
   b. ground water function;
   c. storm and flood water storage;
   d. shoreline protection;
   e. other watershed functions;

3) Recreational, cultural, and economic value;

4) Scarcity of wetland type;

5) Aquatic study areas, sanctuaries, and refuges; and

6) The ecosystem in a regional context.

Numerical model results were related to proposed project activities through a detailed analysis of data for 46 wetlands which were of special interest because of their relationship to these activities. Model results were also evaluated in a regional context by determining the regional scarcity of each wetland type. To provide supporting data for the assessment of wetland functions, plant and animal (wildlife) communities were quantitatively sampled in each representative wetland type.

Detailed wetland mapping for the study area and consideration of many design alternatives have shown that it is not possible to develop an MWDF of the size needed that does not affect some wetlands. The wetland assessment functional models demonstrated that the majority of wetlands in the study area, which have high model values, were large wetlands. They were either part of riparian systems (i.e., associated with a stream or open water), were associated with glacial sand and gravel deposits, or had large water budgets

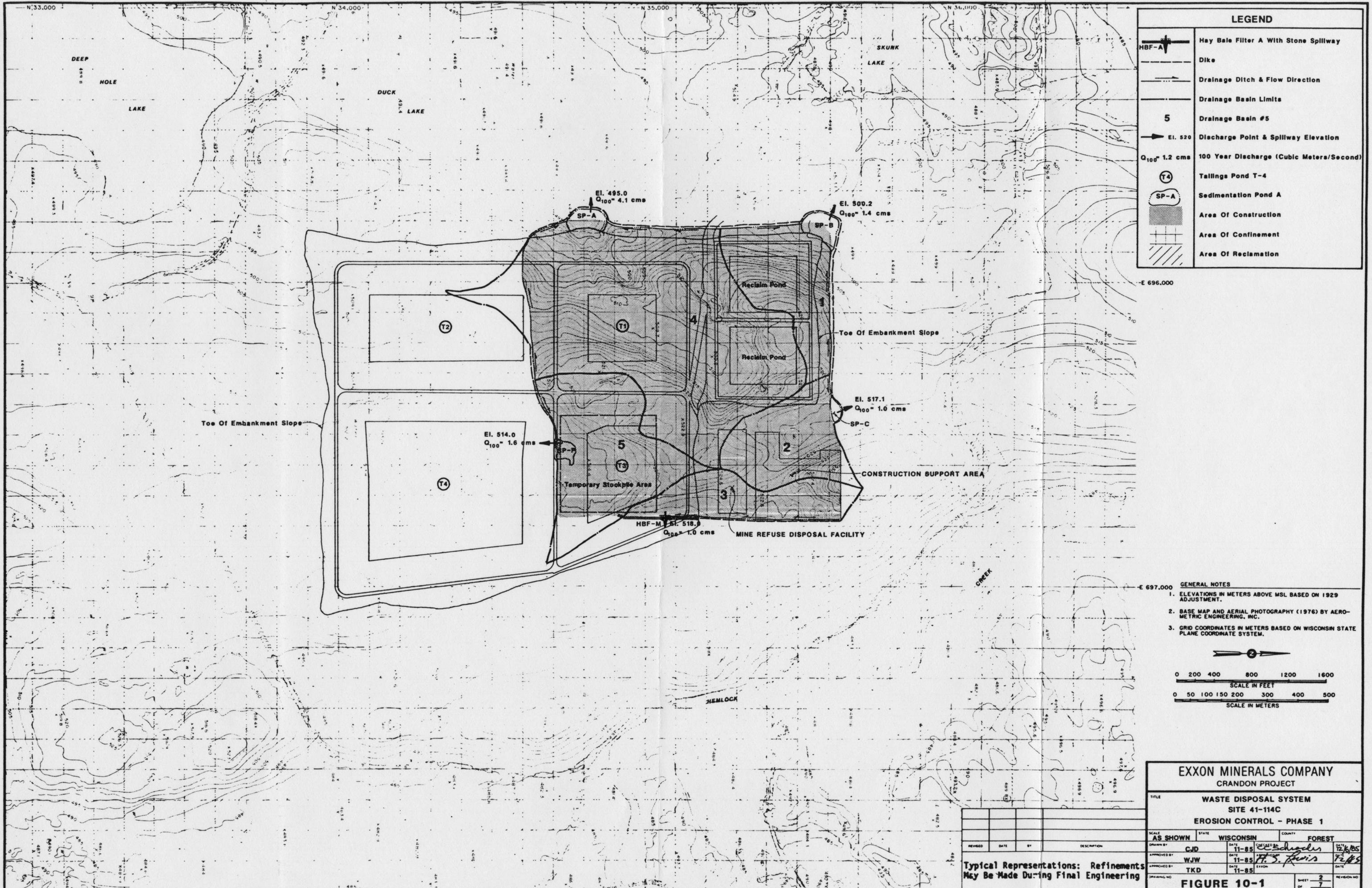
(NAI and IEP, 1982). Since these high value wetlands were associated with the lakes and streams in the study area, the MWDF was designed to maximize separation from these areas to disturb only the smaller upland wetlands with lower functional values.

These evaluations indicated that facility layout 41-114C is expected to have the least overall impact on wetlands within Area 41. This includes wetlands within and outside the boundary of the facility.

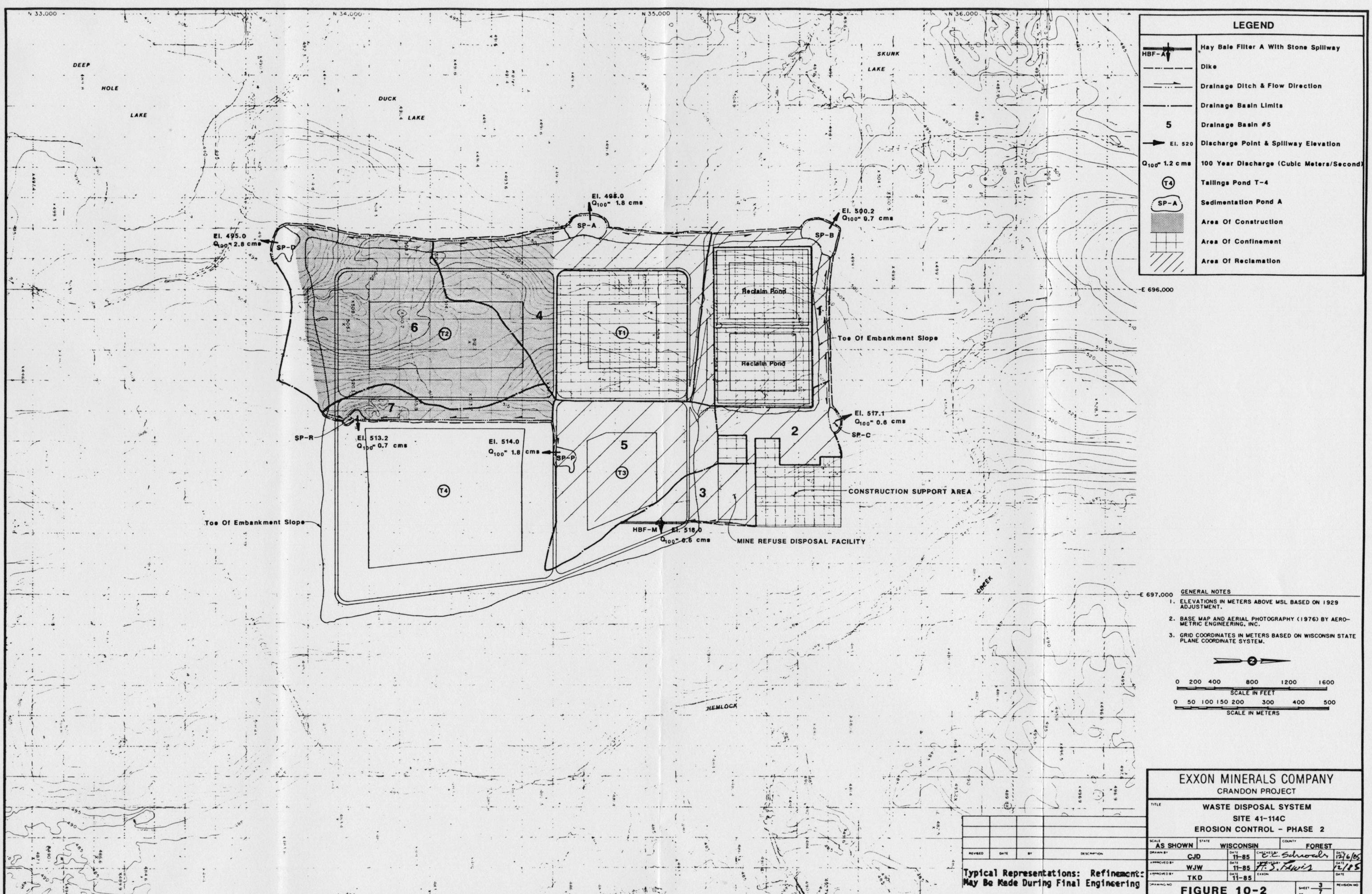
In the engineering design of the proposed MWDF, special attention was directed to control of surface water drainage to maintain the biological and watershed functions of wetlands near the facility. This is critical to ensure that the water presently flowing into wetlands near the facility is not greatly changed in quality and quantity. Surface water drainage from precipitation around the facility will be controlled to maintain water flow to these perimeter wetlands (Figures 10-1 through 10-6). Also, erosion controls will be implemented to minimize the transport of suspended solids into these wetlands.

Figures 10-1 through 10-6 depict the surface water drainage controls planned throughout the Project operating period that will be used as each construction phase of the overall MWDF is developed. These controls will remain in place until the vegetation is established for each phase and the soils have stabilized. After reclamation is complete and the need for the specialized erosion control features no longer exists, they will be removed and any final reclamation work associated with their removal will be completed.

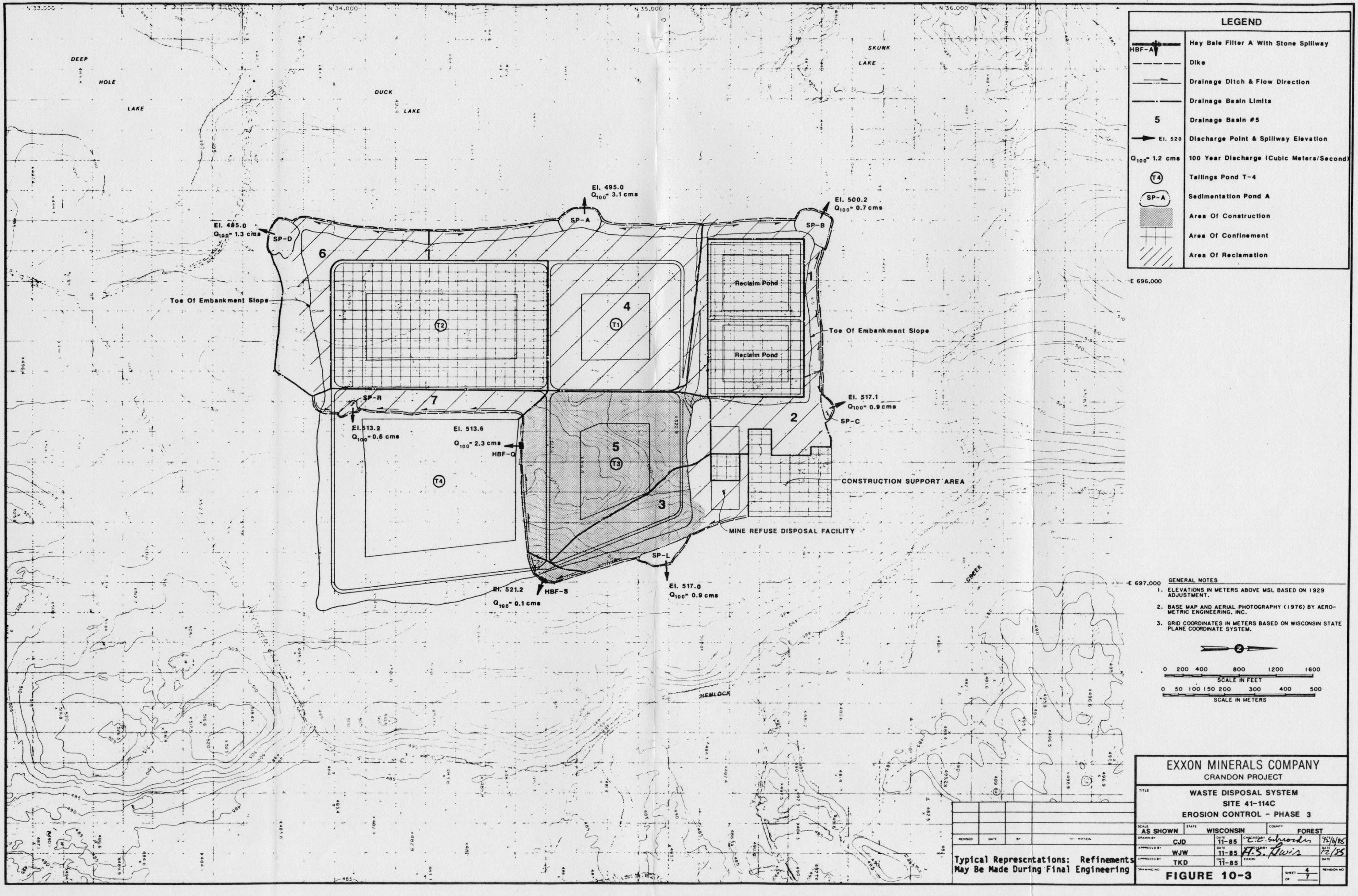
The wetlands south of the proposed facility through which water drains into Deep Hole Lake have received special attention (Figure 10-4). The proposed facility will remove approximately 30 acres of wetlands in the upper

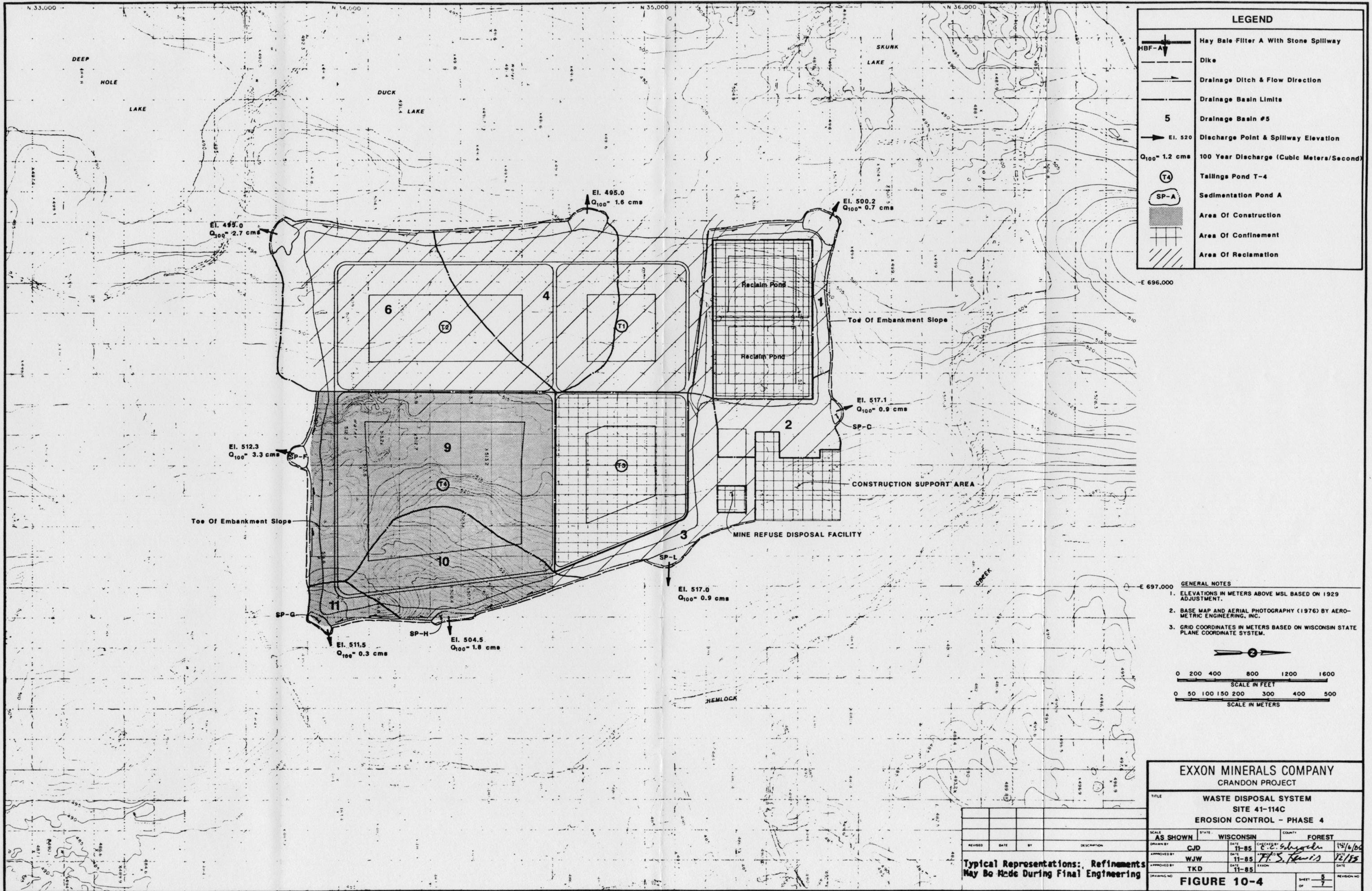


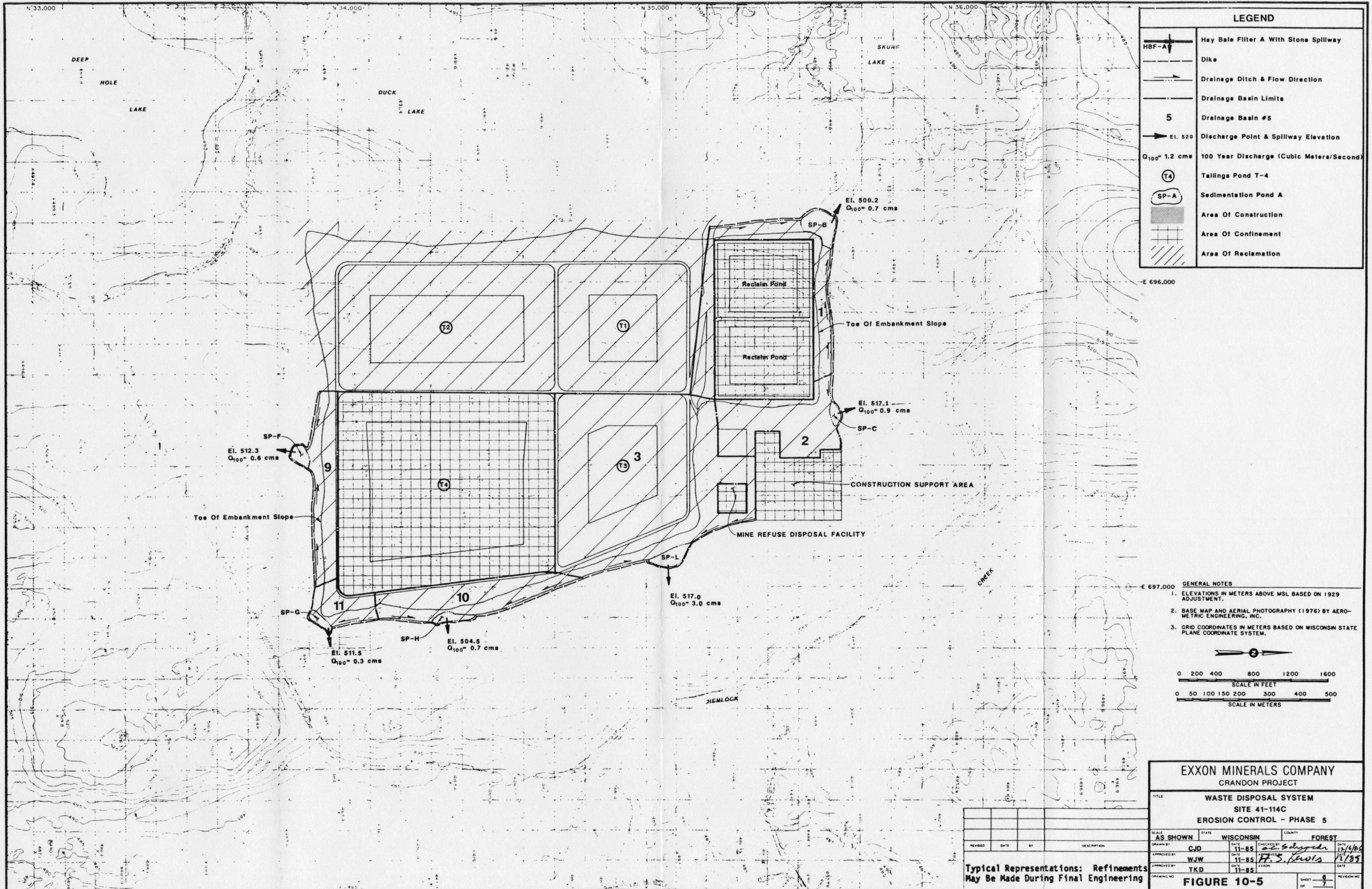
DEEP
HOLE
LAKE
DUCK
LAKE
SKUNK
LAKE
HEMLOCK
CREEK
N 33,000
N 34,000
N 35,000
N 36,000
E 696,000
E 697,000
El. 495.0
Q_{100} = 4.1 cms
SP-A
El. 500.2
Q_{100} = 1.4 cms
SP-B
Reclaim Pond
Reclaim Pond
Toe Of Embankment Slope
El. 517.1
Q_{100} = 1.0 cms
SP-C
Toe Of Embankment Slope
El. 514.0
Q_{100} = 1.6 cms
SP-F
Temporary Stockpile Area
CONSTRUCTION SUPPORT AREA
HBF-M El. 518.0
Q_{100} = 1.0 cms
MINE REFUSE DISPOSAL FACILITY
T1
T2
T3
T4
1
2
3
4
5
LEGEND
HBF-A Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5 Drainage Basin #5
El. 520 Discharge Point & Spillway Elevation
Q_{100} = 1.2 cms 100 Year Discharge (Cubic Meters/Second)
T4 Tailings Pond T-4
SP-A Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
REVISED DATE BY DESCRIPTION
Typical Representations: Refinements May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 1
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD
DATE 11-85
APPROVED BY WJW
DATE 11-85
APPROVED BY TKD
DATE 11-85
DRAWING NO
FIGURE 10-1
SHEET 2 OF 7
REVISION NO



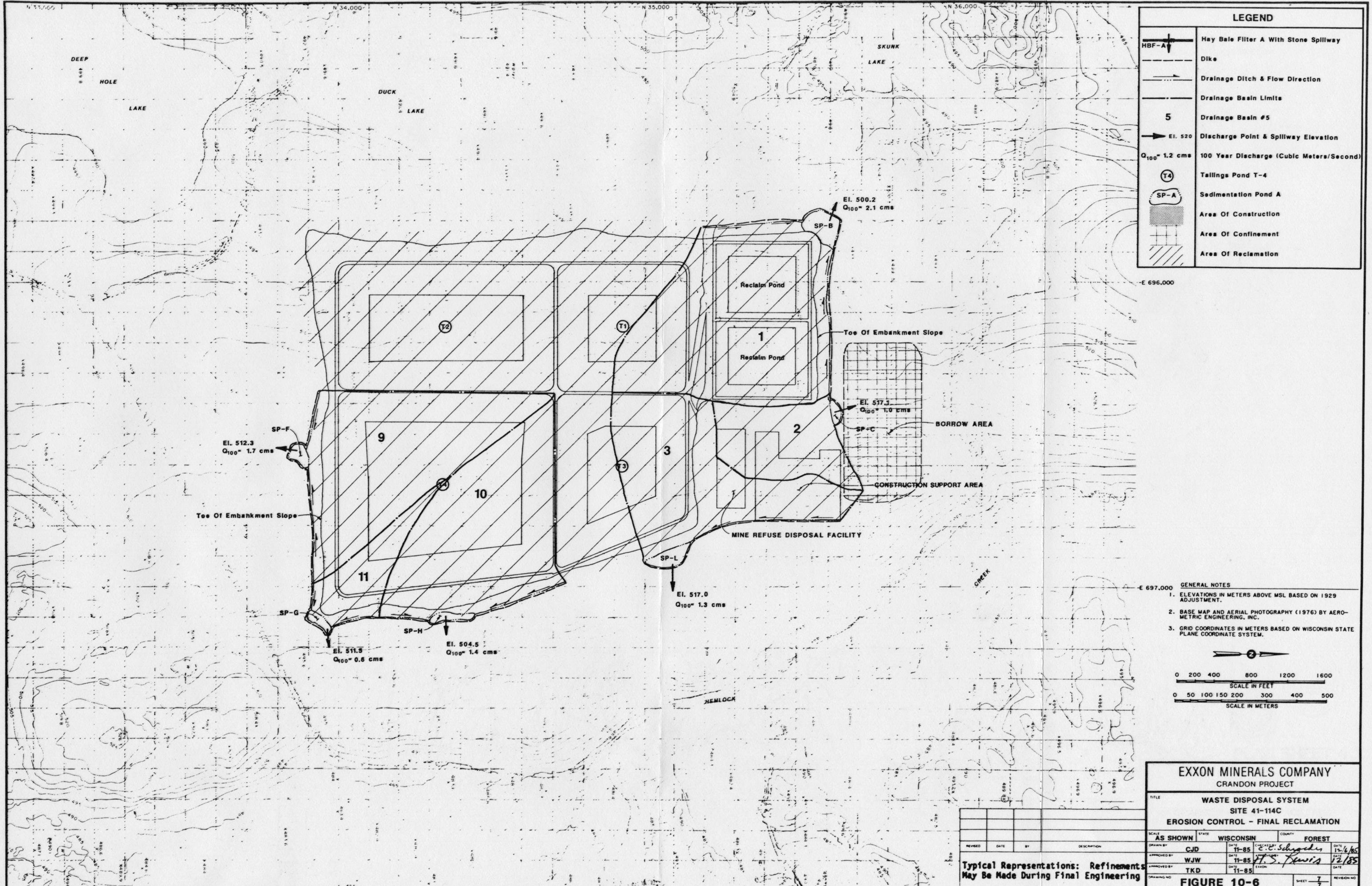
LEGEND
HBF-A Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5 Drainage Basin #5
El. 520 Discharge Point & Spillway Elevation
Q_{100}= 1.2 cms 100 Year Discharge (Cubic Meters/Second)
T4 Tailings Pond T-4
SP-A Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
DEEP HOLE LAKE
DUCK LAKE
SKUNK LAKE
CREEK
HEMLOCK
N 33,000
N 34,000
N 35,000
N 36,000
E 696,000
E 697,000
El. 495.0 Q_{100}= 1.8 cms
El. 500.2 Q_{100}= 9.7 cms
El. 495.0 Q_{100}= 2.8 cms
El. 517.1 Q_{100}= 0.6 cms
El. 513.2 Q_{100}= 0.7 cms
El. 514.0 Q_{100}= 1.8 cms
El. 518.0 Q_{100}= 0.6 cms
SP-A
SP-B
SP-C
SP-D
SP-P
SP-R
HBF-M
Reclaim Pond
Reclaim Pond
Toe Of Embankment Slope
Toe Of Embankment Slope
CONSTRUCTION SUPPORT AREA
MINE REFUSE DISPOSAL FACILITY
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
REVISED DATE BY DESCRIPTION
Typical Representations: Refinement May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 2
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD DATE 11-85
APPROVED BY WJW DATE 11-85
APPROVED BY TKD DATE 11-85
FIGURE 10-2
SHEET 3 OF 7
DESIGN PRODUCTS CO.


LEGEND
HBF-A Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5 Drainage Basin #5
El. 520 Discharge Point & Spillway Elevation
Q_{100} = 1.2 cms 100 Year Discharge (Cubic Meters/Second)
T4 Tailings Pond T-4
SP-A Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
DEEP HOLE LAKE
DUCK LAKE
SKUNK LAKE
El. 495.0 Q_{100} = 3.1 cms
El. 500.2 Q_{100} = 0.7 cms
El. 495.0 Q_{100} = 1.3 cms
SP-D
SP-A
SP-B
Toe Of Embankment Slope
Reclaim Pond
Reclaim Pond
Toe Of Embankment Slope
T2
T1
T3
T4
SP-R
El. 517.1 Q_{100} = 0.9 cms
SP-C
El. 513.2 Q_{100} = 0.5 cms
El. 513.6 Q_{100} = 2.3 cms
HBF-Q
CONSTRUCTION SUPPORT AREA
MINE REFUSE DISPOSAL FACILITY
SP-L
El. 521.2 Q_{100} = 0.1 cms
HBF-S
El. 517.0 Q_{100} = 0.9 cms
CREEK
HEMLOCK
E 696,000
E 697,000
N 33,000
N 34,000
N 35,000
N 36,000
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
Typical Representations: Refinements May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 3
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD DATE 11-85
APPROVED BY WJW DATE 11-85
APPROVED BY TKD DATE 11-85
FIGURE 10-3
SHEET 4 OF 7


LEGEND
HBF-A Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5 Drainage Basin #5
El. 520 Discharge Point & Spillway Elevation
Q100 = 1.2 cms 100 Year Discharge (Cubic Meters/Second)
T4 Tailings Pond T-4
SP-A Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
DEEP HOLE LAKE
DUCK LAKE
SKUNK LAKE
HEMLOCK
CREEK
N 33,000
N 34,000
N 35,000
N 36,000
E 696,000
E 697,000
El. 495.0 Q100 = 1.6 cms
El. 495.0 Q100 = 2.7 cms
El. 500.2 Q100 = 0.7 cms
El. 517.1 Q100 = 0.9 cms
El. 512.3 Q100 = 3.3 cms
El. 517.0 Q100 = 0.9 cms
El. 511.5 Q100 = 0.3 cms
El. 504.5 Q100 = 1.8 cms
SP-C
SP-F
SP-G
SP-H
SP-L
Reclaim Pond
Reclaim Pond
Toe Of Embankment Slope
Toe Of Embankment Slope
CONSTRUCTION SUPPORT AREA
MINE REFUSE DISPOSAL FACILITY
T1
T2
T3
T4
1
2
3
4
6
9
10
11
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
Typical Representations: Refinements May Be Made During Final Engineering
REVISED DATE BY DESCRIPTION
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 4
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD DATE 11-85
CHECKED BY C.C. Schroeder DATE 12/6/85
APPROVED BY WJW DATE 11-85
APPROVED BY F.S. Lewis DATE 12/85
APPROVED BY TKD DATE 11-85
EXXON
DRAWING NO FIGURE 10-4
SHEET 5 OF 7
REVISION NO
DESIGN PRODUCTS CO.



N 33,000
N 34,000
N 35,000
N 36,000
DEEP
HOLE
LAKE
DUCK
LAKE
SKUNK
LAKE
HEMLOCK
CREEK
E 696,000
E 697,000
LEGEND
HBF-A
Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5
Drainage Basin #5
El. 520
Discharge Point & Spillway Elevation
Q100= 1.2 cms
100 Year Discharge (Cubic Meters/Second)
T4
Tailings Pond T-4
SP-A
Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
El. 500.2
Q100= 0.7 cms
SP-B
Reclaim Pond
Reclaim Pond
T2
T1
T3
T4
1
2
3
9
10
11
Toe Of Embankment Slope
El. 517.1
Q100= 0.9 cms
SP-C
CONSTRUCTION SUPPORT AREA
MINE REFUSE DISPOSAL FACILITY
SP-F
El. 512.3
Q100= 0.6 cms
Toe Of Embankment Slope
SP-L
El. 517.0
Q100= 3.0 cms
SP-G
El. 511.5
Q100= 0.3 cms
SP-H
El. 504.5
Q100= 0.7 cms
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
REVISED
DATE
BY
DESCRIPTION
Typical Representations: Refinements May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 5
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD
DATE 11-85
CHECKED BY a.c. Schroeder
DATE 12/6/85
APPROVED BY WJW
DATE 11-85
APPROVED BY H. S. Lewis
DATE 12/85
APPROVED BY TKD
DATE 11-85
EXXON
DATE
DRAWING NO
FIGURE 10-5
SHEET 6 OF 7
REVISION NO

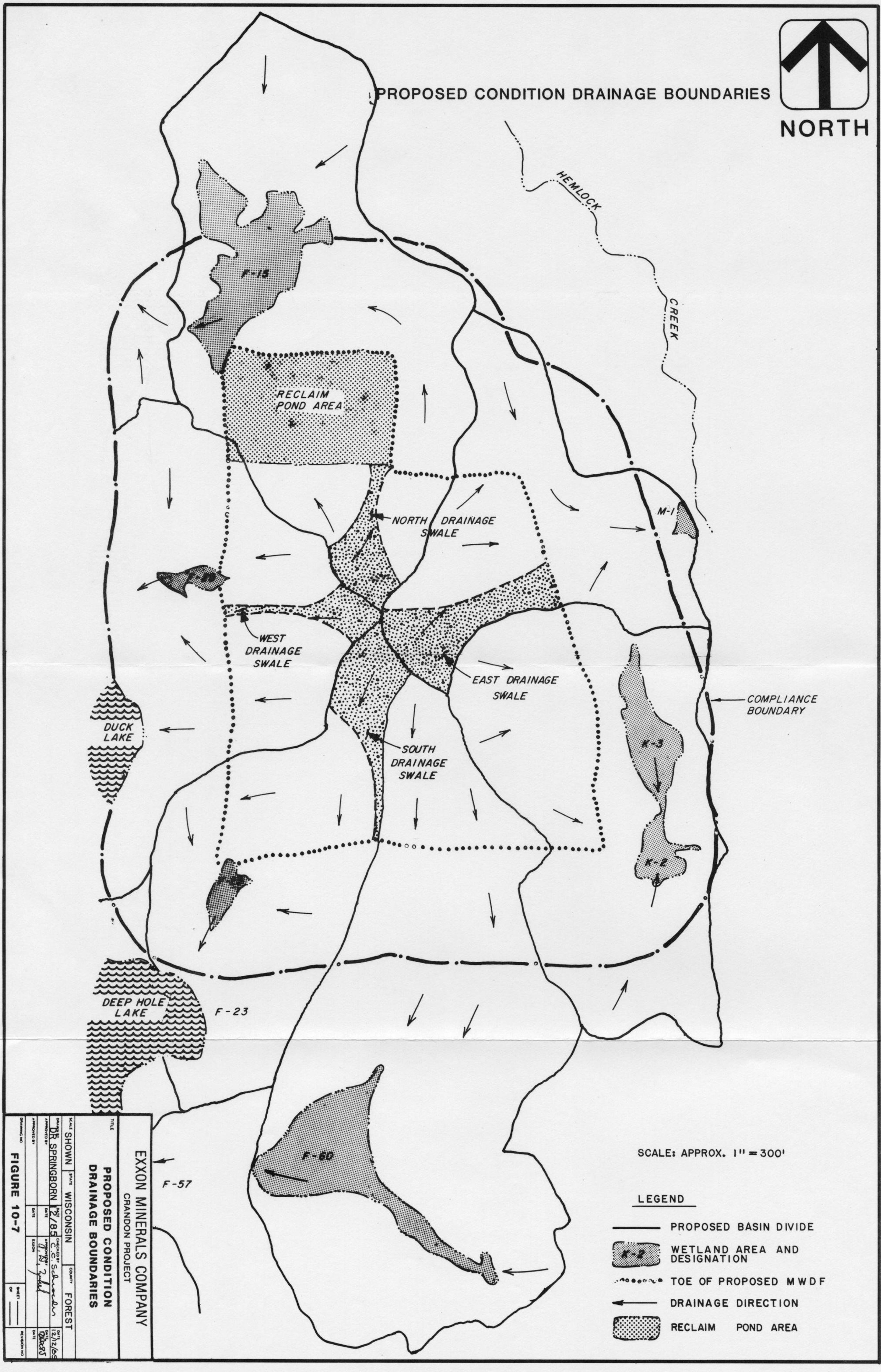

LEGEND
HBF-A
Hay Bale Filter A With Stone Spillway
Dike
Drainage Ditch & Flow Direction
Drainage Basin Limits
5
Drainage Basin #5
El. 520
Discharge Point & Spillway Elevation
Q100 = 1.2 cms
100 Year Discharge (Cubic Meters/Second)
T4
Tailings Pond T-4
SP-A
Sedimentation Pond A
Area Of Construction
Area Of Confinement
Area Of Reclamation
DEEP HOLE LAKE
DUCK LAKE
SKUNK LAKE
HEMLOCK
CREEK
N 34,000
N 35,000
N 36,000
E 696,000
E 697,000
El. 500.2
Q100 = 2.1 cms
SP-B
Reclaim Pond
1
Reclaim Pond
T2
T1
Toe Of Embankment Slope
El. 517.1
Q100 = 1.0 cms
SP-C
BORROW AREA
2
3
9
10
11
T3
T4
SP-F
El. 512.3
Q100 = 1.7 cms
CONSTRUCTION SUPPORT AREA
Toe Of Embankment Slope
MINE REFUSE DISPOSAL FACILITY
SP-L
El. 517.0
Q100 = 1.3 cms
SP-G
SP-H
El. 511.5
Q100 = 0.6 cms
El. 504.5
Q100 = 1.4 cms
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
REVISED DATE BY DESCRIPTION
Typical Representations: Refinements May Be Made During Final Engineering
EXXON MINERALS COMPANY
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - FINAL RECLAMATION
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CJD DATE 11-85
APPROVED BY WJW DATE 11-85
APPROVED BY TKD DATE 11-85
FIGURE 10-6

portions of this larger wetland system with water flow to Deep Hole Lake (see Figure 5-3). However, the large wetland in the lower portion of this wetland system will be preserved since surface water drainage will be maintained to it. Sedimentation and water flow rates will be controlled to duplicate, as much as possible, the water quantity and quality currently entering this lower portion of the wetland system.

Other facility perimeter wetland areas that have received special attention regarding proper control of surface water runoff from precipitation include the Duck Lake wetland area directly west and the Skunk Lake wetland area to the northwest. Surface water runoff control will be provided for these two wetland areas to maintain conditions similar to those that currently exist.

Figure 10-7 depicts the final watershed configuration of the MWDF area after all final grading and reclamation work are complete (Ayres Associates, 1985). Comparing this reclaimed watershed configuration to the currently existing site watershed configuration (Figure 5-6) shows the changes that will ultimately occur from existing to reclaimed conditions. The watershed feeding wetland F60 (a part of the Deep Hole Lake watershed) will experience the greatest area reduction of any of the wetlands. However, detailed water balance analysis for the before and after conditions for the wetland indicates changes to the hydrologic balance are minimal. Overall, the Ayres Associates' study indicates that with the design of the MWDF reclamation cover the hydrologic conditions within the MWDF compliance boundary and the surrounding wetlands areas should not be significantly altered by the MWDF.

The "regional scarcity" of the potentially affected wetlands was also evaluated by considering the relative frequency of the various wetland types as a percentage of those found in the region. Approximately 20 percent



PROPOSED CONDITION DRAINAGE BOUNDARIES
NORTH
HEMLOCK
CREEK
F-15
RECLAIM POND AREA
NORTH DRAINAGE SWALE
M-1
WEST DRAINAGE SWALE
EAST DRAINAGE SWALE
DUCK LAKE
COMPLIANCE BOUNDARY
K-3
SOUTH DRAINAGE SWALE
K-2
DEEP HOLE LAKE
F-23
F-6D
F-57
SCALE: APPROX. 1" = 300'
LEGEND
PROPOSED BASIN DIVIDE
K-2
WETLAND AREA AND DESIGNATION
TOE OF PROPOSED MWDF
DRAINAGE DIRECTION
RECLAIM POND AREA
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
PROPOSED CONDITION
DRAINAGE BOUNDARIES
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 12/85
CHECKED BY C.C. Schroeder
DATE 12/12/85
APPROVED BY
DATE
APPROVED BY
DATE
EXXON
DATE
DRAWING NO
FIGURE 10-7
SHEET
OF
REVISION NO

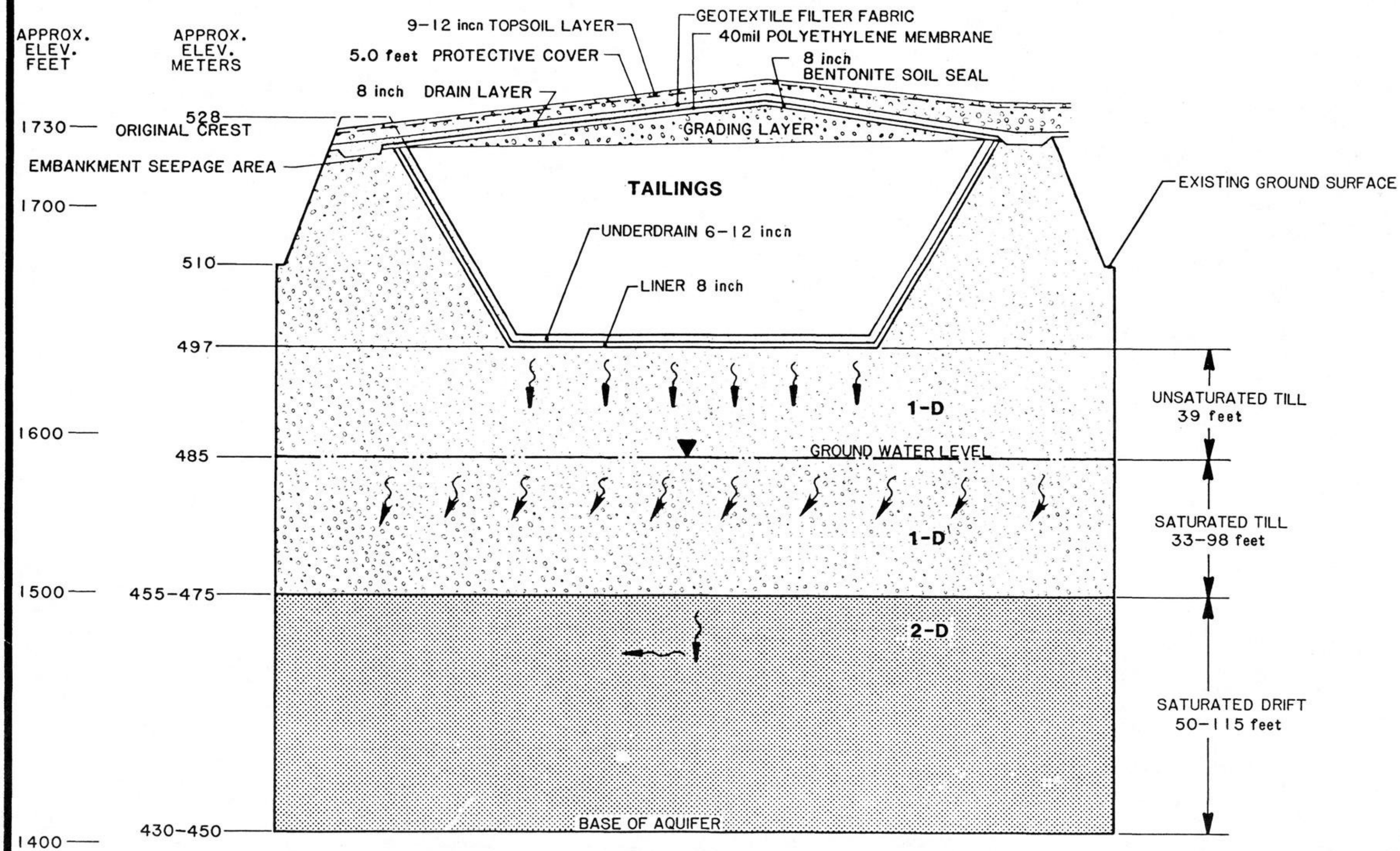
(60,700 acres) of the total land area of the upper Wolf River drainage basin (301,900 acres) consists of wetlands. The wetlands which will be affected by the MWDF comprise less than 0.1 percent of the wetlands in this drainage basin.

The detailed wetland mapping and assessment for the study area has been used in design evaluations of Layout 41-114C. The layout and design of 41-114C will: minimize disturbance to wetlands and avoid high value wetlands; protect surrounding wetlands by routing surface water to them; protect surrounding wetlands by using erosion control measures to limit suspended solids transport; and minimize potential ground water quality effects by choosing a site that balances wetland protection with ground water protection.

10.2 Ground Water Criteria

Ground water protection is provided by the proposed MWDF location and the facility design. The tailing ponds will have a liner and an underdrain system to reduce seepage. The underdrain system allows much less seepage to percolate to the ground water table than alternatives with or without liners. Long-term protection for the facility is provided at reclamation by a low permeability composite seal (bentonite amended soil and synthetic membrane) which practically eliminates infiltration and diffusion of oxygen into the tailings.

The NR 182.075(1) ground water quality criteria states "An important element of groundwater protection is the attenuation capacity and permeability of the soil material between the source of a potential pollutant and underlying aquifers." The location selected for the proposed MWDF optimizes the benefits of the attenuative capacity and low permeability of the soils of this area (Figure 10-8). The upland location of the facility places the



LEGEND

1-D, 2-D MODELING DIMENSIONS

DIRECTION OF WATER MOVEMENT

EXXON MINERALS COMPANY CRANDON PROJECT				
TITLE **GENERALIZED VERTICAL CROSS SECTION OF TAILING POND & UNDERLYING SOIL**				
SCALE	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY D.R.SPRINGBORN	DATE 10/82	CHECKED BY R.P. Harbach	DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12-82	
APPROVED BY	DATE			
DRAWING NO **FIGURE 10-8**			SHEET OF	2

lowest portion of the bottom of the tailing ponds approximately 40 feet above the ground water table to enhance soil attenuation of any seepage. The proposed MWDF location also provides the advantages of long transport times and greater total attenuative capacity between the facility and ground water discharge areas.

A laboratory program and ground water quality studies were performed to determine the extent of additional ground water protection provided by soil attenuation (D'Appolonia, 1982b). Attenuation studies with the soils from the proposed MWDF location integrated the results of the waste characterization and liner investigations. Data from the waste characterization studies indicate sufficient buffering capacity within the tailing to greatly inhibit the production of acid leachate (Colorado School of Mines Research Institute, 1982). The calculated relationship between the pH from acid generation and time to consume carbonate minerals within the reclaimed tailings, assuming a Case I infiltration rate (as explained in Section 9.4.1) of water through the seal of 0.066 inch per year, is shown below (Exxon Minerals Company, 1982c).

Acid Neutralization Capacity of Tailings

pH from Acid Generation	Years to Consume $CaCO_3$
3.4	11,000,000
2.4	1,100,000
1.4	110,000

The Case I seal infiltration rate (0.066 inch per year) used to project the number of years to consume the tailings $CaCO_3$ represents a conservative estimate of MWDF final cap infiltration and ultimate steady-state MWDF leakage. However, as a sensitivity study, in the ground water modeling work, the Case II infiltration (and hence MWDF seepage) of 0.66 inch per year was also analyzed. Even for this unexpectedly high seepage rate (for which the contingency plan presents adequate measures) the number of years to consume the available tailings $CaCO_3$ is only reduced by a factor of ten.

The buffering capacity of the tailings greatly inhibits the potential release of metals to the leachate. These results indicate that near neutral (pH 6 to 8) conditions are the most representative for the seepage from the tailings. Acidic tailings seepage (pH <6) should never occur.

The attenuation studies utilized synthetic leachates and representative soil composites (see Figure 7-14) to determine constant pH batch distribution ratios (K_r) for metals and column retardation factors (R_d) for more mobile chemical constituents (e.g., sulfate). The retardation factors measure the solute transport rates in comparison to the average linear velocity of the ground water. For example, chloride has an R_d equal to 1, and it travels at the same rate as the ground water. If a parameter has an R_d of 10, it travels at one-tenth the velocity of the front.

The studies indicated that the soils under the MWDF have major attenuation capacity for most of the chemical constituents tested. The attenuation capacity of the soils is generally higher at a higher pH of the leachate. Only sulfate, total sulfur, and filterable residue (TDS) were projected to migrate at the same velocity as the seepage from the MWDF (Table 10.1). In addition to chemical attenuation, dilution and dispersion are the non-chemical factors which further reduce the concentration of these constituents in the ground water.

Moreover, the soils beneath the proposed MWDF have a moderate to high acid neutralization (buffering) capacity (0.7 to 2.3 percent calcium carbonate equivalent). This buffering is even much larger than that indicated

TABLE 10.1

GENERAL MOBILITY OF MWDF SEEPAGE CONSTITUENTS[a]

PARAMETER	pH 3	pH 6	pH 9
Filterable Residue[b]	Very Mobile[c]	Very Mobile	Very Mobile
Chloride	Very Mobile	Very Mobile	Very Mobile
Fluoride	Solubility Controlled	Solubility Controlled	Solubility Controlled
Nitrate-Nitrogen	Mobile	Mobile	Mobile
Sulfate	Very Mobile	Very Mobile	Very Mobile
Total Sulfur	Very Mobile	Very Mobile	Very Mobile
Cyanide	Slightly Mobile	Slightly Mobile	Slightly Mobile
Arsenic	Slightly Mobile	Slightly Mobile	Immobile
Barium	Solubility Controlled	Solubility Controlled	Solubility Controlled
Cadmium	Mobile	Immobile	Immobile
Chromium	Slightly Mobile	Solubility Controlled	Immobile
Copper	Mobile	Slightly Mobile	Immobile
Iron	Mobile	Mobile to Slightly Mobile	Solubility Controlled
Lead	Slightly Mobile	Solubility Controlled	Solubility Controlled
Manganese	Very Mobile	Very Mobile	Immobile
Mercury	Slightly Mobile	Solubility Controlled	Immobile
Selenium	Solubility Controlled	Slightly Mobile	Slightly Mobile
Silver	Solubility Controlled	Slightly Mobile	Slightly Mobile to Immobile
Zinc	Mobile	Slightly Mobile	Immobile

a D'Appolonia, 1982b. Note: This table of relative mobility for leachate chemical constituents represents the combined results of the batch and column attenuation testing.

b Filterable Residue = Total Dissolved Solids

c Very Mobile - moves at same velocity as seepage ($R_d = 1$)
Mobile - $R_d<10$
Slightly Mobile - $10<R_d<100$
Immobile - $R_d>100$
Solubility Controlled - Chemical parameter in synthetic leachate at or below the analytical detection limit.

for the tailings. The distribution of carbonate materials, principally dolomite, in the soils beneath the proposed MWDF is somewhat variable vertically and laterally. However, considering the overall amount and distribution of acid neutralizing materials present, there is a high capacity for acid neutralization for all directions of seepage movement from the facility (D'Appolonia, 1982b). Because of this large buffering capacity of soils beneath the proposed MWDF, any metals in the seepage will be controlled by acid neutralization (i.e., greater attenuation with increasing pH).

The studies also indicated that a liner material composed of bentonite and glacial till soil would not undergo any appreciable increase in permeability due to chemical reactions with facility seepage (D'Appolonia, 1982b). In fact, ongoing Exxon studies have indicated there may be some permeability reduction with passage of seepage through the liner. Consequently, the integrity of this type of liner or the soils underlying the MWDF should be maintained throughout the life of the facility and should not degrade over time.

In the final analysis, the reclamation cover governs the final or steady-state MWDF seepage. After operations have ceased and the MWDF has been reclaimed, the only continuing source of seepage water is the precipitation infiltration passing through the reclamation seal and entering the tailings mass. During operations and for any necessary period thereafter (estimated to be 2 years maximum), the pond bottom leachate collection system will remain active allowing the collection and removal of nearly all leachate passing through the tailings. After the MWDF has been reclaimed and any remaining tailings excess water has been collected by the underdrain system, underdrain pumping will stop, and MWDF seepage will eventually reach a steady-state value equivalent to the cap infiltration. Thus, the time frame for which the pond liner is effectively controlling seepage is relatively short, generally less than ten years. Beyond this time the top seal is the controlling factor.

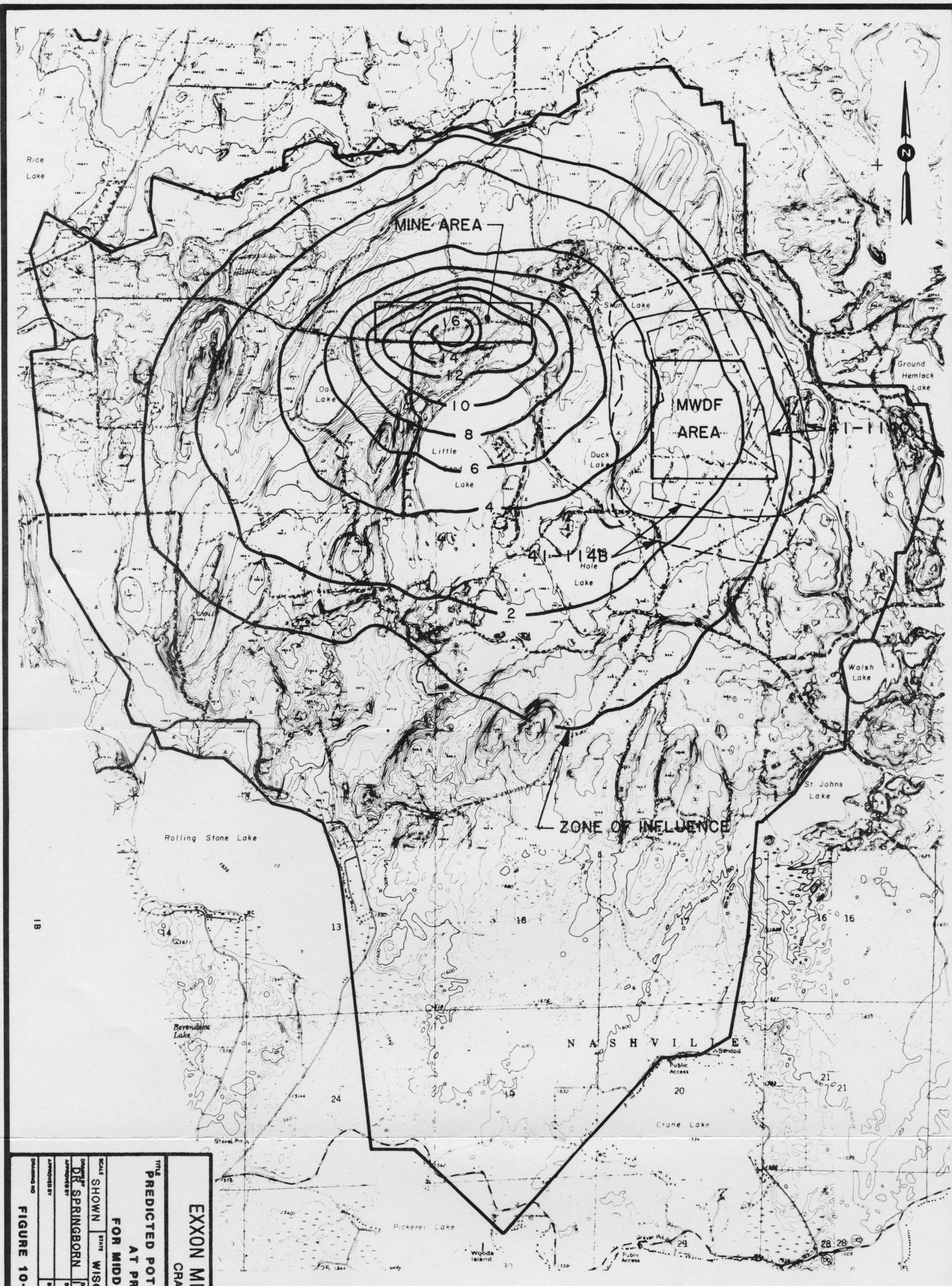
The attenuation and neutralization capacity of the soils beneath the facility were then used in conjunction with ground water models to evaluate potential effects of MWDF seepage on ground water. Several analytical assessments were conducted by Exxon (1982c) and D'Appolonia (1985) to determine the water chemistry and movement within the MWDF, the amount of pond seepage that could be expected over time, its movement in the soils beneath the MWDF site, and the potential for dilution by ground water. The results of these assessments were used to generate inputs for computer models which predicted ground water changes which might occur as a result of mining and MWDF activities. Models were also used to evaluate mass transport from the MWDF.

Ground water modeling studies were conducted by D'Appolonia in 1982 (D'Appolonia [1982a]) and 1984 (D'Appolonia [1984]). At the request of the DNR, substantial additional analysis was added to the 1984 report resulting in the final Hydrologic Impact Assessment (D'Appolonia 1985). The changes to the MWDF and other project plans and facilities made by Exxon in 1985 have been considered in the finalization of the Hydrologic Impact Assessment (D'Appolonia 1985). It was determined that the analyses completed for the MWDF, as designed in October 1984 and designated as Site 41-114B, were still applicable and were conservative for the smaller sized facility designated as Site 41-114C. The comparison of the previous MWDF (Site 41-114B) to the current MWDF (Site 41-114C) with respect to similiarity of hydrologic impacts is included in Attachment A.12 of the Hydrologic Impact Assessment (Appendix 4.1A). The following summary of analyses and results are those for facility

41-114B and determined applicable for facility 41-114C. For convenience, facility 41-114C is also superimposed on the figures.

The primary computer model for evaluating overall hydrogeological impact is a two-dimensional planar numerical model (GEOFLOW; D'Appolonia, 1985). This model simulated the study area ground water system and was calibrated to reflect existing conditions, including the piezometric surface and saturated thickness of the aquifer. The calibrated model was then used to evaluate various effects on the hydrologic system. For example, the effect of mine dewatering was simulated to assess its impact on other parts of the hydrologic system. The results of these model calculations showed that mine dewatering would produce local reductions in the water table beneath the MWDF (Figure 10-9), but have no effect on ground water flow rates when any seepage from the MWDF would percolate to the drift. The studies showed that by the time any MWDF seepage reaches the drift, mine dewatering operations will have been terminated, and ground water levels will have recovered to their approximate pre-mining levels. A full discussion of the ground water drawdown and recovery related to mine inflow and a review of the associated impacts are presented in EIR Appendix 4.1A. Therefore, based on the separation of mine inflow hydrologic effects from the MWDF seepage effects, the main model predictions for the MWDF were related to the evaluation of any impacts of the MWDF seepage on ground water flow rates and quality without including mine inflow interaction.

The quality and quantity of seepage from the MWDF (facility 41-114B) were evaluated using vertical and horizontal numerical models to simulate ground water flow rates and chemical constituent migration in the unsaturated and saturated zones beneath the facility. Vertical models were used to evaluate the concentration distributions in the 40-50 feet layer of



NOTE:
LIMIT OF ZONE OF INFLUENCE IS SET AT A MAXIMUM DRAWDOWN OF 1.0m (3.3feet)

LEGEND:
~2~ PREDICTED POTENTIOMETRIC DRAWDOWN IN METERS

SCALES
0 1000 2000meters
0 2000 4000 6000feet

EXXON MINERALS COMPANY
CRANDON PROJECT

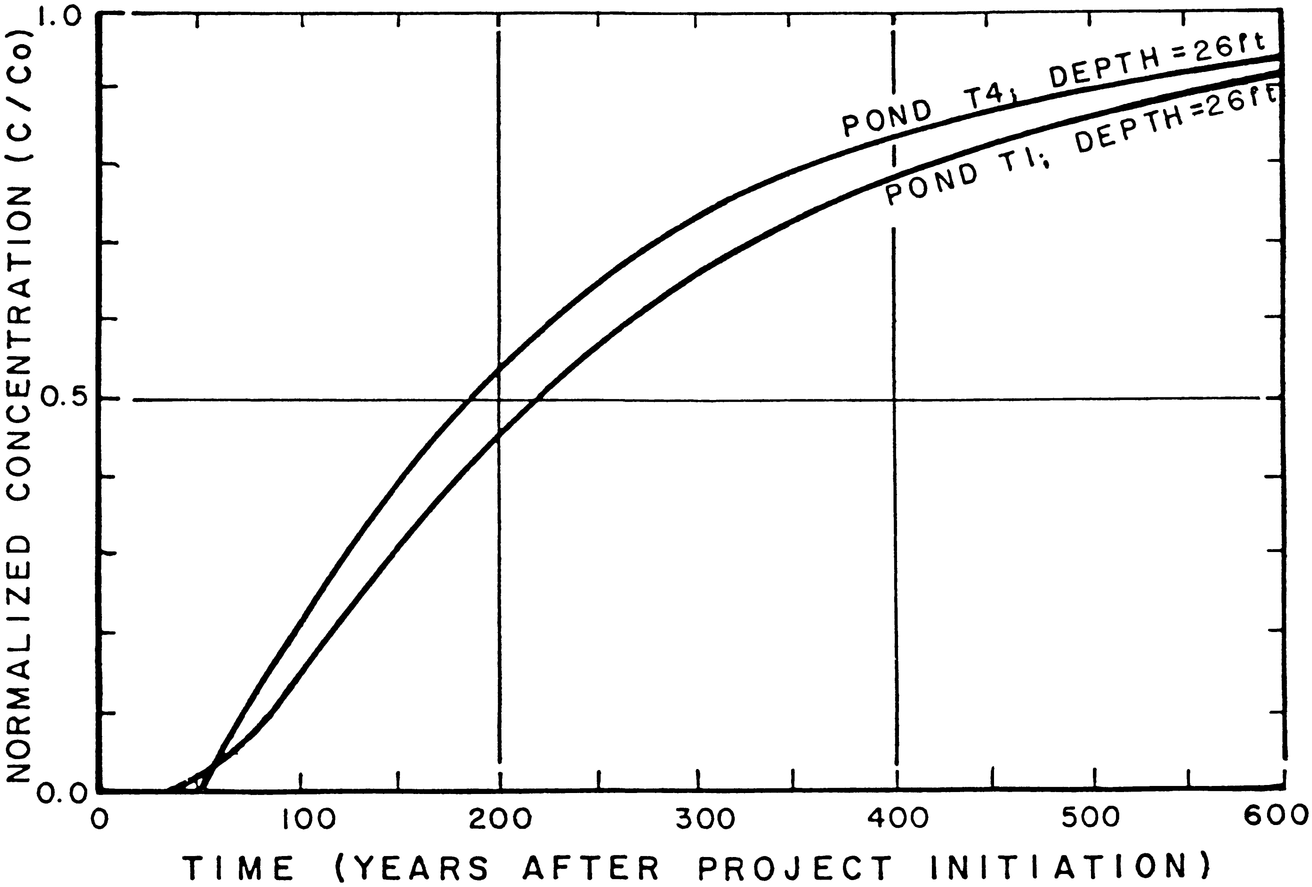
TITLE PREDICTED POTENTIOMETRIC DRAWDOWN AT PROJECT YEAR 28 FOR MIDDLE RECHARGE CASE

SCALE SHOWN | STATE WISCONSIN | COUNTY FOREST
DRAWN BY DR SPRINGBORN | DATE 11/85 | CHECKED BY | DATE
APPROVED BY C.C. Schmidt | DATE 11/85
APPROVED BY | DATE
DRAWING NO FIGURE 10-9 | SHEET OF | REVISION NO

unsaturated till beneath the MWDF ponds. For conservatism in using the models the minimum thickness of till found in the MWDF area (26 feet) was used. The seepage rates input for the modeling were from the Case I seepage projections for tailings ponds T1 and T4 (facility 41-114B) and the seepage was assumed to occur immediately from the bottom of the MWDF liner. The results of the model calculations are displayed as concentration distributions (C/C_o) over time on Figure 10-10. This figure shows that it will be approximately 50 years before any seepage would reach the 26-foot depth. It also indicates that approximately 100 years would be required for an estimated concentration (e.g., C/C_o = 0.2) of a conservative (R_d=1) constituent (e.g., sulfate) to percolate a distance of 26 feet distance.

The areal distribution pattern of the MWDF seepage was analyzed in a two dimensional horizontal model. The steady-state position of the MWDF seepage plume, based on the Case I MWDF seepage conditions (i.e., long-term cap infiltration of 0.066 inch per year), is shown in Figure 10-11. The results of this modeling showed a maximum average seepage concentration of less than C/C_o = 0.02 to the northeast of the MWDF at the compliance boundary. These results indicate which direction or directions are significant for any MWDF seepage movement and indicate an average ground water quality condition assuming seepage is distributed uniformly throughout the depth of the drift layer.

The vertical distribution of seepage water in the drift layer was analyzed by use of a two dimensional model for a vertical cross section calculated to determine the distribution of potential constituents within the main aquifer in the direction of maximum seepage travel. Figure 10-12 indicates the results of this study for the expected conditions. The detailed vertical modeling for steady-state conditions indicates a maximum C/C_o of



NOTES:

1. ANALYSIS ASSUMES A CONSTANT CONCENTRATION SOURCE AND A RETARDATION FACTOR OF 1.0
2. MODEL INCORPORATES TAILINGS PONDS T1 & T4 (FACILITY 41-114B) SEEPAGE RATE SCHEDULES AS SHOWN IN FIGURE A.-3 OF EIR APPENDIX 4.1A
3. OTHER INPUT PARAMETERS AND CONDITIONS ARE DISCUSSED IN ATTACHMENT A.7 OF EIR APPENDIX 4.1A

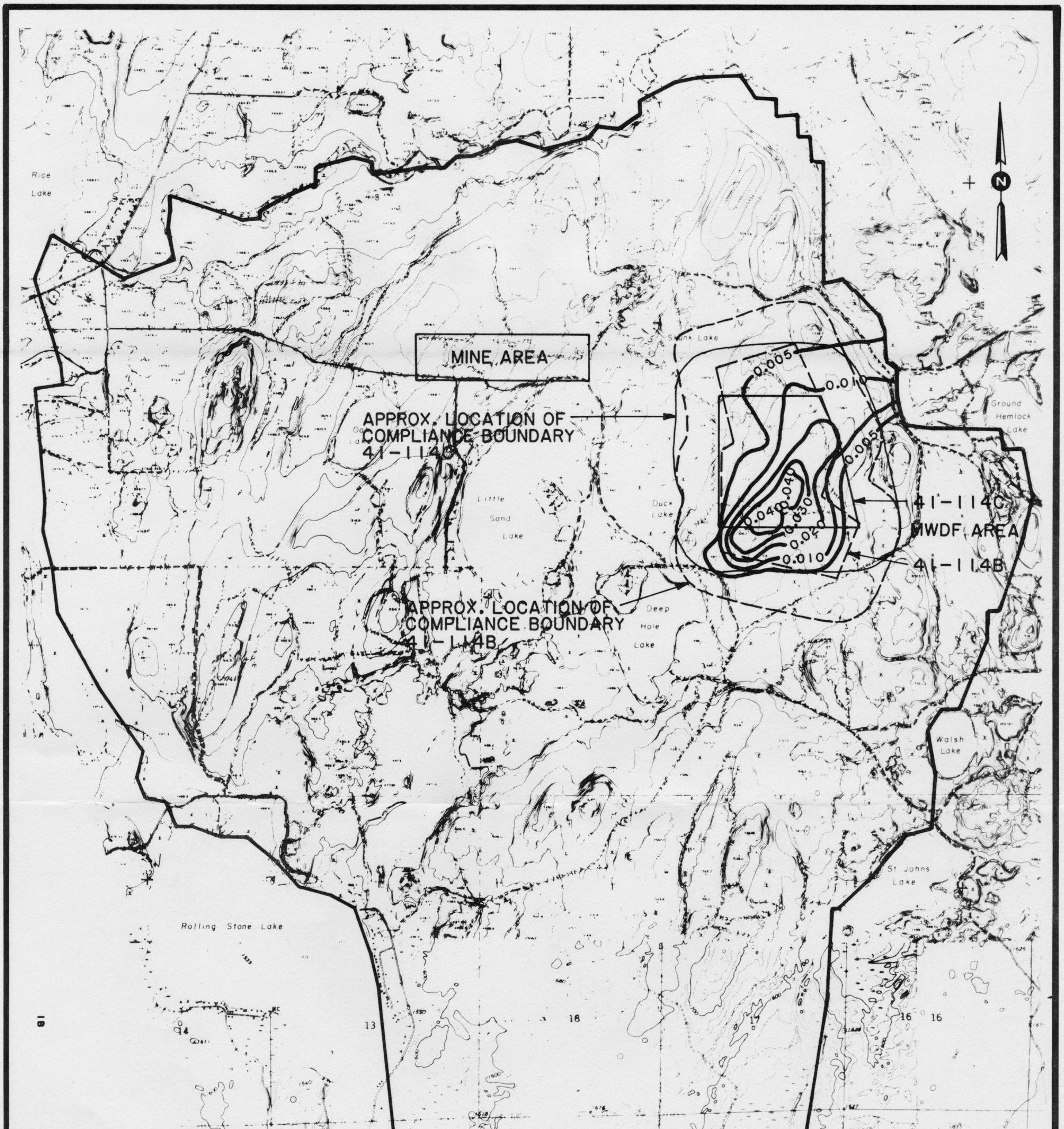
D'APPOLONIA

PROJ NO 846498 | DWG NO A9

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
COMPUTED NORMALIZED CONCENTRATIONS IN PARTIALLY SATURATED TILL 26feet BENEATH MWDF

SCALE AS SHOWN	STATE		COUNTY
DRAWN BY J J L	DATE 9-26-84	CHECKED BY H. S. Luri	DATE 10-15-84
APPROVED BY	DATE	APPROVED BY C. C. Schroedl	DATE 10-15-84
APPROVED BY	DATE	EXXON D. E. Fil	DATE 1/9/-
DRAWING NO FIGURE 10-10		SHEET ___ OF ___	REVISION NO



NOTES:

1. THE ANALYSIS ASSUMES A CONSTANT FLUX AND A RETARDATION FACTOR OF 1.0
2. LONGITUDINAL DISPERSIVITY EQUALS 97 FEET TRANSVERSE DISPERSIVITY EQUALS 49 FEET
3. OTHER INPUT PARAMETERS AND CONDITIONS ARE DISCUSSED IN ATTACHMENT A.7 OF EIR APPENDIX 4.1A

SCALES

0 1000 2000 meters

0 2000 4000 6000 feet

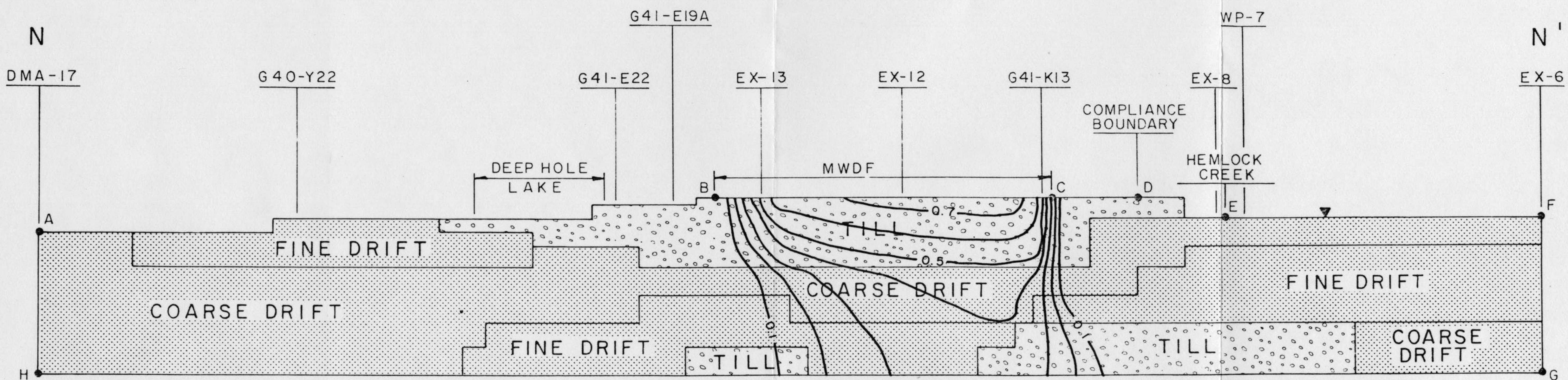
LEGEND:

~0.020~ NORMALIZED CONCENTRATIONS CONTOURS

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PREDICTED STEADY STATE NORMALIZED CONCENTRATIONS FOR MIDDLE RECHARGE CASE

SCALE	SHOWN	STATE	WISCONSIN	COUNTY	FOREST
DRAWN BY	DR SPRINGBORN	DATE	1/85	CHECKED BY	
APPROVED BY		DATE		DATE	1/85
APPROVED BY		DATE		DATE	
DRAWING NO	FIGURE 10-11			SHEET OF	REVISION NO



NOTES:

1. FOR PLAN AND LOCATION OF SECTION N-N' REFER TO FIGURE A.8 OF EIR APPENDIX 4.1A
2. VERTICAL EXAGGERATION 15X
3. THE ANALYSIS ASSUMES A CONSTANT MASS FLUX AND A RETARDATION FACTOR OF 1.0
4. A RECHARGE RATE OF 8.5 inch/yr. IS USED
5. VERTICAL TO HORIZONTAL PERMEABILITY RATIO, TILL = 1/1, DRIFT = 1/50.
6. LONGITUDINAL DISPERSIVITY = 197 feet
7. LONGITUDINAL TO TRANSVERSE DISPERSIVITY RATIO = 50
8. OTHER MODEL INPUT PARAMETERS AND CONDITIONS ARE DISCUSSED IN ATTACHMENT A.7. OF EIR APPENDIX 4.1A

LEGEND:

A ● POINTS REFERRED TO IN TEXT

—0.1— NORMALIZED CONCENTRATION CONTOUR

HORIZONTAL SCALE

0 300 600 900 meters

0 1000 2000 3000 feet

VERTICAL SCALE

0 20 40 60 meters

0 50 100 200 feet

D'APPOLONIA

PROJ NO 846498 DWG NO B43

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

PREDICTED NORMALIZED CONCENTRATIONS AT YEAR 4800 FOR SECTION N-N'

SCALE	STATE	COUNTY
AS SHOWN		

	DATE		DATE
DRAWN BY D.Weick		CHECKED BY H.S. [illegible]	10-15-84
APPROVED BY		APPROVED BY C.C. Schroeder	10-15-84
APPROVED BY		EXXON [illegible]	[illegible]
DRAWING NO FIGURE 10-12		SHEET OF	REVISION

less than 0.10 at the compliance boundary. Moreover, it is expected to take nearly 5,000 years for this steady-state condition to be reached.

The results presented above represent conservative projections with regard to ground water effects from MWDF seepage. Sensitivity analyses have been performed to determine the significance of various parameters affecting model results and that work has been utilized in the above information. Also, an increased seepage condition (Case II) has been investigated. The Case II condition, which includes a ten-fold increase in MWDF steady-state seepage, results in ground water effects where there is only one small area where C/C_o approaches a maximum of 0.3 at the compliance boundary.

These modeling evaluations were performed to determine if the proposed MWDF will comply with the ground water quality standards specified in NR 182.075. The results indicate that even under the most conservative assumptions the MWDF will not exceed NR 182 ground water quality standards at the compliance boundary during the operation or closure period of the facility. For example, sulfate which has conservatively been assigned a very high initial concentration in the MWDF and has an assumed retardation coefficient of 1 (i.e., no attentuation) will not exceed its drinking water standard (250 mg/l) at the compliance boundary.

Attenuation and modeling results performed specifically for Layout 41-114B (and which are applicable for Layout 41-114C) demonstrate that the facility will not violate the ground water quality standards because:

1) The tailings have a high percentage of carbonate minerals that provide acid neutralization capacity lasting thousands of years;

2) The soils beneath the MWDF (till and coarse-grained stratified drift) also have large acid neutralization capacities because of the presence of carbonate (mostly dolomite);

3) Chemical constituents movement in these soils also have large retardation factors ($R_d>5$), except for sulfates and TDS, even when subjected to leachates that have a pH much lower than will ever be found at the MWDF;

4) To reach steady-state conditions even for the most conservative parameters (such as sulfate $R_d = 1$) travel time to the compliance boundary is considerable. Normalized concentrations of $C/C_o = 0.1$ are not expected to reach the coarse drift layers beneath the MWDF for a period of 800 years (EIR Appendix 4.1A).

5) Even for the high gradient flow directions (northeast) for the conservative parameters the steady-state C/C_o concentration is expected to be less than 0.1.

6) The sulfate concentration of the seepage from the MWDF is expected to decrease over the long term (Exxon 1982d).

10.3 Surface Water Criteria

The surface water criteria for the MWDF are referenced in NR 182.07(1)(i) which states that facilities shall not be located within an area where the Department after investigation finds that there is reasonable probability that disposal of solid waste within such an area will result in violation of surface water quality criteria and standards.

NR 102 establishes water quality standards for Wisconsin surface waters. The intent of the standards ". . . shall be such as to protect the public interest, which includes the protection of the public health and welfare and the present and prospective future use of such waters . . ." (Chapter 144, Stats. of Wisconsin).

Surface water drainage will be directed off and around the MWDF and will not contact the wastes. Surface water during construction activities will be routed through sedimentation control devices as necessary. During operations, water within the MWDF will be pumped to the water reclaim ponds and eventually reused or treated and discharged under a WPDES permit.

With the proposed MWDF reclamation cap design and resulting negligible seepage, the MWDF will cause virtually no change in water quality in any Project area surface waters. However, as part of the solute transport modeling analysis, water quality effects for Hemlock and Swamp Creeks were determined based on the assumed Case I and II MWDF seepage rates discussed in Section 9.5

Figure 10-11 shows the steady-state impacts to Hemlock Creek based on the Case I MWDF seepage conditions. Although these concentrations are well within the ground water standards at the MWDF compliance boundary, they do result in some very low concentration solute discharge to Hemlock Creek.

Utilizing the stream base flows the following changes were calculated for Hemlock Creek (4.0 CFS at S. G. 6 upstream of its juncture with Swamp Creek) and for Swamp Creek (19.0 CFS at Highway 55):

MWDF Seepage Condition	Change in Sulfate	
	Hemlock Creek	Swamp Creek
Expected	0	0
Case I	<2 mg/l	<0.5 mg/l
Case II	<20 mg/l	<5 mg/l

These calculations conservatively assume the entire MWDF seepage quantity (approximately 1 gpm for Case I and 10 gpm for Case II), with a sulfate concentration of 2000 ppm, is entering the creek system.

Use of the average stream flows for these calculations would further reduce the estimates of increased sulfate concentrations by approximately one-half.

Additional information and discussion of the effects of MWDF seepage discharge to Hemlock and Swamp Creeks is included in Chapter 4 of the EIR.

10.4 Conservative Aspects of MWDF Design and Analysis

This subsection is included to address various aspects of the MWDF design and analysis that result in conservative or greater than expected projections of impacts.

The solute transport modeling results presented in this chapter are a conservative estimate of probable effects from the construction, operation, reclamation and final use of the MWDF. Throughout the design of the MWDF and the characterization of the site area geohydrological system, analytical values were chosen to produce conservative results. For example, the final steady-state pond seepage value of 0.066 inch/year, designated as Case I for modeling, could be much lower based on the actual permeabilities expected from the synthetic membrane incorporated in the reclamation cap. The Case I seepage value was based on the Case II analysis which considered only the bentonite-modified soil seal. The Case II seepage value was then reduced by an order of magnitude for the Case I analysis. Also, with the rigorous construction control and inspection planned for installation of the seal, the security of the seal will be assured.

The seepage quality designation is another example of conservative modeling input that could greatly influence the long-term ground water quality projections. All of the analyses have assumed a continuous seepage flux from the MWDF at a constant concentration. Estimates of concentration change over time are difficult to predict but the seepage concentrations should eventually lessen. With the time frames forecasted by the modeling work (approximately 5,000 years to reach steady-state ground water conditions), it is realistic to predict an eventual reduction in seepage concentration. Any reduction in seepage concentration would provide corresponding similar reduced impacts on ground water quality. In addition to the MWDF seepage rate and seepage chemistry considerations, there are several other areas that have been treated conservatively in the development of the MWDF that will result in a positive change from the predicted ground water impacts.

In general, computer models provide precise results that exceed the level of accuracy available for a majority of the modeled parameters or other modeling criteria. Value ranging and sensitivity analyses were completed to eliminate concern over uncertainty in ground water modeling assumptions. The evaluations using these extended parameter limits did not severely effect the final hydrological results. Also, realistically, the time frames (thousand of years) forecasted to notice any change in ground water conditions, and particularly the time required to reach steady-state conditions (4800 years), is approaching the limit of usefulness. Natural changes could occur within the modeling time frames that could greatly affect the final analysis or possibly even reconfigure the hydrogeology of the site area.

In the final analysis, the MWDF design provides a high degree of certainty with regard to predicted facility performance and ultimately to ground water protection over the foreseeable future. Because of the conservative data employed throughout the MWDF design and analysis work the actual effects will be substantially less than those presented herein.

11.0 ALTERNATIVES

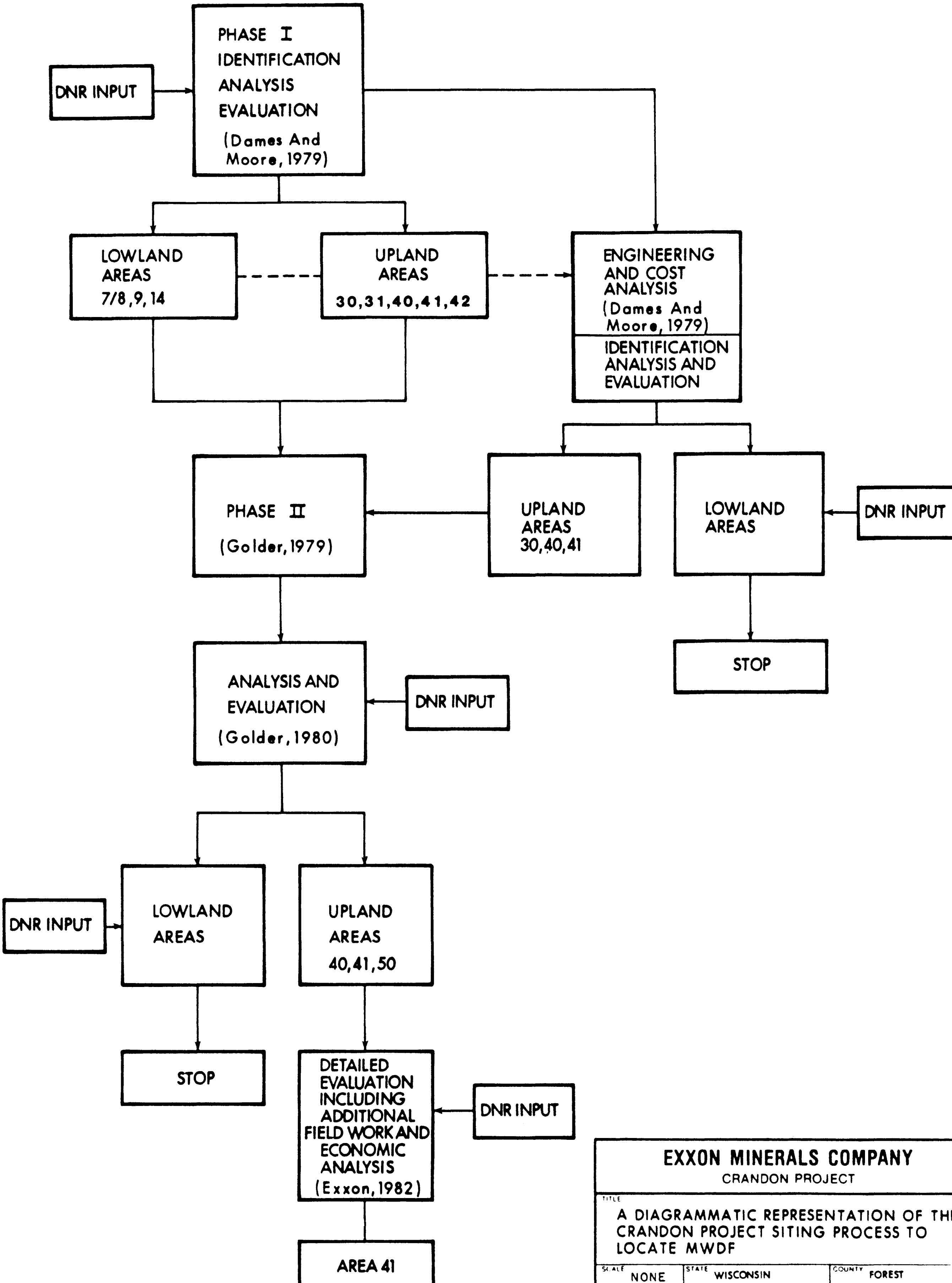
This chapter summarizes the information utilized in locating an acceptable MWDF site for the Crandon Project. The approach generally consisted of eliminating environmentally unacceptable land areas on the basis of location criteria, including those in NR 182, and engineering and economic factors. Figure 11-1 is a summary of the process used to locate the mine waste disposal facility (MWDF).

After a suitable area was designated, a specific facility layout was developed based on numerous options, as discussed in Section 11.2 of this chapter. Throughout the process, DNR review and input has been obtained and used to assist Exxon in locating and designing the MWDF.

11.1 Alternative Areas

The two phase study process shown on Figure 11-1 was conducted to locate potential areas for the MWDF. The first phase, started in 1978 (Dames & Moore, 1979), began with an evaluation of potential areas within the regional study area. An initial conclusion of this phase was that further efforts should be confined to an area within a 12 mile radius of the ore deposit because the possibility of locating a better area beyond the 12 mile radius was not economically justifiable nor was the environmental disturbance required for the longer pipeline and roadway corridors. Therefore, the Phase I studies were completed by concentrating efforts within the 12-mile radius of the ore deposit (Dames & Moore, 1979).

The objective of this phase was to select the potential areas within the 12 mile radius, in which an MWDF could be developed and operated with the



EXXON MINERALS COMPANY			
CRANDON PROJECT			
TITLE: A DIAGRAMMATIC REPRESENTATION OF THE CRANDON PROJECT SITING PROCESS TO LOCATE MWDF			
SCALE: NONE	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: BWM	DATE: 07/26/82	CHECKED BY: C.P. Harbick	DATE: 12-'82
APPROVED BY	DATE	APPROVED BY: C.C. Schroeder	DATE: 12-82
APPROVED BY	DATE	EXXON: D.T. Moe	DATE: 1-1
DRAWING NO: FIGURE 11-1	SHEET ___ OF ___		REVISION: 0

fewest possible engineering problems and adverse effects on the environment (Dames & Moore, 1979). The first step was to identify a broad spectrum of potential areas. Mine waste containment volume and distance from the ore deposit were the two major criteria used in this step. Areas within 1,000 feet from lakes were eliminated. Both upland and lowland areas were included. Ideally, a facility should be developed on the area using topographic containment to eliminate the need to construct large earth embankments to contain wastes. However, several areas were selected where topographic containment was not possible and earth embankments would be needed to provide the containment volume. This study identified 35 potential areas within the 12 mile radius of the ore deposit (Dames & Moore, 1979).

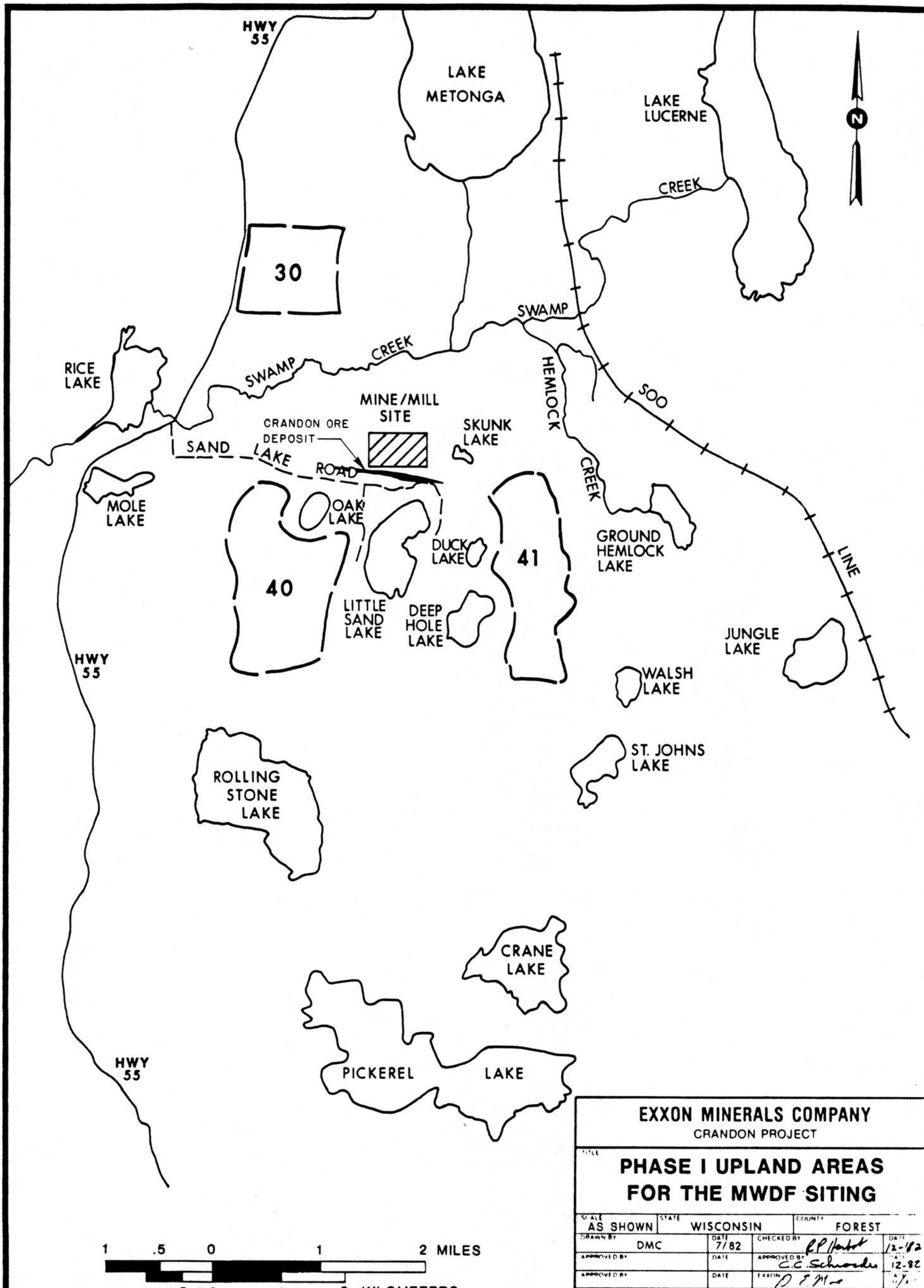
In the second step of Phase I several additional criteria were applied to the 35 potential areas to reduce the number for further evaluation. The criteria were deliberately general so as not to eliminate potentially viable areas for detailed review. Areas meeting the following criteria were eliminated: less than 10.40 million cubic yards (6,450 acre-feet) in potential capacity; less than 0.5 mile from cities or towns; and less than 0.5 mile from Native American communities. When these criteria were applied, 15 potential areas were rejected, leaving 20 for further evaluation.

The third step of Phase I was to gather information in the field for the 20 areas and then rank them. Information was collected on environmental factors, land use, and geohydrology. The areas were surveyed from the air and, in most cases, in the field. Soil borings were completed at most areas. A comprehensive scoring and ranking system was developed, and areas 7/8, 9, 14 (lowland) and 30, 31, 40, 41, and 42 (upland) were ranked highest (Dames & Moore, 1979).

Conceptual engineering was determined for construction, operation, and reclamation of a MWDF in each area followed by a technical and economic evaluation of each (Dames & Moore, 1979). Areas 30, 40, and 41 were considered the best based on this technical and economic evaluation. Areas 40 and 41 were also rated high based on environmental considerations conducted earlier in Phase I. Phase I concluded with the recommendation that Areas 30, 40, and 41 be further evaluated for location of the MWDF. Figure 11-2 shows Areas 30, 40, and 41.

The second phase of the study process began in 1979. Golder (1979) used an 5-mile instead of the 12-mile radius. Areas beyond the 5-mile radius were eliminated because of land use and topographic features and the desire to be as close to the mine/mill site as possible to minimize the potential environmental effects from wetland and trout stream crossings as well as the pipeline corridor construction. The first step in Phase II eliminated non-viable areas based on similar criteria used in Phase I: all lakes and areas less than 1,000 feet from a lake; all areas below elevation 1,600 feet MSL because they are almost entirely major wetlands; areas containing special habitats or endangered species; and Native American land and Nicolet National Forest land.

Several large geographic areas were also eliminated from further consideration because of tailing pipeline corridor stream crossings, land use, undesirable topographic features, and distance from the ore deposit. Thirteen potential areas were selected for further evaluation. Each of these 13 areas were upland and further evaluated from topography, distance from the ore deposit, and environmental considerations. Area D along with portions of



EXXON MINERALS COMPANY

CRANDON PROJECT

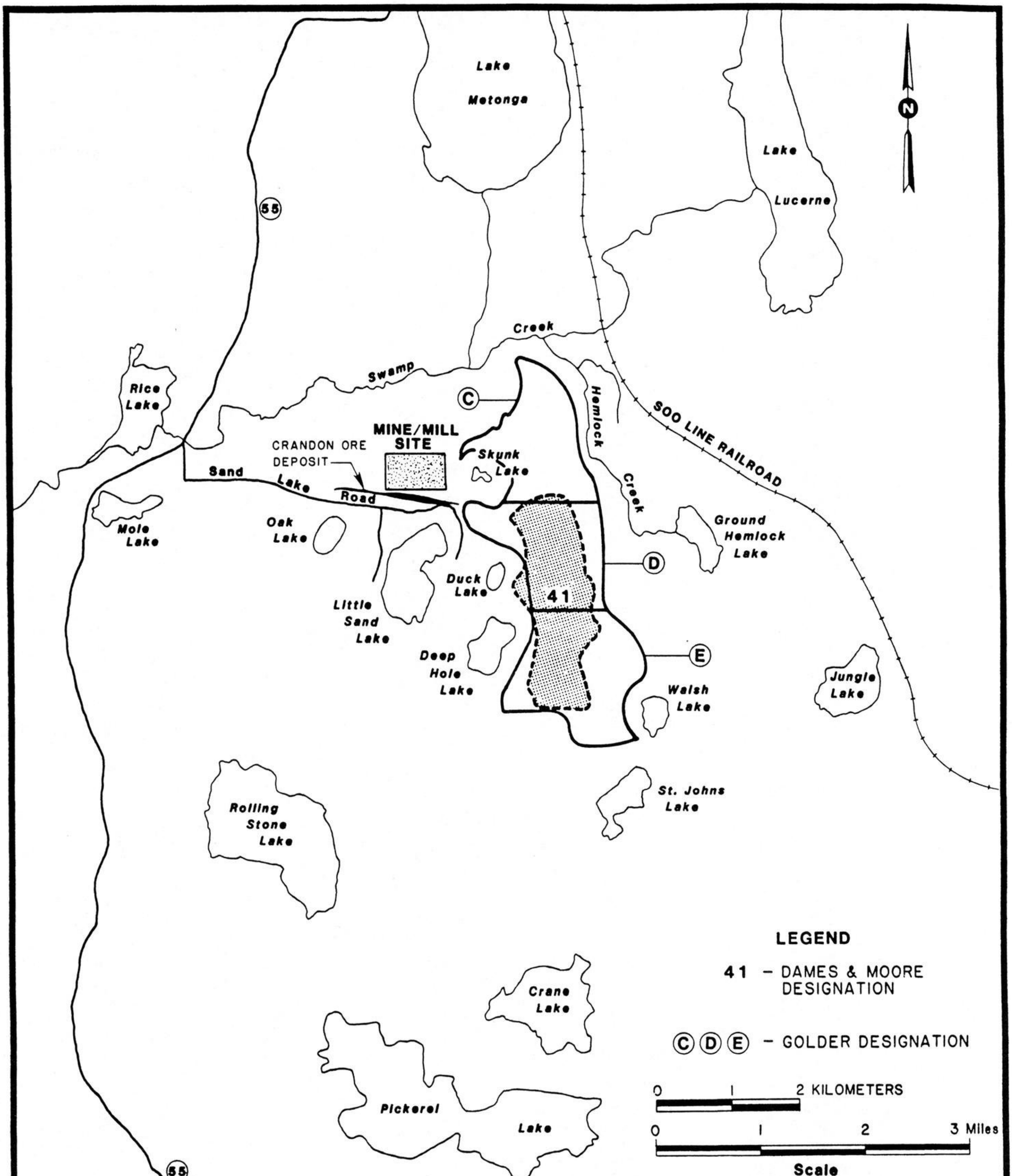
TITLE

PHASE I UPLAND AREAS FOR THE MWDF SITING

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DMC	DATE 7/82	CHECKED BY	DATE 12-82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	12-82
APPROVED BY	DATE	EXXON	
DRAWING NO.	**FIGURE 11-2**	SHEET ____ OF ____	0

Areas C and E were determined best from both environmental and engineering criteria (Golder, 1979; 1980). Figure 11-3 indicates the location of these areas and also shows how Area 41 generally coincides with Area D and parts of C and E. A major advantage to Area 41 is the protection of ground water provided by the attenuation capacity of the soil, which is approximately twice the depth compared to the other areas (Exxon, 1982b). The result of the Phase I and II studies was the selection of Area 41 for further design and development of the MWDF (Exxon, 1982b).

In the final analysis, the siting studies have arrived at what would probably have been a logical location choice without benefit of the detailed study. Basically, a more simplified approach to siting would be to look for suitable tailings facilities areas as close to the plant site as possible. With the need to move tailings and waste rock and water quantities to the reclaim ponds, and with no compelling reasons to provide a large separation distance between the mine/mill facilities and the disposal facilities, a closer location would be preferred over an equally suitable more distant location. Pumping requirements, pipeline lengths, haul road lengths, truck haul time, personnel travel time and other operations between the two areas all increase as separation distance increases. In addition to the impacts from the increased facility size, construction and operating costs for those portions of the disposal system also increase almost proportionally to relative distance from the mill.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RELATIONSHIP OF AREA 41 TO PHASE II AREAS C, D, AND E

SCALE SHOWN		STATE WISCONSIN		COUNTY FOREST	
DRAWN BY S. J. Harvey	DATE 8/19/82	CHECKED BY		DATE 12-82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO	FIGURE 11-3	SHEET 1 OF		REVISION 0	

11.2 Facility Site Layout and Design Selection

11.2.1 Site Layout Selection

After Area 41 was selected, the next step was to determine a specific MWDF site layout. Numerous layouts were evaluated within Area 41. The goal was a layout in which the topography could be used to maximum advantage to limit effects on the environment and the amount of required earthwork. Over 100 layouts and designs were considered within Area 41, and options 41-114 (41-114B), 41-103, and 41-121 were determined to be the most desirable, considering possible effects on ground water, surface water, and wetlands.

Comparisons were made of numerous siting features for disposal sites 41-103, 41-114B, and 41-121 (Table 11.1). While 41-103 covers fewer wetlands than 41-114B, its lowest pond bottom would be closer to the ground water table than the proposed layout. This is because the topography is low on the east side of the hill just north of Deep Hole Lake. Site 41-121 would also have its pond bottoms closer to the ground water table and would cover more wetlands, but would require less earthwork and involve less total area. Both sites encroach upon the minimum 1,000-foot distance from a lake and would, therefore, require a variance from NR 182.

Throughout the MWDF siting study period, the reclaim water ponds were considered along with the MWDF tailings ponds in siting these facilities. Various MWDF and reclaim pond layouts were reviewed during this study, including some layouts with separated ponds. As a result of the studies, it was generally concluded that separate locations for these facilities would not be desirable since they would result in increased land disturbance and complicate the transfer of water from the tailings ponds to the reclaim ponds thereby increasing potential impacts.

TABLE 11.1

SUMMARY OF COMPARATIVE FEATURES
OF WASTE DISPOSAL FACILITY LAYOUTS

Comparative Feature	System Designation 41-114C	41-114B	41-103	41-121
Number of tailings ponds	4	4	3	2
Distance from nearest lake, (feet)	1,000	1,050	170	200
Wetlands covered, (acres)	44	55	34	43
Total land area, (acres)	360	577	505	485
Area inside crests, (acres)	271	449	405	406
Height above ground water,* (feet)	38	48-54	30-69	30-55
Height crest elevation, (feet) MSL	1,732	1,737	1,735	1,723
Max. pond depth, (feet)	99	102	90	98
Max. exterior fill height, (feet)	110	107	123	98

*Heights given are from tailings pond bottoms only. Reclaim pond bottoms for all four cases range from 35 to 45 feet above ground water.

Source: Exxon, 1982b

In the final analysis, Site 41-114B was judged to be the best overall layout with the least overall potential environmental impact (see Mine Permit Application, Section A - Item 14).

The revised facility design and layout designated as Site 41-114C incorporates the advantages previously enumerated for 114B while addressing a smaller reserve estimate and reduced contingency. For comparative purpose summary data for layout 41-114C is also included in Table 11-1.

11.2.2 Liner and Underdrain Systems

Several alternative materials and system designs were considered for the liner and underdrain. The liner selection criteria may be separated into two major categories: technical evaluation of the anticipated performance of the liner system; and the availability of materials, manufacturers, fabricators, and/or suppliers and installers (Golder, 1981c).

The following requirements were assessed for each liner system considered:

1) Compatibility and durability of the liner in the presence of the waste to be disposed;

2) Reliability and low risk of failure;

3) Sufficiently low permeability for the design life of the facility; and

4) Relative ease of installation, quality control, repair and maintenance (Golder, 1981c).

The alternative liners considered were native soil materials (clay), polymeric materials, surface sealants, and soil additives.

11.2.2.1 Native Soil Materials (Clay)

A study was conducted to locate clay deposits of sufficient volume in the regional study area for lining the proposed MWDF (Exxon, 1979a, 1983b). Sufficient quantities of low permeability native clay soils are not locally or economically available for the MWDF (Exxon, 1979a, 1983b). The nearest potential source is near Goodman in Florence County, Wisconsin, approximately 40 miles away. Adverse impacts could occur in the mining of clay soil, and high costs are required to buy and transport these soils to the site area. Estimated purchase and hauling costs would be approximately 50 million dollars for 3.2 million cubic yards of this clay for a 5-foot thick liner. Also, depending upon the actual permeabilities of the clay materials, the seepage rate from the MWDF could be higher than for the proposed bentonite amended soil liner. Native clays having a permeability of 3.28×10^{-9} ft/sec. are generally recommended for consideration as liner materials for solid waste disposal facilities in Wisconsin. The proposed bentonite-soil liner will be constructed to an in-place permeability of 1.6×10^{-9} ft/sec. in accordance with strict quality control procedures. This permeability is one-half that of the native clays. Therefore, seepage across a native clay liner, meeting minimum permeability requirements, would be twice that across the proposed liner. In addition, several problems can occur with the use of clay, including inconsistent permeability rates, chemical reactions leading to liner deterioration, and physical instability after compaction. Therefore, alternative designs and liner materials other than native clays were considered for the MWDF.

A potential alternative liner within the native soil materials category would be the fine fraction (-200 sieve size) of the site till materials. This fine fraction, about 15-20 percent of the total material by weight, would be separated by screening and washing and then deposited as a thickened slurry in the pond bottom. For the pond side slopes, the material would be dried and spread on the slopes. Preliminary laboratory tests show that permeabilities approximating those for acceptable native clays (3.78×10^{-9} m/s) can be achieved with this type of liner (Knight and Piesold, Ltd., 1982). Additional study to determine how this material would perform in a full-scale field installation is necessary before this alternative could be advanced further. However, there is no advantage for a native clay liner or a sedimented slurry liner derived from washed till unless uniform permeabilities of less than 1.6×10^{-9} m/s could be achieved, comparable with the proposed bentonite/till liner.

11.2.2.2 Polymeric Materials

Polymeric materials are used to form synthetic liners of various chemical formulations such as EPDM (ethylene propylene dienemonomer); PVC (polyvinyl chloride); CPE (chlorinated polyethylene); butyl rubber; neoprene; HDPE (high density polyethylene); and CSPE (chlorosulfonated polyethylene, or Hypalon [trademark - E.I. DuPont Company]). Some advantages of synthetic liners are that they can contain a wide variety of fluids with minimum seepage; have high resistance to chemical and bacterial deterioration; are readily installed for many applications; and are relatively economical to install and maintain. Their disadvantages include a relative vulnerability to attack from ozone and ultraviolet light (sunlight); limited ability to withstand stress from heavy machinery; susceptibility to laceration, abrasion, and puncture; prone to cracking and crazing at very low temperatures or stretching and distortion at very high temperatures; and difficulties associated with field seaming (Golder, 1981c).

While the information base associated with synthetic liners continues to increase rapidly, their long-term performance has not been completely assessed because of their limited use until recently. However, significant improvements with respect to material quality control and factory and field seaming techniques continue to make synthetic membranes more attractive alternatives. The most significant advantage of synthetic membranes is their extremely low permeability which offers the prospect of negligible seepage. In addition, the many varieties and variations of synthetics available allow for a choice of material tailored to the specific physical and chemical demands of the facility.

However, for the tailings pond liner application the use of a synthetic membrane was not considered a prudent alternative. Used alone, in place of the preferred bentonite amended soil liner, there would be concern over the continuous integrity of the membrane throughout the operating life of the MWDF. If there were a major liner deterioration or other widespread failure, the membrane would not be replaceable, and while there would be contingency measures available, they would be costly, disruptive, and perhaps of questionable efficiency. If the membrane would be used in an alternative to construct a composite liner in conjunction with the bentonite amended soil liner, the overall seepage improvement would be insignificant over the relatively short operating time frame and the benefit to cost ratio would be extremely poor.

Based on these considerations, the proposed bentonite amended soil liner is considered a more efficient liner system for the type of design utilized for the MWDF.

11.2.2.3 Surface Sealants

Asphalt is the most prominent of the surface sealants used for lining of pollution control facilities. However, soil asphalt does not compare favorably with some of the other studied liner materials. Although soil asphalt has some favorable physical and chemical properties, it generally has higher permeability than clay or polymeric liners, and asphalt would require a waterproofing membrane over it to be similarly effective. This, together with the limited past use of soil asphalt mixtures for lining purposes, has excluded it from further consideration for the MWDF (Golder, 1981c).

11.2.2.4 Soil Additives

Bentonite is an inorganic expansive clay mineral. The basic composition is a three layer alumina silicate clay with the mineralogical name montmorillonite. The feature that makes bentonite a desirable soil additive for liners (i.e., reducing soil permeability) is its ability to swell to 10-15 times its original volume when it is hydrated, thereby filling soil pore spaces which reduces permeability.

There are several commercially available bentonites specifically formulated to counteract the effect of any chemical actions which might result from the storage of different waste products. A summary of the bentonite products supplied by American Colloid Company is presented in Table 11.2 to illustrate the range of products available.

An important beneficial property of bentonite-soil liners is their plasticity. When saturated, bentonite will reseal minor fissures or cracks which may occur in the soil liner (Golder, 1981c). The amount of bentonite required to construct a 8 inch soil liner with a permeability less than

TABLE 11.2

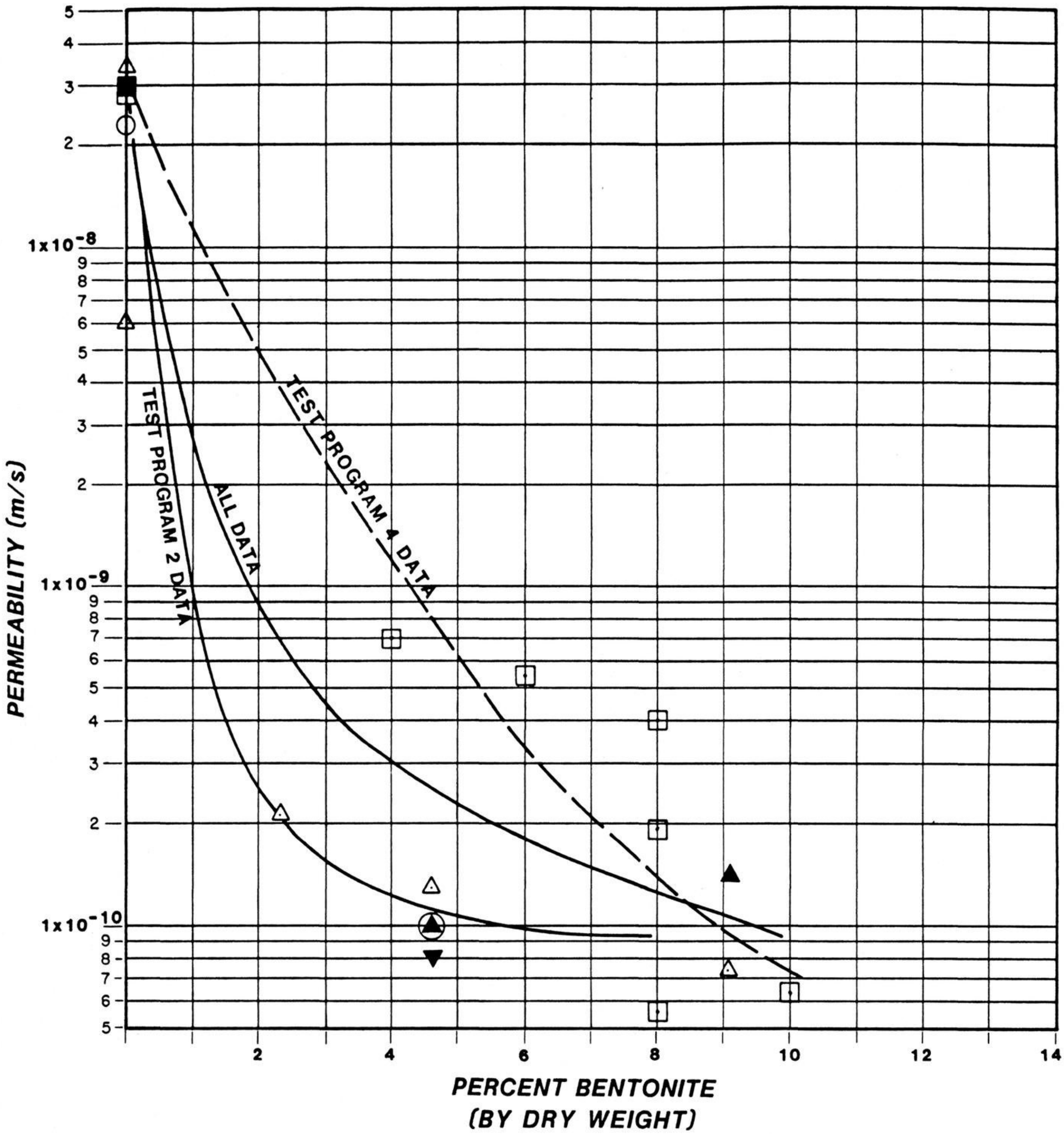
AMERICAN COLLOID PRODUCT LISTING*

CONDITIONS	PRODUCT USE AND TYPE	PRODUCT DESCRIPTION
	LAGOONS, PONDS, DAMS	
Water with less than 1000 ppm TDS	SG-40	Highest efficiency, low tolerance for contamination
Water with TDS between 1000 and 10,000 ppm	PLS-50	High efficiency, medium tolerance for contamination
Water with TDS in excess of 10,000 ppm	Saline Seal 100	Contaminant resistant soil sealant will resist contamination in excess of 100,000 ppm TDS
	SANITARY LANDFILLS	
Hazardous industrial waste	SLS-70	Will contain highly contaminated leachate
Municipal waste only	SLS-71	High efficiency sealant which will contain leachate from municipal waste, but not industrial waste
	TANK FARMS	
Chemical storage - inorganic	TFS-80	Will contain spills of strong inorganic chemicals
Crude petroleum or other organics contaminated with inorganics	TFS-81	High efficiency soil sealant which will contain spills of organic contaminated with mild inorganic or subject to inorganic contamination such as sea spray

*Golder, 1981c.

1.6×10^{-9} feet per second is estimated to be less than 3.2 pounds per square foot (4 percent). Contents as low as 1.6 pound per square foot (approximately 2 percent) should be adequate (STS, 1984b).

Permeability tests were performed with glacial till bentonite admixtures, obtained from Area 41, in laboratory test programs. A graph of the preliminary laboratory testing program data for these admixtures is presented in Figure 11-4 (Golder, 1981c). Figure 11-4 shows a general decrease in permeability as bentonite content increases. The decrease is from 1.5 to 2 orders of magnitude at relatively low percentages of bentonite (from 1 to 4 percent) and slightly more than 2 orders of magnitude for 4 to 10 percent bentonite. The preliminary testing programs approached the determination of bentonite content in a very conservative manner. Test pit soils were conservatively chosen to be in the lower end of the range of available tills with regard to fines content. Also, mixing and moisture control procedures were not chosen to necessarily improve or optimize results achievable from the bentonite admixture. A more comprehensive program undertaken by STS Consultants, Ltd. in July 1984 was designed to utilize representative site soils and more rigid mixing and moisture control procedures that were expected to better represent field mixing and provide more uniformity in the test results. The results of this latter, more comprehensive testing program are summarized in Figure 11-5 and presented in detail in STS Consultants, Ltd. (1984b) report. These results show that bentonite content of less than 2 percent by weight usually exceeded the design objective for liner permeability of 1.6×10^{-9} feet per second. The data showed a theoretically anticipated behavior exhibiting the high quality of the test results. The results of the STS Ltd. test program provides assurance that the design permeability of 1.6×10^{-9} ft/sec. can be achieved, and a



LEGEND

Test Program 2

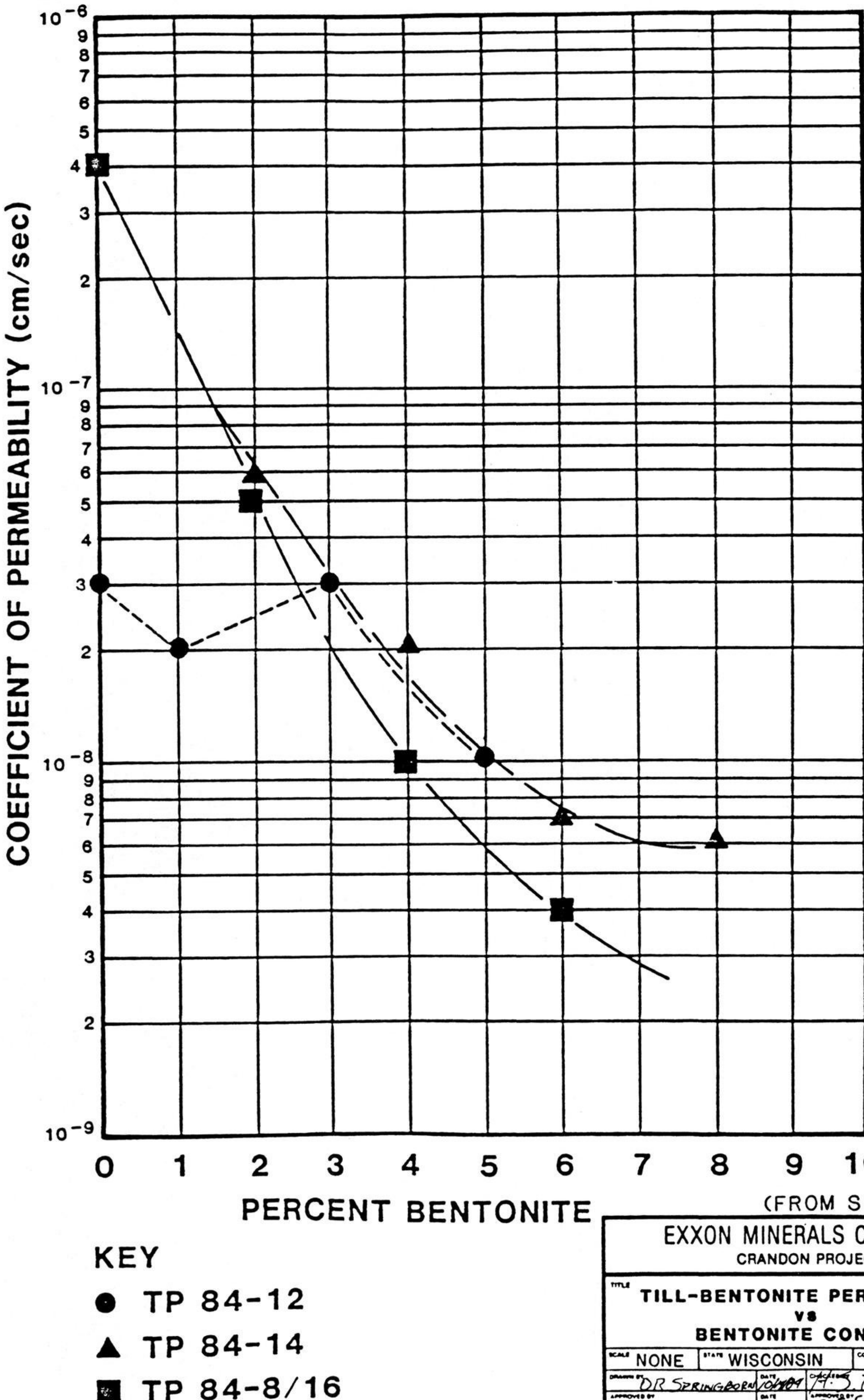
- △ TP-TW-41, Water as permeant
- ▲ TP-TW-41, Liquor with pH = 2.4 as permeant
- ▼ TP-TW-41, Liquor with pH = 9.6 as permeant
- ⊙ TP-2 Water as permeant

Test Program 4

- ■ BP-GT4, Water as permeant
- ⊡ TP-GT4, Liquor with pH 11 as permeant (Sample from Test Pit TP-22)

(FROM GOLDER, 1981d)

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE: TILL-BENTONITE ADMIXTURES PERMEABILITIES			
SCALE: NONE	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: IM	DATE: 9/82	CHECKED BY: RP Hebel	DATE: 12-'82
APPROVED BY	DATE	APPROVED BY: C.C. Schroeder	DATE: 12-82
APPROVED BY	DATE	EXXON	DATE
DRAWING NO: FIGURE 11-4		SHEET ___ OF ___	0



(FROM STS, 1984b)

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **TILL-BENTONITE PERMEABILITY vs BENTONITE CONTENT**

SCALE NONE	STATE WISCONSIN	COUNTY FOREST
DRAWN BY DR SPRINGBORN DATE 10/4/84	CHECKED BY M.S. Lewis	DATE 10-15-84
APPROVED BY DATE	APPROVED BY C.C. Schroeder	DATE 10-15-84
APPROVED BY DATE		DATE
DRAWING NO **FIGURE 11-5**	SHEET ___ OF ___	REVISION NO

measure of redundancy or conservatism can also be offered, with bentonite content of about 2 percent by weight. As noted in Section 9.2, the construction plans include specific test and quality control procedures that will provide on-going control of bentonite addition to assure achievement of liner design permeability.

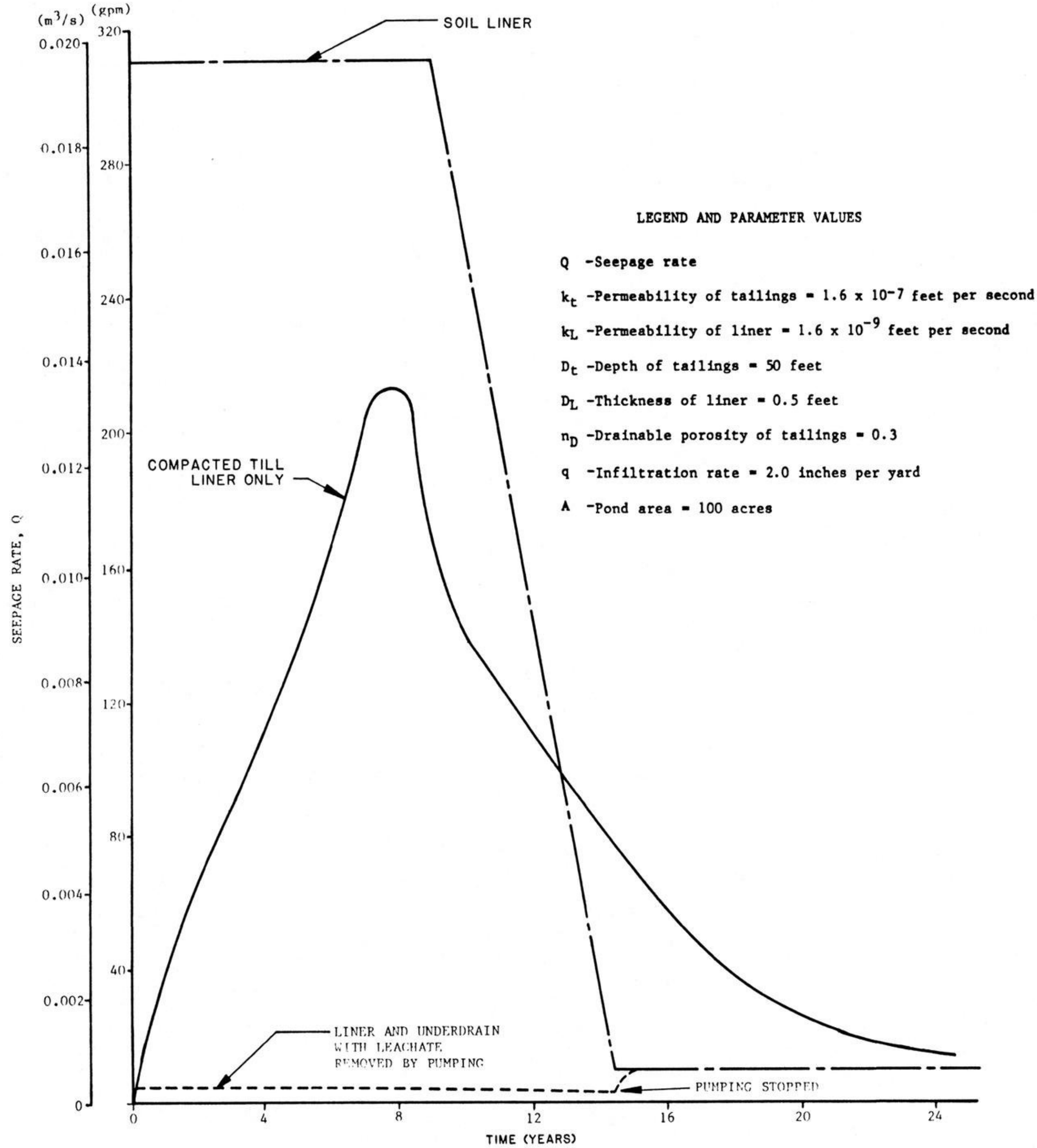
11.2.2.5 Seepage Rate Comparisons

Another evaluation of the alternative liner systems included the anticipated performance of a liner with and without an underdrain and leachate collection system. Preliminary seepage rate estimates were calculated for unlined ponds, lined ponds without underdrains, and lined ponds with underdrains. Seepage rate estimates were also completed for ponds during their operation and after reclamation, when steady-state conditions exist.

For a tailing pond without a drain layer, the hydraulic resistance the tailings must also be accounted for in calculating the quantity of seepage

For any liner system with a pumped overlaying drain layer on the liner, reduction of water depth or head on the liner, and seepage rates through the liner system will be at a minimum.

As an example, Figure 11-6 presents seepage rate curves for a 50-foot deep, 100-acre pond with a liner thickness of 0.5 foot and an infiltration rate of 2.0 inches per year with and without underdrains. An estimated seepage rate is also presented for an unprepared soil lined pond. The estimated maximum seepage rates during operation for a pond 100 acres in area and 50 feet deep are also summarized in Table 11.3. Seepage rates are presented for an unprepared soil (till) lined pond and for liners of compacted till, bentonite-till, and synthetic materials, with and without underdrains.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
LEACHATE MANAGEMENT EFFECTS ON SEEPAGE RATES

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY R. C. Dietz	DATE 8/82	CHECKED BY RP Harbek		DATE 12-'82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12-82	
APPROVED BY	DATE	EXXON D.E. Moe		DATE	
DRAWING NO	FIGURE 11-6	SHEET OF		REVISION 0	

TABLE 11.3

MAXIMUM SEEPAGE RATES[a]

LINER MATERIAL	LINER THICKNESS (feet)	SEEPAGE RATE LINER ONLY (gpm)[b]	R[c] %	SEEPAGE RATE LINER AND UNDERDRAIN[d] (gpm)	R[c] %
Soil Lined-Till[e]	0	310	100	310	100
Compacted Till[f]	0.5	213	69	10	3
Bentonite-Till[g]	0.25	212	68	6	2
Bentonite-Till[g]	0.5	160	52	5	2
Bentonite-Till[g]	1.0	108	35	4	1
Bentonite-Till[g]	2.0	65	21	3	1
Synthetic[h]	0.003	1	0.3	0.005	0.002

[a] Seepage quantities are based on a 100 acre, 50 feet deep pond. Tailings permeability = 1.6×10^{-7} feet per second.

[b] gpm = Gallons per minute.

[c] R = Ratio of seepage rate for any liner and underdrain condition to seepage rate for a soil lined-till pond.

[d] Water depth in underdrain = 0.25 feet.

[e] Permeability of soil-lined till = 3×10^{-6} feet per second.

[f] Permeability of compacted till = 3.3×10^{-9} feet per second.

[g] Permeability of bentonite-till liner = 1.6×10^{-9} feet per second.

[h] Permeability of synthetic liner = 3.3×10^{-14} feet per second.

This comparison shows the effectiveness of the underdrain in reducing the maximum seepage rate from a pond. Table 11.3 presents the results of these calculations for the other liner materials. The table also indicates that increasing liner thickness in ponds with underdrains does not have a substantial effect on the maximum seepage rate.

A 6-inch compacted till liner substantially reduces the total volume of seepage from that of the unprepared soil lined pond. The liner and underdrain reduce the total volume of seepage still further. The total volume of seepage from a pond with a 3-inch bentonite-till liner is estimated to have an approximate 33 percent reduction from that of the unlined pond, beginning at its operation. Over the same period, the total volume of seepage from the pond with a liner and underdrain is estimated at approximately 2 percent of the volume from the unlined pond.

Considering only the analytical aspects of the soil-bentonite liner with respect to seepage performance, it is apparent liners ranging in thickness from 3 to 6 inches give very satisfactory results. As described above, with the combination underdrain and liner system, the liner thickness is not a significant factor in the strict analytical evaluation of seepage. However, there is a requirement, as the thickness is reduced to provide increasingly tighter construction controls to assure the minimum thickness and design permeability coefficients are being achieved.

Although as shown above a liner thickness of 3-6 inches has been shown to be adequate the new increased thickness liner has been selected to provide an additional measure of security and redundancy above that afforded by the thinner liner. The following section (11.3) covering construction aspects of the seepage control system provides additional information related to the final liner thickness choice of 8 inches.

In evaluating the underdrain system, the following design characteristics were examined: alternate material requirements and sources, varying thicknesses for both drain and filter, and varying pond bottom slope conditions. A conservative thickness varying between 6 and 12 inches has been designed for the drain. Hydraulically, a thickness of less than 1 inch is adequate to move the water through the drain.

The analyses performed also show that the seepage rate at the base of the liner will not likely be affected by the subsurface soil conditions for seepage rates less than 1,800 gallons per minute per 100 acres (Golder, 1982a). It was also shown that even for unlined ponds, pooled water at a ratio of 1.2 or greater to tailing depths would be necessary to have seepage rates greater than 700 gallons per minute per 100 acres. Thus, the MWDF subsurface soil conditions are not expected to affect seepage rates at the base of the liner (Golder, 1982a).

11.3 Construction Aspects

To maximize control of liner thickness a pavement-type installation plan has been adopted for liner placement. Liner thickness control initially was proposed to be achieved using standard surveying technology for both subgrade and control of the final liner surface through a grid of grade stakes. Liner placement with a paver provides greater assurance of thickness control with less subgrade control. Also, with the pavement placement technique the liner will be placed in two 4-inch lifts with seams offset between overlying lifts. This procedure affords additional measures of security and redundancy over a single layer placement.

As part of the earlier studies, a mix in place liner alternative was rejected in favor of the proposed central mix system. Although more expensive, the central mix system was judged to offer better quality/control assurance regarding the overall uniformity and performance characteristics of the liner mix.

11.4 Seepage Control System Cost Comparisons

Cost comparisons for the seepage control alternatives were included as components of the system were evaluated and developed. Costs of alternative liners were evaluated in the liner report by Golder (1981c) and bentonite modified soil liner costs were compared to native clay liner costs by Exxon Minerals Company (1983b). Underdrain costs were developed by INDECO (1982).

Relative cost comparisons of a synthetic membrane liner versus bentonite modified soil liners are included below. Approximate costs, as estimated by Exxon Minerals Company (1983b) for a 5-foot thick native clay liner, are also included. All of the costs presented were updated by Exxon Minerals Company in 1983. The cost of individual components of the seepage control systems can be compared directly or they can be combined to form an alternative system, i.e., an underdrain layer over a synthetic liner. Also, costs for varying thickness bentonite modified soil liners can be determined by factoring up or down the cost for the 8-inch thickness. The bentonite modified soil liner cost is based on a central mix, haul, and paving type placement process. A mix in-place alternative would lower the overall cost and bentonite adjustments would increase or lower costs directly according to the bentonite content change.

The approximate installed costs (contractors' cost including indirect and field labor overhead) for seepage control systems and components as determined for the MWDF are listed below. All costs are in constant 1983 dollars:

		$/ft^2
1)	Bentonite Modified Soil Seepage Control System	
a.	8-inch (2-4 inch lifts) thick bentonite modified till liner	$0.55
b.	nominal 8-inch (varies 6-12 inches) thick underdrain layer of processed till	0.22
c.	12-inch thick filter layer of unprocessed till	0.14
	Total Cost	$0.91
2)	Membrane Liner and Underdrain Seepage Control System	
a.	synthetic liner including subgrade preparation - 40 mil polyethylene	$0.66
b.	nominal 8-inch thick underdrain layer of processed till	0.22
c.	12-inch thick filter layer of unprocessed till	0.14
	Total Cost	$1.02
3)	Native Clay Liner and Underdrain Seepage Control System	
a.	5-foot thick native clay liner hauled from Fence area in Florence County	$4.10
b.	nominal 8-inch thick underdrain layer of processed till	0.22
c.	12-inch thick filter layer of unprocessed till	0.14
	Total cost	$4.46

In any of these alternative seepage control systems an equally important component is the underdrain. In performing its function to reduce the pressure head acting on the liner, seepage quantities will be minimized.

11.5 Reclamation Cap Design and Water Balance Analysis

To aid in designing the cover system for the MWDF, four capping systems were analyzed using a water balance model (Owen Ayres and Associates, Inc., 1982; Ayres Associates, 1984, 1985):

Alternative 1:	36 inches glacial till underlain by a 6-inch bentonite modified soil seal layer.
Alternative 2:	36 inches glacial till underlain by a 8-inch coarse drain, in turn, underlain by a 6-inch bentonite modified soil seal layer.
Alternative 3:	28 inches glacial till underlain by a 8-inch coarse drain, in turn, underlain by a 6-inch bentonite modified soil seal layer.
Alternative 4:	5 feet glacial till underlain by a 8-inch coarse sand drain, in turn underlain by a 40 mil polyethylene membrane, in turn underlain by a 8 inch (4-inch lifts) bentonite modified soil seal layer.

Of the above capping system designs, Alternative 2 was initially selected as the preferred cap system. Additional study and design in response to DNR concerns about Alternative 2 lead to a design revision presented as Alternative 4 , the proposed cap design. The design and selection of Alternative 4 is discussed in greater detail in the Reclamation Plan and in Ayres Associates (1984) report.

The use of a geomembrane in the cap was considered feasible even though its use had previously been rejected as a pond liner alternative. A geomembrane incorporated in the cap design could be repaired or replaced in the cap if ever necessary. Also, the primary feature of the geomembrane, its very low permeability, is used to maximum advantage in reducing seepage through the cap, therefore minimizing long-term MWDF steady state seepage. The membrane in conjunction with the 8 inch bentonite modified seal and the 5 foot protective cover layer adds significantly to the redundancy and security of the overall reclamation cap in offering a sound engineering approach in minimizing long-term seepage.

Other studies related to the reclamation cap alternatives have dealt with handling of the drain layer water as it is carried to the perimeter of the MWDF. All of the alternatives had the objective of reincorporating the drain layer water as ground water recharge within the immediate perimeter area of the MWDF. The proposed design presented in Section 9.4 achieves this objective and reintroduces the drain water within the limits of the embankments of the MWDF.

Additional alternative studies for seal preparation and placement have been completed in conjunction with those for the pond bottom liner. Basically the same conclusions reached for the pond bottom liner have been applied to selection of the reclamation seal regarding liner preparation, thickness, and placement or construction procedures.

Extensive moisture balance analysis work was completed for all of the alternatives for normal rainfall, wet and dry years.

Cap designs for Alternatives 2 and 3 differed from that used in Alternative 1 by the inclusion of a 8-inch thick coarse drain layer between the glacial till top layer and the bentonite modified soil seal. Inclusion of a coarse drain layer prevented saturation of the glacial till overburden (Owen Ayres and Associates, Inc., 1982) by admitting free drainage from the overburden at all times. In the wettest year, no adverse soil water conditions would occur. Potential difficulties with Alternative 3 could occur during dry periods. The water balance calculations indicate that in an average year, dry soil moisture conditions would occur in August and September, whereas in the driest year, such conditions would exist for 5 months. Such patterns of soil moisture storage, availability and drainage in the Alternative 4 system would actually reflect naturally occurring conditions on similar soils in undisturbed areas of the Project site.

Alternative 4, the proposed design described in Chapter 9, is similar to Alternatives 2 and 3 but improves on their water balance performance. Also, the increased protective layer thickness allows more overall soil moisture storage thereby lessening possibilities of soil drying. The incorporation of a synthetic membrane reduces a very minimal final seepage rate to almost a negligible amount.

Regardless of the alternative chosen for the reclamation cap, the seepage rates from the ponds will be reduced after the reclamation cap is in place eventually reaching a rate equal to the rate of infiltration through the reclamation cap (i.e., steady-state conditions).

Reanalysis by Ayres Associates for the currently proposed site 41-114C facility produced very similar reclamation cap water balance components (Ayres Associates, 1985). The similarity to the 1984 study results did not warrant change to the previously selected overall seepage and runoff values.

Additional details of the moisture balance analysis work and the revegetation aspects for the various reclamation cap alternatives are presented in the Ayres' reports (Ayres Associates, 1984, 1985) and Chapter 3 of the EIR.

11.6 Operating Methods

11.6.1 General

Three different operating methods have been evaluated for the proposed MWDF: wet (or subaqueous), subaerial, and dry. Throughout the entire study and design process for the proposed MWDF, the approach was to assume that unless a better concept is found, the wet method would be used because it is technically proven.

The wet concept is at one end of the operating spectrum and the dry concept is at the other. The subaerial concept is a combination of the wet and dry concepts. Like the wet concept, it involves slurry transport of the waste to the facility, but the waste is air dried after it is deposited at the facility. Wet, subaerial, and dry operating methods are discussed below. Additional, generalized information covering alternative disposal methods and other aspects of tailings disposal is presented in Vick (1983).

11.6.2 Wet (Subaqueous) Method

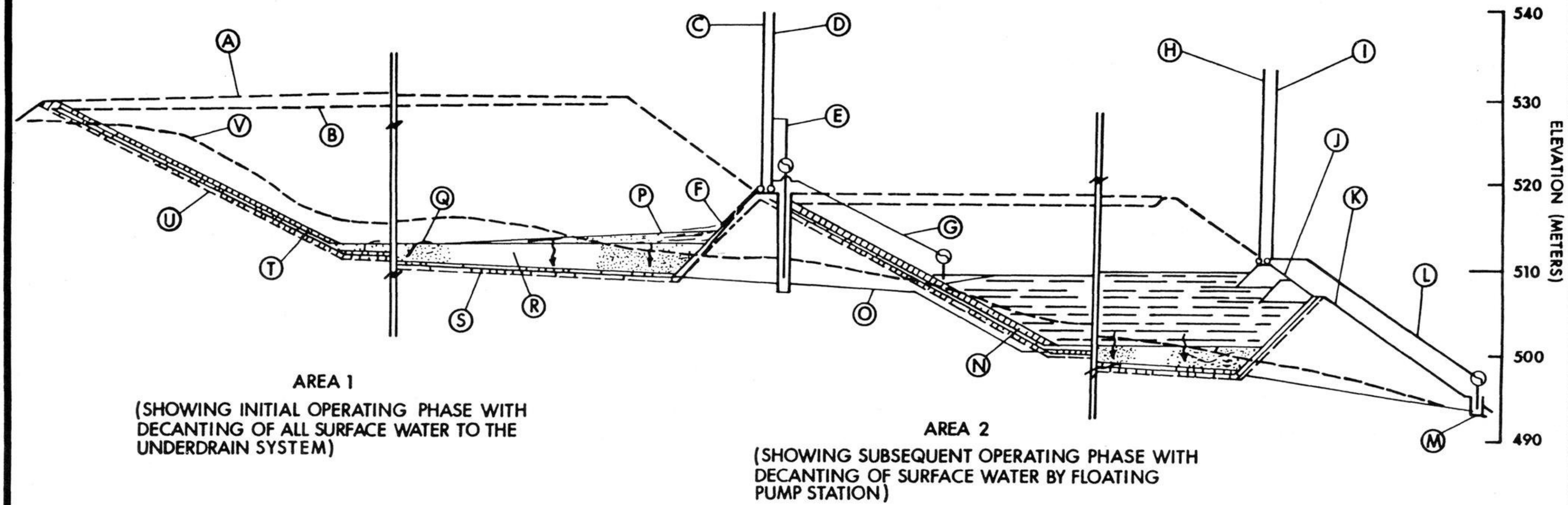
The wet method, chosen as the preferred operating method, has been thoroughly described in Section 9.0.

The liner for the proposed MWDF will be designed to inhibit seepage from the mine wastes and water. The water will be decanted from the facility and recycled and treated for further use or discharge. Also, leachate from the underdrain of the MWDF will be collected, recycled, and treated. The use of an underdrain, and also the tails thickening step eliminating 90 percent of the water coming to the pond with the tailings, and other measures (such as pond phasing) all tend to improve the pond water balance. These measures result in a modified or hybrid wet system which will perform substantially better than a more conventional wet system design with respect to seepage control.

11.6.3 Subaerial Method

With a subaerial operation, waste rock would still be dry hauled to the facility. The facility access corridor would be identical in size and design to the wet method corridor. As with the wet method, tailing wastes and water treatment sludge will be slurried to the MWDF. However, the water would be allowed to evaporate and drain at the MWDF (Figure 11-7). The dried or dewatered mine wastes consisting of small sized particles would then consolidate into a relatively impermeable deposit. The only liquid collected would be the drainage from the newly layered tailings and any atmospheric precipitation on the facility. Like the wet method, a subaerial facility would also have a liner and leachate collection system (Figure 11-7).

The subaerial method may achieve greater in-place tailing densities through more intensive management of the tailings as they are deposited in the waste facility, resulting in greater strength and lower permeability. In the subaerial facility, tailings deposition is cycled from area to area within the facility. An approximate 4 inch layer of tailings is deposited in one area of the pond and then the operation is moved to another area, while the drying and consolidation process begins on the first area. Based on climatic conditions and the rate of tailings production, the number of areas within a facility are planned so that after a complete cycle, the first area is ready for another



A. SURFACE COVER GRADED TO REDUCE PRECIPITATION INFILTRATION
B. FINAL OUTLINE OF TAILINGS SURFACE
C. TAILINGS FROM MILL
D. RECYCLED WATER TO RECLAIM POND
E. WATER FROM UNDERDRAIN COLLECTOR SUMP RECYCLED TO RECLAIM POND DURING OPERATING PHASE
F. SPRAY BAR FOR SUB-AERIAL DEPOSITION OF TAILINGS
G. WATER FROM SUPERNATANT POND DECANTED BY FLOATING PUMP STATION AND RECYCLED TO RECLAIM POND
H. TAILINGS FROM MILL
I. RECYCLED WATER TO RECLAIM POND
J. INTERMEDIATE CONFINING EMBANKMENT
K. STARTER EMBANKMENT
L. WATER FROM UNDERDRAIN COLLECTOR SUMP RECYCLED TO RECLAIM POND DURING OPERATING PHASE
M. LONG TERM SINGLE POINT GRAVITY WATER FLOW MONITORING SYSTEM FOR VERTICAL SEEPAGE FROM TAILINGS DEPOSIT
N. INTERMEDIATE SEAL
O. VALVED OUTLET PIPE CONNECTED TO AREA 2 UNDERDRAIN SYSTEM
P. TAILINGS BEACH
Q. GRAVITY DRAINAGE OF ALL SURFACE WATER INTO UNDERDRAIN SYSTEM
R. FINE FILTER BLANKET
S. COARSE FILTER BLANKET
T. INTERMEDIATE SEAL
U. UNDERSEAL
V. ORIGINAL GROUND LEVEL

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
SUB-AERIAL METHOD

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY BWM	DATE 07/22/82	CHECKED BY R P Hart	DATE 12-'82		
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12-82		
APPROVED BY	DATE	EXXON	DATE		
DRAWING NO **FIGURE 11-7**		SHEET ___ OF ___	REVISION NO 0		

layer of tailings. Drying of the tailings in thin layers produces an over-consolidation of the tailings which increases densities approximately 25 to 30 percent compared to those obtained with the wet method (Knight and Piesold, 1982). Increased densities and some differential settling by size of tailings in each layer also reduces vertical permeability.

Overall, because of the increased deposited densities, the size of the required facility is considerably smaller than the wet method design being proposed. For comparison, the original wet method facility proposed requires approximately 499 acres versus 276 acres for a subaerial facility addressing the same orebody size. However, because of the necessary method of operation, the entire subaerial facility must be operated for most of the mine life and the concept of phasing as used in the proposed facility cannot be employed.

Although a subaerial facility would also include a leachate management system similar to that planned for the wet method facility, the reduced permeability and water content of the deposited tailings aids in the control of seepage. For the subaerial facility, a higher portion of water is handled through the surface water decant system.

Another major advantage with a subaerial facility is the material strengths that are achieved through the deposition method. Also, earthwork required for the subaerial method facility embankments is reduced by approximately a third because of upstream construction (Knight and Piesold, 1982). With the tailings becoming a part of the embankments, the areal size of the facility is substantially reduced.

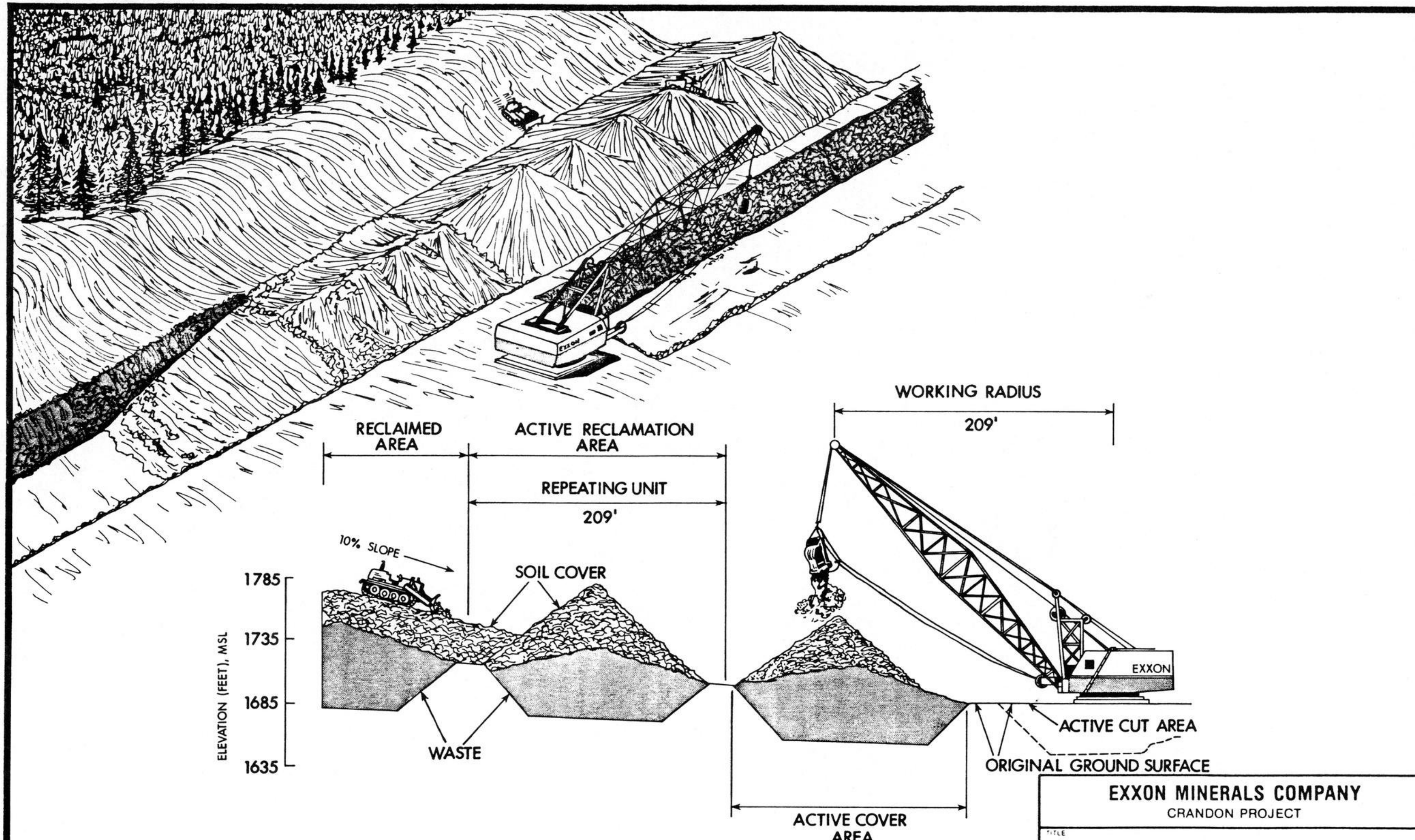
Work with the subaerial method has progressed to a completed preliminary design for a facility. The preliminary design includes laboratory testing and has continued to provide increased confidence in the system (Knight and Piesold, 1982). However, there is a lack of operating experience for subaerial facilities with climatic conditions similar to northern Wisconsin. This operating experience will be available in the next few years from facilities now under construction in Canada. This evidence, coupled with the reduced environmental effects of the system and the major capital cost savings provided, suggests potential for revision of the MWDF design to a subaerial method at a later time.

11.6.4 Dry Method

The "dry" method involves transporting all mine wastes to the MWDF in relatively dry form by truck or conveyor belts. The waste rock would be dry, although the tailings waste from the mill would contain some water (<20%). The milling and concentrating processes use water and the tailing wastes are generated wet. However, they would be dewatered at the mill to <20 percent water to waste ratio by weight and then hauled or conveyed to the proposed MWDF.

The access corridor to the facility would be somewhat smaller for the dry method than for the wet and subaerial techniques, because the transport system (pipes, drainage basins, maintenance road) would be eliminated or much smaller in size. The corridor would still contain a road and utility lines.

Like the subaerial method, the dry method does not require massive earth embankments, greatly reducing the acreage required for the facility. This is a major advantage. Wastes would be compacted into large cells or trenches (Figure 11-8). In addition, the dry method has several feet of soil for final cover and reclamation of the waste. Soil materials for cover are not needed until areas of the facility reach final grades.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE

DRY METHOD

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY BWM	DATE 07/20/82	CHECKED BY C P Herbst	DATE 12-'82
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12-82
APPROVED BY	DATE	EXXON D. T. Hoe	DATE 1/1/83
DRAWING NO **FIGURE 11-8**		SHEET ___ OF ___	REVISION NO. 0

A cut-and-cover operation was studied whereby trenches are excavated in step with tailings production and the tailings are deposited and covered continuously. Figure 11-8 is an example of such a dry method facility. One alternative for the dry method facility is a somewhat conventional landfill type operation that basically stacks the tailings above ground and then covers them periodically.

Although there are potential cost and environmental advantages to a dry disposal system, there are unknowns associated with dewatering the tailings for transport to a MWDF (Scheiner, 1982). However, with the phasing concept proposed with the wet method, a dry disposal facility could be proposed at a later date. Depending upon future developments in the area of tailings dewatering, a dry system pilot operation may be included in early operating plans. Based on the results of such a pilot operation, a conversion to a dry disposal system for the later stages of the MWDF operation could be accomplished in a relatively short time.

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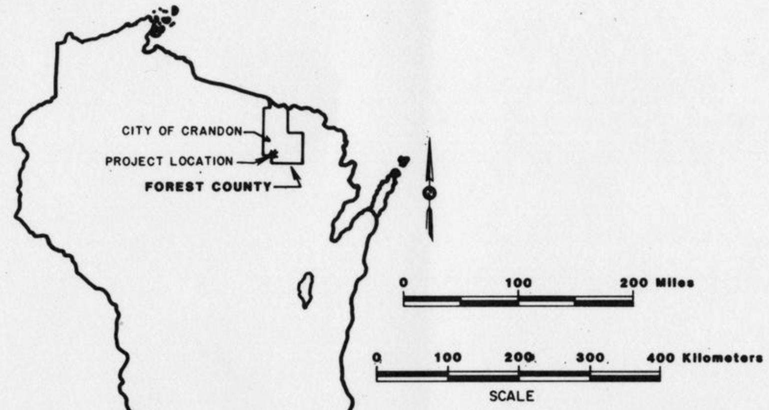
EXXON MINERALS COMPANY

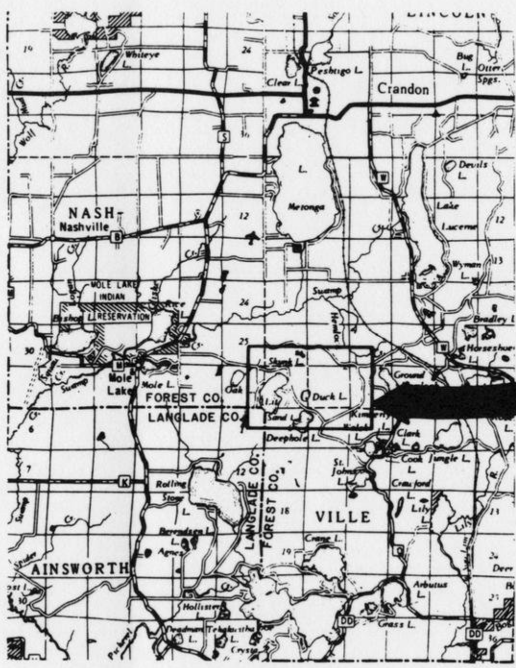
CRANDON PROJECT

NR 182.08

FEASIBILITY REPORT PLAN SHEETS
MINE WASTE DISPOSAL FACILITY
SITE 41-114C



COUNTY MAP

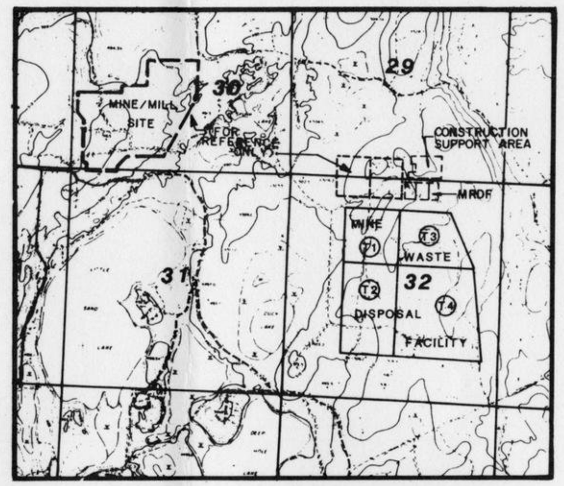


VICINITY MAP

0 1 2 3 4 Miles

0 2 4 6 8 Kilometers

Scale



SITE MAP

0 1/2 1 Miles

0 1 2 Kilometers

Scale

INDEX	
SHEET	TITLE
1	TITLE SHEET
2	MWDF AREA EXISTING CONDITIONS / LAND USE
3	MINE WASTE DISPOSAL FACILITY AREA LAND OWNERSHIP & ZONING MAP
4	CRANDON PROJECT FACILITIES
5	MINE WASTE DISPOSAL FACILITY AREA SITE 41-114C
6	BORING AND GEOLOGY SECTION PLAN
7	BORING AND GEOLOGY PROFILES SECTION A-A
8	BORING AND GEOLOGY PROFILES SECTION B-B
9	BORING AND GEOLOGY PROFILES SECTION C-C
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22	UNDERDRAIN & COLLECTION PIPE DETAILS
23	UNDERDRAIN COVER, ACCESS ROAD AND CREST DETAILS
24	ROCK SLOPE PROTECTION PLAN
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33	RECLAMATION CAP PERFORMANCE MONITORING LOCATION
34	MONITORING WELL LOCATIONS
35	MONITORING DETAILS
36	CONSTRUCTION SUPPORT AREA - PLAN AND ELEVATION

PLAN SHEET 1

FOR SUBMITTAL TO WISCONSIN DNR

INITIAL SUBMITTAL - 12/82

REVISED SUBMITTAL -11/85

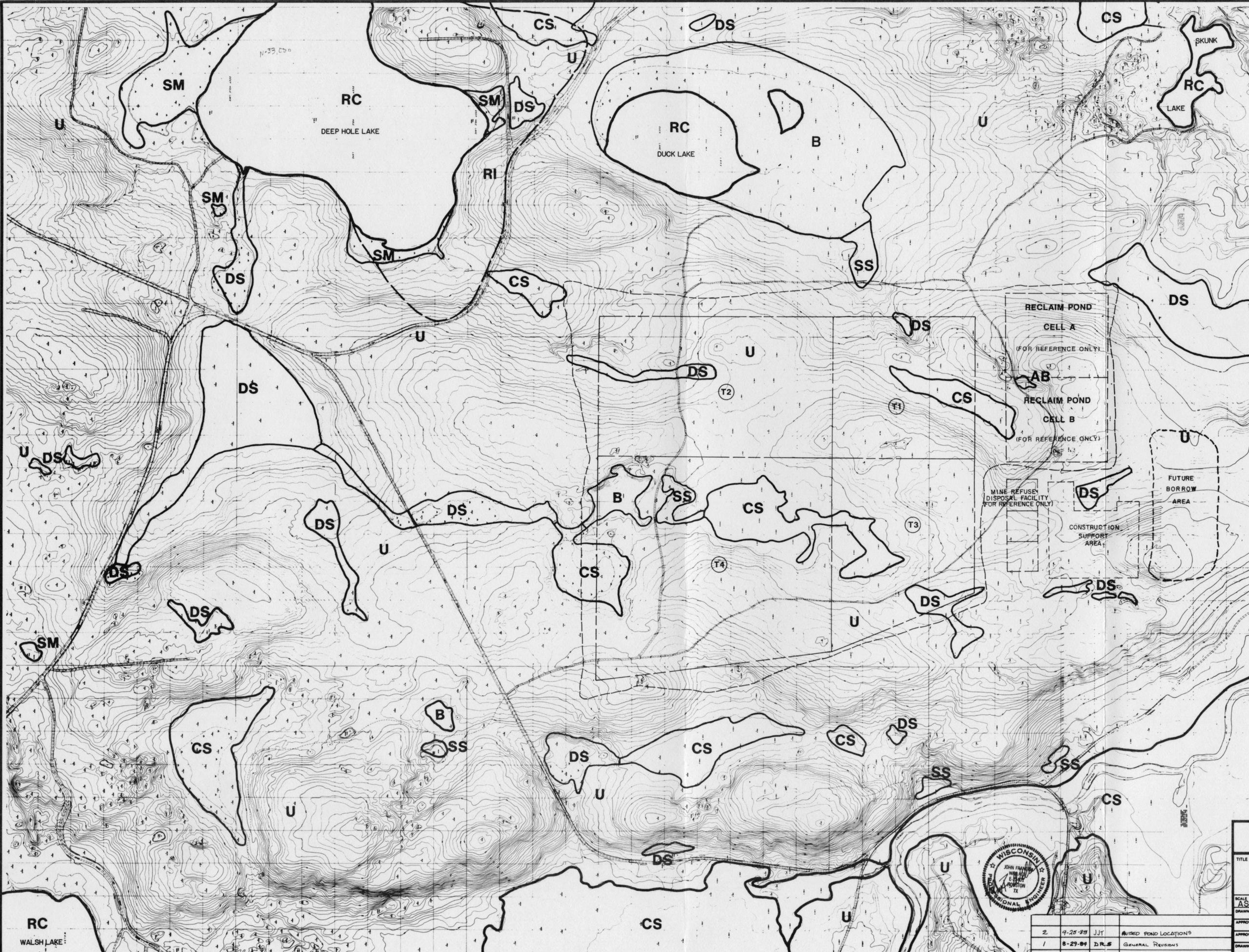
REVISED	DATE	BY	DESCRIPTION
2	9-24-85	JJT	REVISED POND LOCATIONS, RENUMBERED PLAN SHEETS
NO.1	8-31-84	DRS	ADDED PLAN SHEETS 26-37

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: TITLE SHEET

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: C.A. HACKER	DATE: 7/82	CHECKED BY: cc Schroeder	DATE: 12/6/85
APPROVED BY	DATE	APPROVED BY: J.W. Ellen	DATE: 12/7/85
APPROVED BY	DATE	EXXON: D.E. Moe	DATE: 12/9/85
DRAWING NO		SHEET 1 OF 36	REVISION NO 2



REVISED	DATE	BY	DESCRIPTION
2	9-25-85	JJT	Revised Pond Locations
1	8-29-84	DRS	General Revisions

LEGEND

- U - UPLAND FOREST
- DS - DECIDUOUS SWAMP
- CS - CONIFEROUS SWAMP
- SS - SHRUB SWAMP
- SM - SHALLOW MARSH
- AB - AQUATIC BED
- B - BOG
- RI - RESIDENTIAL/INSTITUTIONAL
- RC - RECREATIONAL

NOTES

1. NO THREATENED OR ENDANGERED SPECIES HABITAT
2. NO ARCHAEOLOGICAL OR HISTORICAL SITES

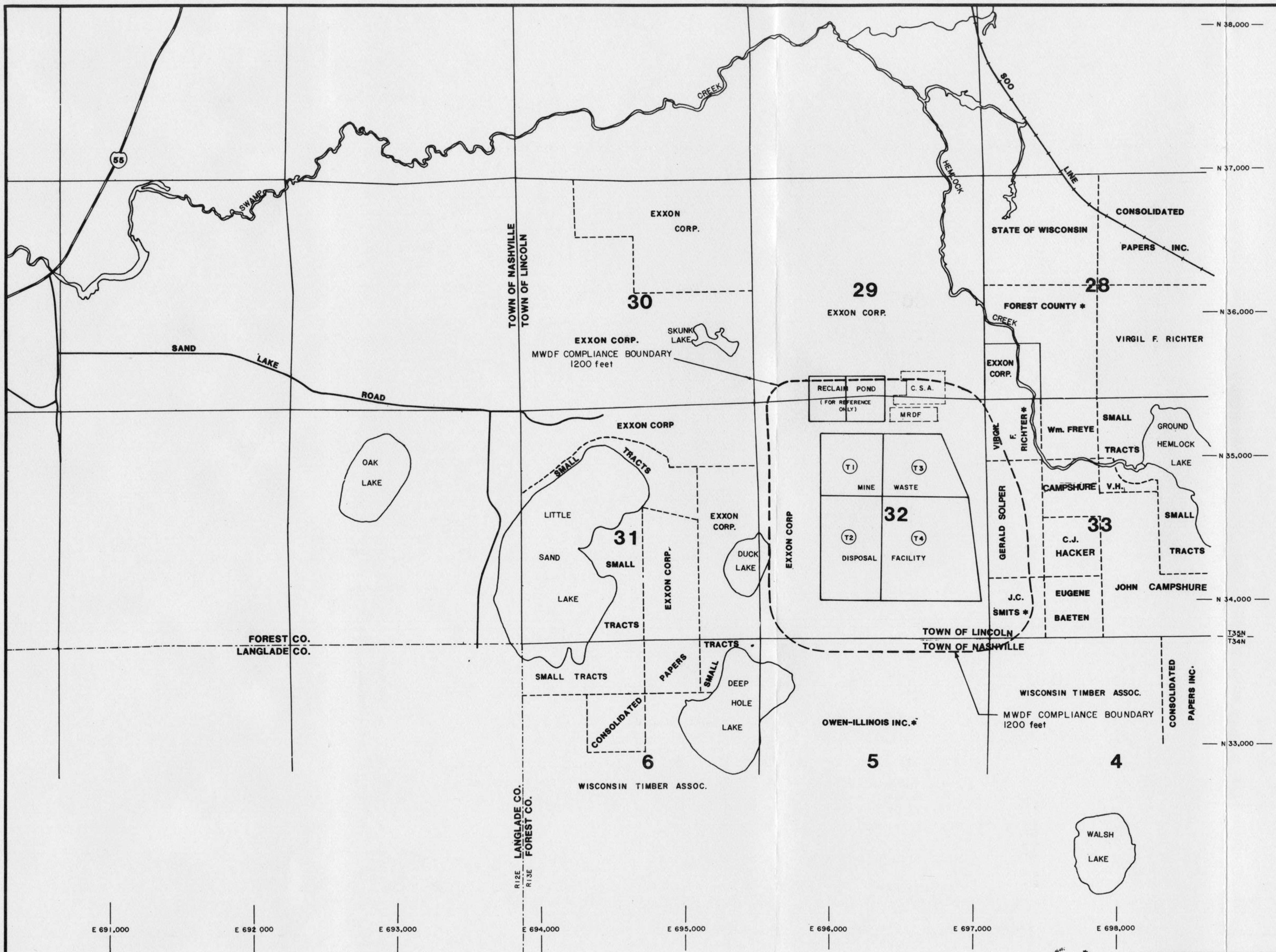
Typical Representation: Refinements may be made during final design.

0 400 800 1200 1600
SCALE IN FEET

0 100 200 300 400 500
SCALE IN METERS

PLAN SHEET 2

EXXON MINERALS COMPANY CRANDON PROJECT				
TITLE: MWDF AREA EXISTING CONDITIONS/LAND USE				
SCALE: AS SHOWN	STATE: WISCONSIN		COUNTY: FOREST	
DRAWN BY: C. HACKER	DATE: 8/82	CHECKED BY		DATE
APPROVED BY	DATE	APPROVED BY: J.E. Willen		DATE: 11/27/85
APPROVED BY	DATE	EXXON: D.E. Moe		DATE: 12/4/85
DRAWING NO.			SHEET 2 OF 36	REVISION NO. 2



NOTES:

1) ZONING IS ALL GENERAL RURAL EXCEPT THOSE LANDS WITHIN 300 FEET FROM NORMAL HIGH WATER MARK OF CREEKS AND STREAMS AND 1000 FEET FROM NORMAL HIGH WATER MARK OF LAKES WHICH ARE ZONED AS SHORELINE

2) MAP COORDINATES ARE IN METERS REFERENCED TO WISCONSIN STATE PLANE COORDINATE SYSTEM

3) *. EXXON LAND PURCHASE OPTION

LEGEND

T1 TAILINGS POND NO. 1

0 250 500 750 1000 Meters

SCALE 1:12,500

0 1000 2000 3000 Feet

PLAN SHEET 3

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: MINE WASTE DISPOSAL FACILITY AREA LAND OWNERSHIP & ZONING MAP

REVISED	DATE	BY	DESCRIPTION
No. 1	9-25-85	JJT	POND RELOCATION & LAND OWNERSHIP

Typical Representation: Refinements may be made during final design.

SCALE 1:12500	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY JP BECKER	DATE 9/82	CHECKED BY CC Schroeder		DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY JEW [illegible]		DATE [illegible]	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 12/4/85	
DRAWING NO			SHEET 3 OF 36		REVISION NO. 1

GBS 5/1981

PLAN SHEET 4

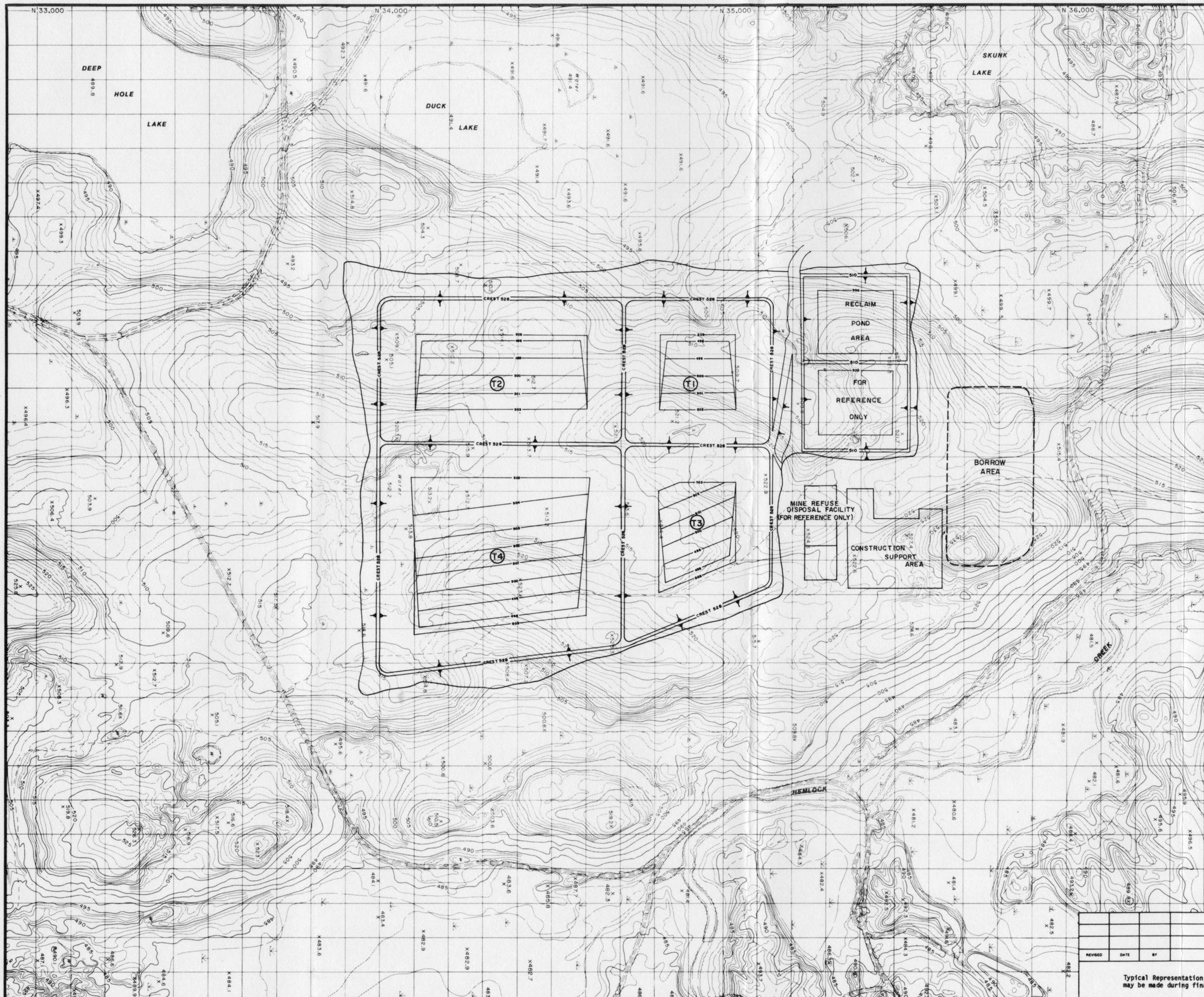
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: **CRANDON PROJECT FACILITIES**

SCALE: SHOWN	STATE: WISCONSIN	COUNTY: FOREST			
DRAWN BY: DR SPRINGBORN	DATE: 10/85	CHECKED BY: C.C. Schroed	DATE: 12/6/85		
APPROVED BY		APPROVED BY: J. Miller	DATE: 1/27/86		
APPROVED BY	DATE	EXXON: D.S. Moe	DATE: 12/18/85		
DRAWING NO		SHEET 4 OF 31	REVISION NO 0		

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.



WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA			
Tailings and Reclaim Pond Area (ac) (1)	390	Abandonment Cover Seal Thickness (in)	8
Tailings Pond Abandonment Area (ac.) (2)	360	Minimum Abandonment Cover Thickness (ft.)	5
Wetlands Covered (ac.) (3)	46	Underdrain Drain Layer Thickness (in)	6-12
Pond Excavation ($x 10^6 yd^3$)	14.99	Minimum Underdrain Filter Layer Thickness (in)	12
Till Embankment Fill ($x 10^6 yd^3$)	7.95	Minimum Rock Slope Protection Thickness (ft)	3.0
Minimum Crest Width (ft) (5)	16.00	Reclaim Pond Synthetic Liner Thickness (in)	0.036
Tailings Pond Reclamation Cap Synthetic Membrane Thickness (in)	0.040	Reclaim Pond Till/Bentonite Liner Thickness (in)	8
Tailings Slope (%)	0.5	Sand Cushion Above Synthetic Liner ($x 10^6 yd^3$)	0.09
Abandonment Cover Slope (%) (Varies)	1-2	Sand Cushion/Drain Layer Below Synthetic Liner Thickness (in)	12
Till/Bentonite Tailings Pond Liner Thickness (in)	8	Protective Cushion Above Synthetic Liner Thickness (in)	18
Abandonment Cover Drain Layer Thickness (in)	8	Transition Below Reclaim Pond Rock Slope Protection Thickness (in)	12

POND DATA / POND NUMBER	RECLAIM POND DATA FOR REFERENCE ONLY						
	CELL A	CELL B	T1	T2	T3	T4	Σ
Period of Use (yrs.) (4)	2-32	3-32	3-7	7-14	14-21	21-32	—
Area Inside Crest (ac)	18	18	43	71	50	107	307
Bottom Area (ac)	10.5	10.5	9	22	12	39	103
Lined Slope Area (ac)	6.5	6.5	35	50	39	70	207
Maximum Interior Depth (ft)	33	33	99	99	99	99	—
Maximum Exterior Fill Heigth (ft)	35	—	110	107	36	77	—
Crest Elevation (ft)	1673	1673	1732	1732	1732	1732	—
Lowest Bottom Elevation (ft)	1640	1640	1633	1633	1633	1633	—
Struck Storage Volume ($x 10^6 yd^3$)	0.83	0.83	3.56	6.59	4.25	10.46	24.86
Design Storage Volume ($x 10^6 yd^3$)	—	—	3.1	5.7	3.7	9.1	21.6
Till Excavation ($x 10^6 yd^3$)	3.82		1.21	2.35	2.44	5.17	14.99
Till Embankment ($x 10^6 yd^3$)	0.36		2.25	2.81	0.69	1.84	7.95
Synthetic Liner/Reclamation Seal Area (ac.)	36		43	71	50	107	307
Till/Bentonite Liner Volume ($x 10^6 yd$)	0.040		0.047	0.077	0.055	0.117	0.336
Underdrain Drain Material Volume ($x 10^6 yd$)	0.040		0.039	0.067	0.046	0.104	0.296
Underdrain Filter Material Volume ($x 10^6 yd^3$)	—	—	0.071	0.116	0.082	0.176	0.445
Rock Slope Protection Volume ($x 10^6 yd^3$)	0.053		0.047	0.093	0.053	0.094	0.340
Abandonment Cover Volume ($x 10^6 yd^3$) (6)	—	—	1.03	1.64	0.90	2.03	5.60
Till/Bentonite Abandonment Cover Seal ($x 10^6 yd^3$)	—	—	0.046	0.076	0.054	0.115	0.291
Abandonment Cover Drain Layer ($x 10^6 yd^3$)	—	—	0.046	0.076	0.054	0.115	0.291
Underdrain Collector Pipe Length (ft)			590	1500	660	1510	4260

Notes:

1. Measured to outside toe of slope.
2. Includes tailings ponds only.
3. Represents wetland areas within toe of facility.
4. Start of construction for Crandon Project of beginning of year one. Schedule includes 30 months construction, 29years operation and 4 years reclamation.
5. Crest width varies from 16 feet to 23 feet depending on number of pipelines along crest.
6. Includes material for grading below top seal and 5 feet of till cover over top seal.

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER
JOHN FRANCIS WALLACE
HOUSTON - TX

PLAN SHEET 5

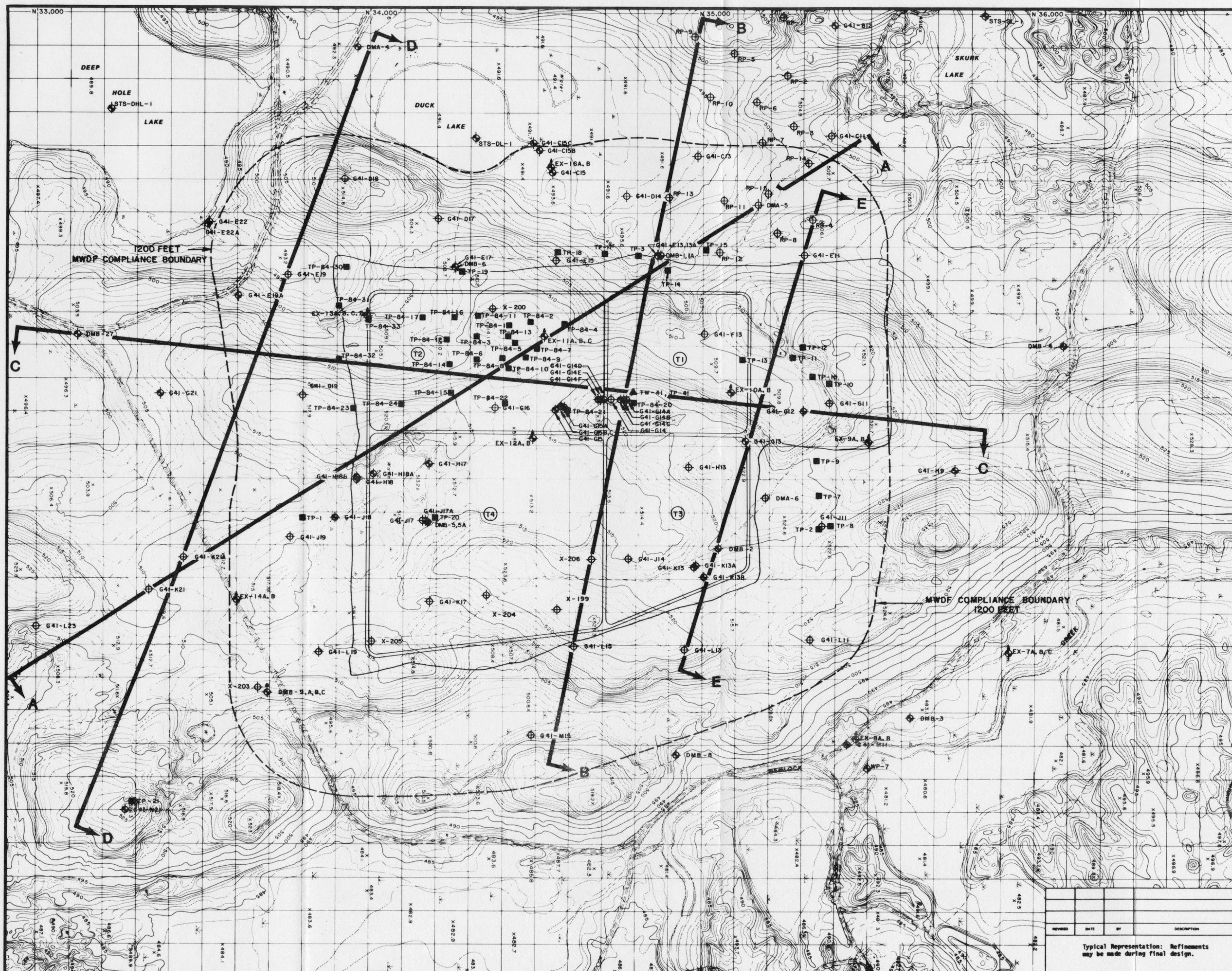
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE MINE WASTE DISPOSAL FACILITY AREA
SITE 41-114C

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY J.J.T.	DATE 9-27-85	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY J F Wallace		DATE 11/27/85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 12/4/85	
DRAWING NO			SHEET 5 OF 36	REVISION NO 0	



LEGEND:

- TEST BORING LOCATION
- TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
- TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
- GOLDER ASSOCIATES & STS LTD., TEST PIT LOCATION
- GOLDER ASSOCIATES TEST WELL TW-41 LOCATION
- DAMES & MOORE TEST WELL TW-1 LOCATION
- USGS OBSERVATION WELL LOCATION
- A — A BORING AND GEOLOGIC CROSS-SECTION LOCATION
- (T2) POND NUMBER

NOTES:

1. FOR SECTIONS A-A THROUGH E-E SEE DRAWING NUMBER 050-1-81340 THROUGH 050-1-81344 (PLAN SHEET Nos. 7 THROUGH 11)
2. INSPECTION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION AND REPORT REFERENCES FOR LOGS AND DETAILS AS FOLLOWS:

BORING PREFIX	INSPECTION BY	REPORT REFERENCE FOR DETAILS
G40, G41, and TP	GOLDER ASSOCIATES	GOLDER ASSOCIATES, "GEOTECHNICAL REVIEW, CRANDON PROJECT WASTE DISPOSAL SYSTEM, PROJECT REPORT 2", VOLUMES 1, 2, and 3, OCTOBER 81.
X	EXXON MINERALS CO.	SAME AS ABOVE
DMA, DMB, and DW	DAMES & MOORE	DAMES & MOORE, "EXXON MINERALS COMPANY CRANDON PROJECT ENVIRONMENTAL BASELINE STUDY", SECTION 2.2, GEOLOGY STUDY and STUDY METHODS, APRIL 1981
TW-41	GOLDER ASSOCIATES	GOLDER ASSOCIATES, "PUMP TEST and ANALYSES, CRANDON PROJECT WASTE DISPOSAL SYSTEM, PROJECT REPORT 4", SEPTEMBER 1981.
TW-1	DAMES & MOORE	DAMES & MOORE, " INVESTIGATION OF FEASIBILITY OF DEWATERING and OTHER ALTERNATIVES FOR OPEN PIT MINE OPTION, NEAR CRANDON, WISCONSIN", MAY 1977.
FR	UNKNOWN (DATA SUPPLIED BY USGS)	GOLDER ASSOCIATES, "GROUNDWATER POTENTIOMETRIC CONTOURS, CRANDON PROJECT WASTE DISPOSAL SYSTEM, PROJECT REPORT 7", SEPTEMBER 1981.
EX, WP and STS	EXXON, STS LTD.	STS LTD., "HYDROGEOLGIC STUDY UPDATE", JUNE 1984
TP-84-1	EXXON, STS LTD.	STS LTD., "MWDF LINER MATERIALS TEST PITS", AUGUST 1984

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

WISCONSIN JOHN FRANCIS WALLACE PROFESSIONAL ENGINEER

PLAN SHEET 6

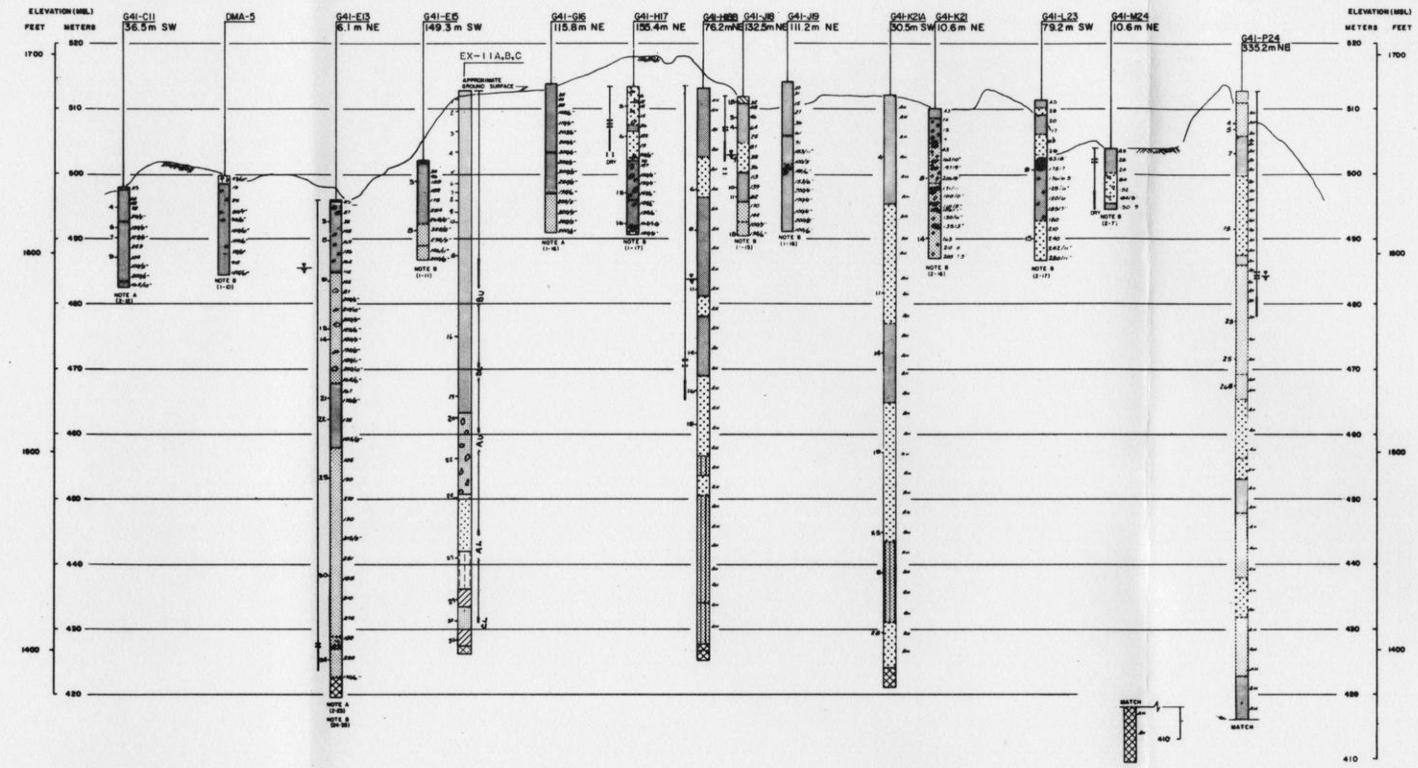
EXXON MINERALS COMPANY
CRANDON PROJECT

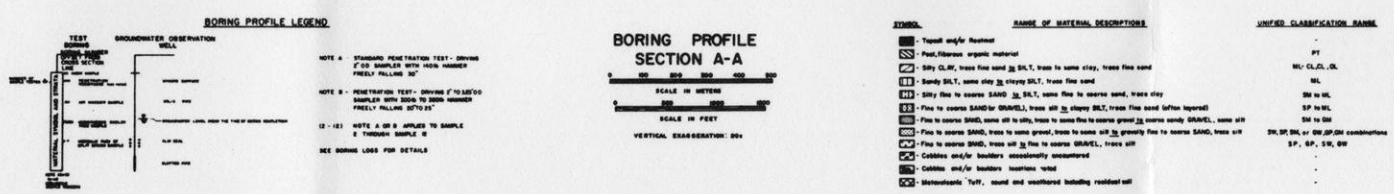
TITLE
MINE WASTE DISPOSAL FACILITY AREA
BORING AND GEOLOGY SECTION PLAN
SITE 41-114C

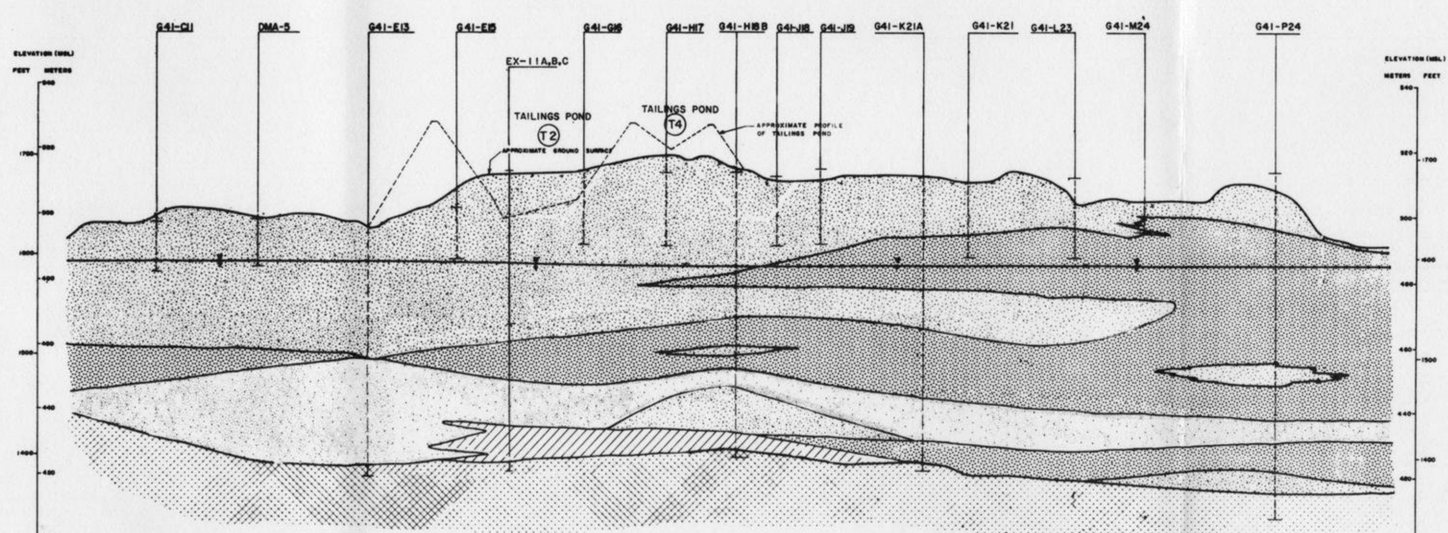
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY K.J.C.	DATE 10-1-85	CHECKED BY C L Schroeder	DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J F Wallace	DATE 12/6
APPROVED BY	DATE	EXXON D.E. Moe	DATE 12/9/85
DRAWING NO		SHEET 6 OF 36	REVISION NO 0







MAJOR GLACIAL FORMATION CATEGORIES

The Geologic Profiles are for illustrative purposes only. The distribution of the glacial formations has been inferred from the test borings shown on this section, test borings from the general site area, and trends implied from the glacial history and boring data. The actual distribution of materials may vary from that shown.

Categorization of the overburden soils into the various major glacial formations has been primarily based on the shape of the grain size curves of the samples tested. The various glacial formations do not correlate on a direct one-to-one basis with the classification of the materials by the Unified Soil Classification System. The major glacial formations are briefly described as follows:

Till: Deposited directly by a glacier, not water sorted. Fairly well graded (poorly sorted) with the uniformity coefficient (D_{60}/D_{10}) of samples tested ranging from 6 to 290 with all but nine samples being above 10. Primarily in the Unified Soil Classification System designations SM and SP-SM.

Coarse Grained Stratified Drift: Deposited by meltwater. Moderately uniformly graded (well sorted) with the uniformity coefficient of samples tested ranging from 2 to 15 with all but four being below 8. Primarily in the Unified Soil Classification System designations SP and SP-SM.

Fine-Grained Stratified Drift: Deposited by meltwater. Uniformly graded (well sorted) fine sand. Unified Soil Classification System designation SP.

Lacustrine Deposits: Deposited in bodies of still water. Commonly moderately uniformly graded (well sorted). Similar to fine grained stratified drift in the shape of the grain size curve but finer in overall grain size. Primarily in the Unified Soil Classification System designation ML.

LEGEND

GEOLOGICAL DEPOSIT SYMBOLS

- WETLAND AND MARSH
- FINE-GRAINED STRATIFIED DRIFT
- COARSE-GRAINED STRATIFIED DRIFT
- TILL
- LACUSTRINE
- BEDROCK
- INTERPRETED STRATA BOUNDARIES
- STRATA BOUNDARIES UNKNOWN

G41-H18B
GROUND SURFACE AT BORING LOCATION
BOREHOLE ON LINE OF SECTION
BOTTOM OF BOREHOLE

DMA-5
GROUND SURFACE AT BORING LOCATION
BOREHOLE OFF LINE OF SECTION
BOTTOM OF BOREHOLE

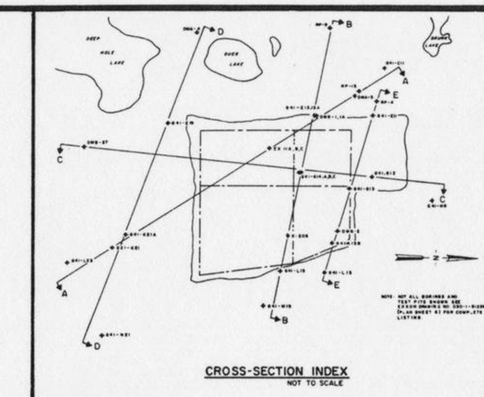
GROUNDWATER LEVEL

GEOLOGIC PROFILE SECTION A-A

0 100 200 300 400 500
SCALE IN METERS
0 500 1000 1500
SCALE IN FEET
VERTICAL EXAGGERATION: 10x

NOTES

1. PROFILE SECTION LOCATIONS SHOWN ON BORING AND GEOLOGY SECTION PLAN, DRAWING NO. 050-1-81339 (PLAN SHEET 6)
2. GROUNDWATER LEVEL PROFILE FROM GROUNDWATER POTENTIOMETRIC CONTOURS, DRAWING NO. 050-1-81117 (PLAN SHEET 12)
3. BEDROCK PROFILE FROM BEDROCK CONTOURS, STS DWG 12959-6 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984)
4. FOR BORING LOCATIONS AT EXTREME ENDS OF SECTIONS REFER TO SOIL BORING AND PIEZOMETER LOCATION MAP, STS DRAWING 12959-1 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984.



LABORATORY TEST DATA AND CLASSIFICATION OF SAMPLES TESTED

BORING NO.	SAMPLE NO.	% PASSING #200 SIEVE	UNIFORMITY COEFFICIENT D_{60}/D_{10}	PERCENT $CaCO_3$ EQUIVALENT	UNIFIED CLASSIFICATION	GEOLOGIC FORMATION (1)
G41-C11	SA-4	23	--	3.8	SM	T
	SA-6	Note 2	--	1.1	SM	T
	SA-7	Note 2	--	0.6	SM	T
	SA-9	20	--	0.8	SM	T
G41-E13	SA-3	16	10	--	SM	T
	SA-5	19	8	--	SM	T
	SA-9	11	60	--	SM	T
	SA-13&14	20	28	--	SM	T
	SA-21	18	--	--	SM	T
	SA-22	14	--	--	SM	T
	SA-25	4	2	--	SP	C
	SA-30	5	2	--	SP-SM	C
	SA-34	7	3	--	SP-SM	C
G41-E15	SA-3	23	--	--	SM	T
	SA-8	7	18	--	SP-SM	T
G41-H17	SA-3	4	7	--	SP	T
	SA-6	3	71	--	GP	T
	SA-13	15	--	--	SM	T
	SA-16	30	--	--	SM	T
G41-H18B	SA-2	22	--	--	SM	T
	SA-6	2	--	7.6	GP	C
	SA-8	25	--	0.2	SM	T
	SA-11	Note 2	--	0.5	SM	T
	SA-13	15	--	--	SM	T
	SA-14	Note 2	--	0.7	SM	T
	SA-16	8	--	0.4	SM-SP	C
	SA-17	6	--	--	SM-SP	C
	SA-18	Note 2	--	1.3	SP	C
	SA-22	24	--	--	SM	T
	SA-27	98	--	--	ML-CL	L
G41-J18	SA-1B	36	--	--	SM	T
	SA-3	21	--	--	SM	T
	SA-4	19	--	--	SM	T
	SA-7	3	18	--	SP	T
	SA-10	26	--	--	SM	T
	SA-11	22	19	--	SM	T
	SA-15	6	33	--	SP-SM	T
G41-K21	SA-8	12	40	--	SP-SM	T
	SA-14	5	4	--	SP-SM	C
G41-K21A	SA-4	Note 2	--	1.8	SM	T
	SA-11	Note 2	--	0.8	SP	C
	SA-14	Note 2	--	0.4	SM	T
	SA-19	Note 2	--	3.2	SP	C
	SA-23	Note 2	--	1.2	SP	C
	SA-25	Note 2	--	8.0	SP to ML	F
	SA-28	Note 2	--	3.6	SP	C
G41-L23	SA-8	30	110	--	SM	T
	SA-15	4	6	--	SP	C
G41-M24	SA-1	21	33	--	SM	T
G41-P24	SA-4	7	5	--	SP-SM	C
	SA-5	Note 2	--	0.8	SP-SM	C
	SA-7	16	22	--	SM	T
	SA-15	Note 2	--	0.4	SP to GP	C
	SA-23	9	3	--	SP-SM	C
	SA-25	Note 2	--	1.2	SP-SM	C
	SA-26B	11	39	--	SM-SM	T
EX-11	SA-1	20	--	--	SM	T
	SA-2	22	--	--	SM	T
	SA-3	18	--	--	SM	T
	SA-4	26	--	--	SM	T
	SA-5	23	--	--	SM	T
	SA-6	22	--	--	SM	T
	SA-7	24	--	--	SM	T
	SA-8	22	--	--	SM	T
	SA-9	20	--	--	SM	T
	SA-10	16	--	--	SM	T
	SA-12	16	--	--	SM	T
	SA-16	15	--	--	SM	T
	SA-19	18	--	--	SM	T
	SA-20	7	--	--	SM-SP	CD
	SA-22	6	--	--	SM-SP	CD
	SA-24	4	--	--	SP	FD
	SA-27	23	--	--	SM	L
	SA-29	96	--	--	CL	L
	SA-30	11	--	--	SM-SP	CD
	SA-31	98	--	--	CL	L

(1) T - Till
C - Coarse Grained Stratified Drift
F - Fine Grained Stratified Drift
L - Lacustrine

(2) Grain size determination not made for these samples. Unified Classification from boring log stratigraphy.

WISCONSIN
JOHN FRANK ... E-23401
HOUSTON TX
PROFESSIONAL ENGINEER

PLAN SHEET 7

REVISED	DATE	BY	DESCRIPTION
NO. 3	9-28-85	KJC	UPDATED CROSS SECTIONS
NO. 2	9-4-84	DRS	Updated Cross Sections
NO. 1	11-3-82	EXXON	ADDED PLAN SHEET NOS.

Typical Representation: Refinements may be made during final design.

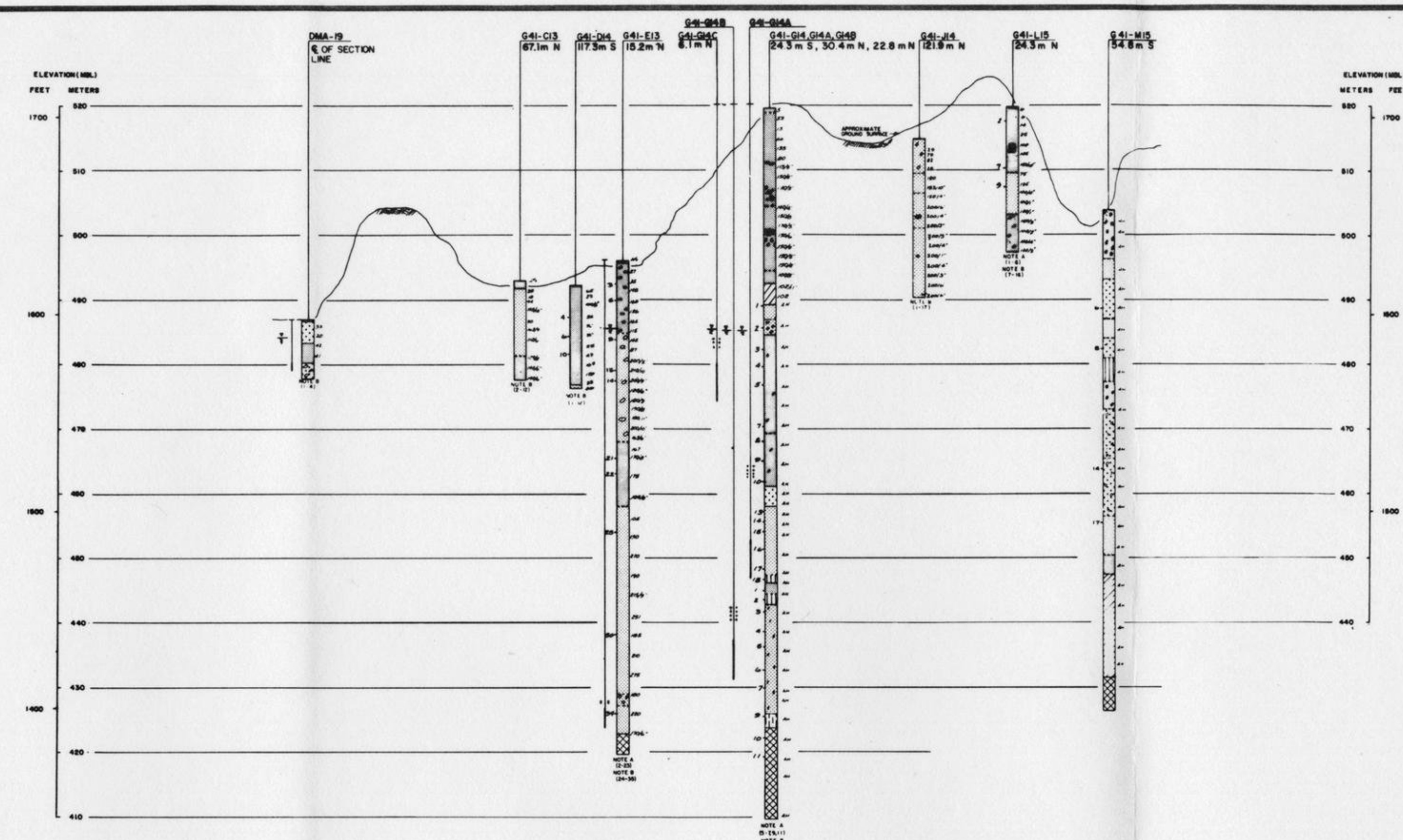
EXXON MINERALS COMPANY
CRANDON PROJECT

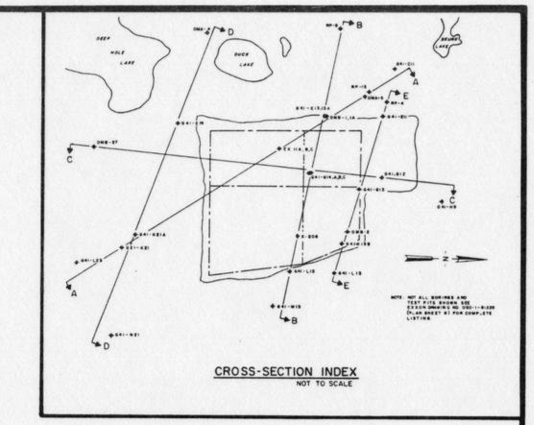
TITLE: BORING AND GEOLOGY PROFILES SECTION A-A

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

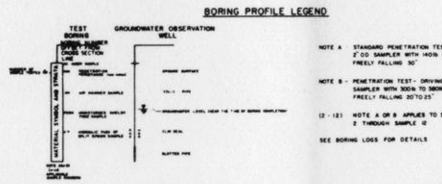
DRAWN BY: SKB	DATE: 10-12-82	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON: D. E. Moe	DATE: 12/4/85
DRAWING NO.		SHEET 7 OF 36	REVISION NO. 3

050 5/1981





BORING PROFILE LEGEND



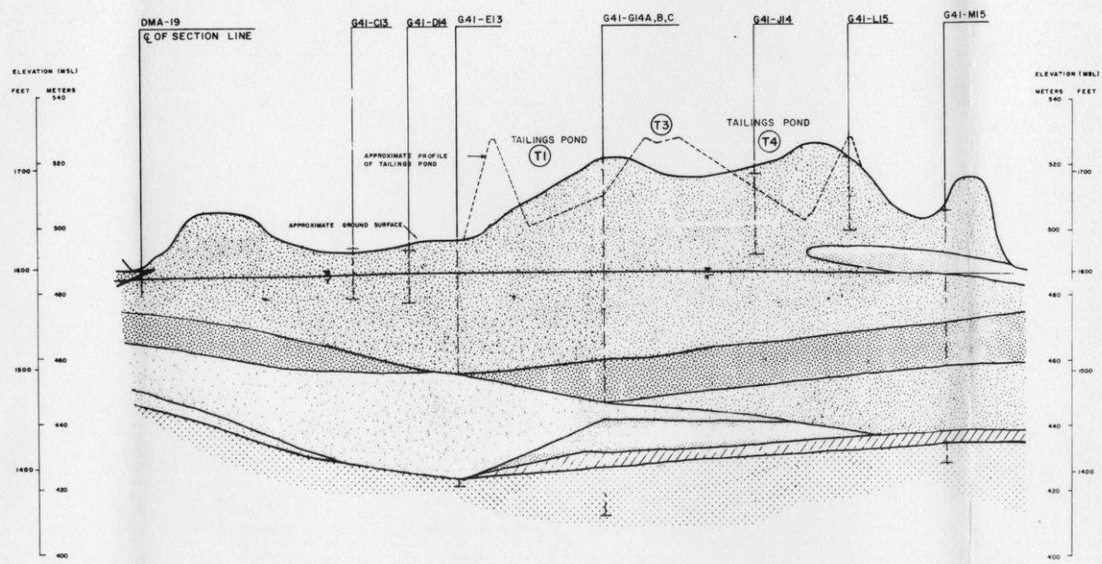
BORING PROFILE SECTION B-B

SCALE IN METERS

SCALE IN FEET

VERTICAL EXAGGERATION 20x

SYMBOL	RANGE OF MATERIAL DESCRIPTIONS	UNIFIED CLASSIFICATION RANGE
	- Topsoil and/or Rootmat	-
	- Peat, fiberous organic material	PT
	- Silty CLAY, trace fine sand to SILT, trace to some clay, trace fine sand	ML-CL, CL, OL
	- Sandy SILT, some clay to clayey SILT, trace fine sand	ML
	- Silty fine to coarse SAND to SILT, some fine to coarse sand, trace clay	SM to ML
	- Fine to coarse SAND (or GRAVEL), trace silt to clayey SILT, trace fine sand (often layered)	SP to ML
	- Fine to coarse SAND, some silt to silty, trace to some fine to coarse gravel to coarse sandy GRAVEL, some silt	SM to GM
	- Fine to coarse SAND, trace to some gravel, trace to some silt to gravelly fine to coarse SAND, trace silt	SW, SP, SM, or GW, GP, GM combinations
	- Fine to coarse SAND, trace silt to fine to coarse GRAVEL, trace silt	SP, GP, SW, GW
	- Cobbles and/or boulders occasionally encountered	-
	- Cobbles and/or boulders locations noted	-
	- Metavolcanic Tuff, sound and weathered including residual soil	-



MAJOR GLACIAL FORMATION CATEGORIES

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LABORATORY TEST DATA AND CLASSIFICATION OF SAMPLES TESTED

BORING NO.	SAMPLE NO.	% PASSING #200 SIEVE	UNIFORMITY COEFFICIENT D_{60}/D_{10}	PERCENT $CaCO_3$ EQUIVALENT	UNIFIED CLASSIFICATION	GEOLOGIC FORMATION(1)
G41-D14	SA-4	Note 2	--	5.3	SM	T
	SA-6	Note 2	--	2.8	SM	T
	SA-10	Note 2	--	3.0	SM	T
G41-E13	SA-3	16	10	--	SM	T
	SA-5	19	8	--	SM	T
	SA-9	11	60	--	SM	T
	SA-13&14	20	28	--	SM	T
	SA-21	18	--	--	SM	T
	SA-22	14	--	--	SM	T
	SA-25	4	2	--	SP	C
	SA-30	5	2	--	SP-SM	C
	SA-34	7	3	--	SP-SM	C
G41-G14A	SA-1	6	9	--	SP-SM	T
	SA-2	6	50	--	GP-GM	T
	SA-3	22	33	--	SM	T
	SA-4	21	28	--	SM	T
	SA-5	30	15	--	SM	T
	SA-7	17	13	--	SM	T
	SA-8	13	--	--	SM	T
	SA-9	17	13	--	SM	T
	SA-10	16	9	--	SM	T
	SA-13	8	5	--	SP-SM	C
	SA-14	3	2	--	SP	C
	SA-15	6	4	--	SP-SM	C
	SA-16	6	3	--	SP-SM	C
	SA-17	8	3	--	SP-SM	C
	SA-18	74	3	--	ML	L
G41-G14B	SA-1	22	4	--	SM	L
	SA-2	78	3	--	ML	L
	SA-3	17	14	--	SM	T
	SA-4	23	15	--	SM	T
	SA-5	21	20	--	SM	T
	SA-6	7	68	--	SP-SM	T
	SA-7	13	11	--	SM	T
G41-G14B	SA-9	48	12	--	SM	T
	SA-10	71	16	--	ML	T
	SA-11	19	290	--	SM	T
G41-L15	SA-2	20	37	--	SM	T
	SA-7	15	--	--	SM	T
	SA-9	10	6	--	SP-SM	T
G41-M15	SA-5	8	--	--	SM-SP	C
	SA-6	Note 2	--	36.7	SP to GP	T
	SA-8	Note 2	--	0.3	SP	T
	SA-10	36	--	--	SM	T
	SA-13	8	--	--	SM-SP	C
	SA-14	Note 2	--	0.4	SP to GP	C
	SA-16	8	--	--	SM-SP	C
	SA-17	Note 2	--	0.2	SP-SM	C
	SA-18	10	--	--	SM-SP	C

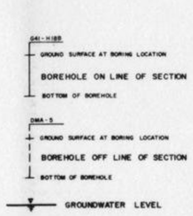
(1) T - Till
C - Coarse Grained Stratified Drift
F - Fine Grained Stratified Drift
L - Lacustrine

(2) Grain size determination not made for these samples. Unified Classification from boring log stratigraphy.

LEGEND

GEOLOGICAL DEPOSIT SYMBOLS

- WETLAND AND MARSH
- FINE-GRAINED STRATIFIED DRIFT
- COARSE-GRAINED STRATIFIED DRIFT
- TILL
- LACUSTRINE
- BEDROCK
- INTERPRETED STRATA BOUNDARIES
- STRATA BOUNDARIES UNKNOWN



GEOLOGIC PROFILE SECTION B-B

SCALE IN METERS

SCALE IN FEET

VERTICAL EXAGGERATION 10x

NOTES

1. PROFILE SECTION LOCATIONS SHOWN ON BORING AND GEOLOGY SECTION PLAN, DRAWING NO. 050-1-81339 (PLAN SHEET 6)
2. GROUNDWATER LEVEL PROFILE FROM GROUNDWATER POTENTIOMETRIC CONTOURS, DRAWING NO. 050-1-81117 (PLAN SHEET 12)
3. BEDROCK PROFILE FROM BEDROCK CONTOURS, STS DWG 12959-6 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984)
4. FOR BORING LOCATIONS AT EXTREME ENDS OF SECTIONS REFER TO SOIL BORING AND PIEZOMETER LOCATION MAP, STS DRAWING 12959-1 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984.

REVISED	DATE	BY	DESCRIPTION
No. 3	10-17-85	J.J.T.	UPDATED CROSS-SECTIONS
NO. 2	8-31-84	DRS	UPDATED CROSS SECTIONS
NO. 1	11-3-82	EXXON	ADDED PLAN SHEET NOS.

Typical Representation: Refinements may be made during final design.

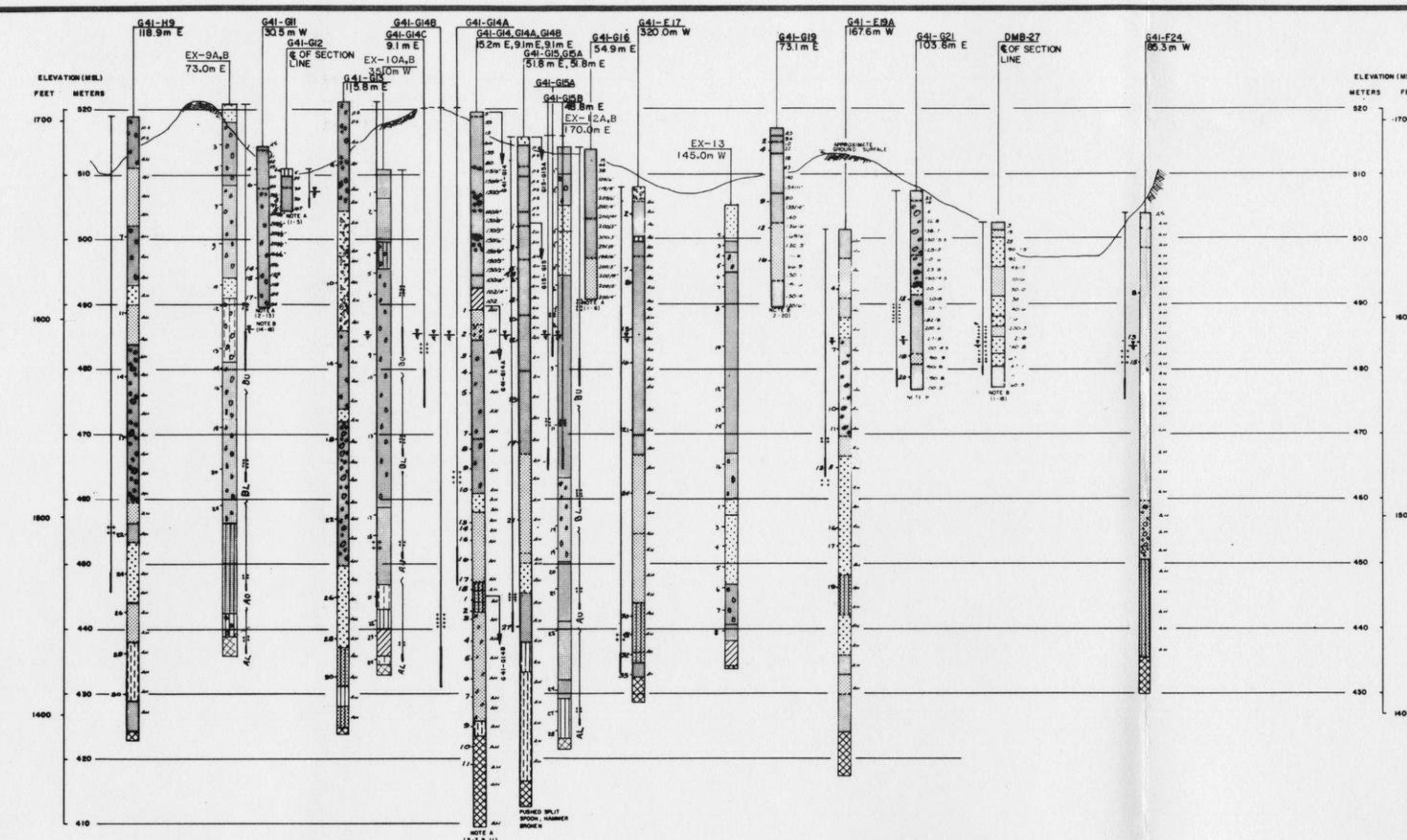
PLAN SHEET 8

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE BORING AND GEOLOGY PROFILES SECTION B-B

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SKB	DATE 10-13-82	CHECKED BY	DATE 10-15-82
APPROVED BY	DATE	APPROVED BY John E. Wallace	DATE [illegible]
APPROVED BY	DATE	EXXON D.S. Muc	DATE 12/4/85
DRAWING NO.		SHEET 8 OF 36	REVISION NO. 3

GSD 5/1981



BORING PROFILE LEGEND

TEST BORING — BORING NUMBER, OFFSET FROM CROSS SECTION LINE — MATERIAL SYMBOL AND STRATA

GROUNDWATER OBSERVATION WELL

NOTE A - STANDARD PENETRATION TEST - DRIVING 2" OD SAMPLER WITH 140lb HAMMER FREELY FALLING 30"

NOTE B - PENETRATION TEST - DRIVING 2" TO 3.25" OD SAMPLER WITH 300lb TO 380lb HAMMER FREELY FALLING 20" TO 25"

(2 - 12) NOTE A OR B APPLIES TO SAMPLE 2 THROUGH SAMPLE 12

SEE BORING LOGS FOR DETAILS

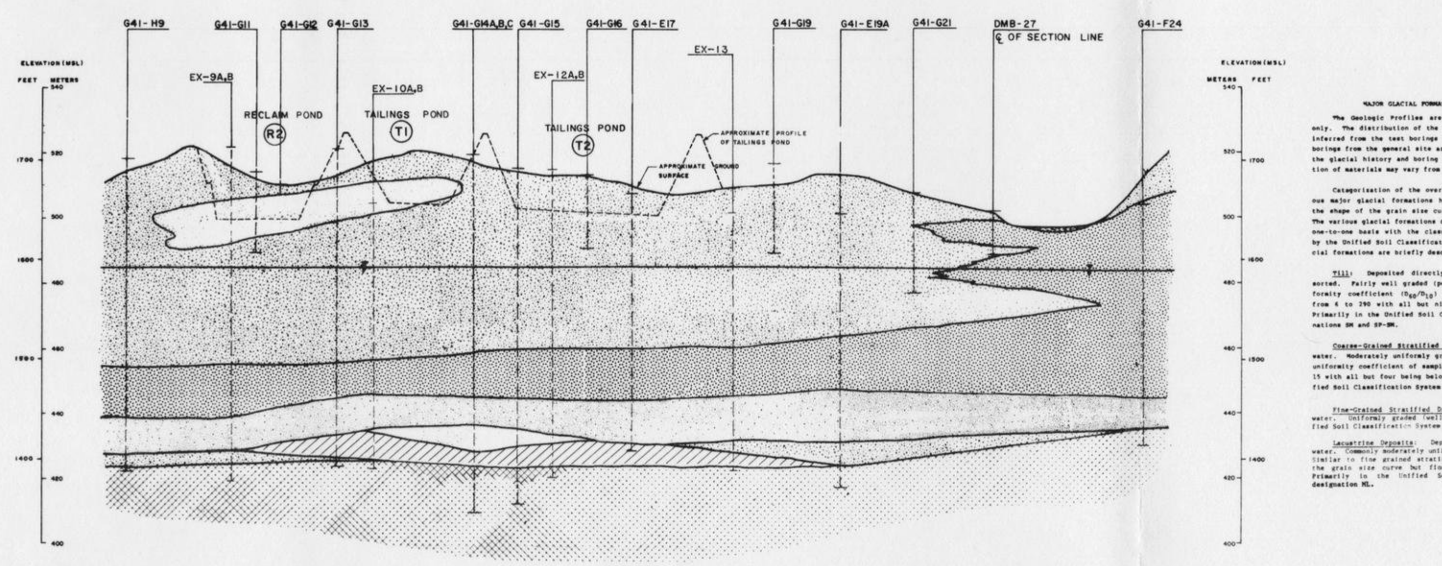
BORING PROFILE SECTION C-C

SCALE IN METERS: 0 100 200 300 400 500

SCALE IN FEET: 0 500 1000 1500

VERTICAL EXAGGERATION: 20x

SYMBOL	RANGE OF MATERIAL DESCRIPTIONS	UNIFIED CLASSIFICATION RANGE
	Topsoil and/or Rootmat	-
	Peat, fibrous organic material	PT
	Silty CLAY, trace fine sand to SILT, trace to some clay, trace fine sand	ML- CL, CL, OL
	Sandy SILT, some clay to clayey SILT, trace fine sand	ML
	Silty fine to coarse SAND to SILT, some fine to coarse sand, trace clay	SM to ML
	Fine to coarse SAND (or GRAVEL), trace silt to clayey SILT, trace fine sand (often layered)	SP to ML
	Fine to coarse SAND, some silt to silty, trace to some fine to coarse gravel to coarse sandy GRAVEL, some silt	SM to GM
	Fine to coarse SAND, trace to some gravel, trace to some silt to gravelly fine to coarse SAND, trace silt	SW, SP, SM, or GW, GP, GM combinations
	Fine to coarse SAND, trace silt to fine to coarse GRAVEL, trace silt	SP, GP, SW, GW
	Cobbles and/or boulders occasionally encountered	-
	Cobbles and/or boulders locations noted	-
	Metavolcanic Tuff, sound and weathered including residual soil	-



GEOLOGIC PROFILE SECTION C-C

SCALE IN METERS: 0 100 200 300 400 500

SCALE IN FEET: 0 500 1000 1500

VERTICAL EXAGGERATION: 10x

LEGEND

GEOLOGICAL DEPOSIT SYMBOLS

- WETLAND AND MARSH
- FINE-GRAINED STRATIFIED DRIFT
- COARSE-GRAINED STRATIFIED DRIFT
- TILL
- LACUSTRINE
- BEDROCK
- INTERPRETED STRATA BOUNDARIES
- STRATA BOUNDARIES UNKNOWN

G41-H9B — GROUND SURFACE AT BORING LOCATION — BOREHOLE ON LINE OF SECTION — BOTTOM OF BOREHOLE

DMA-5 — GROUND SURFACE AT BORING LOCATION — BOREHOLE OFF LINE OF SECTION — BOTTOM OF BOREHOLE

GROUNDWATER LEVEL

NOTES

1. PROFILE SECTION LOCATIONS SHOWN ON BORING AND GEOLOGY SECTION PLAN, DRAWING NO 050-1-81336 (PLAN SHEET 6)
2. GROUNDWATER LEVEL PROFILE FROM GROUNDWATER POTENTIOMETRIC CONTOURS, DRAWING NO. 050-1-81117 (PLAN SHEET 12)
3. BEDROCK PROFILE FROM BEDROCK CONTOURS, STS DWG 12959-F (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984)
4. FOR BORING LOCATIONS AT EXTREME ENDS OF SECTIONS REFER TO SOIL BORING AND PIEZOMETER LOCATION MAP, STS DRAWING 12959-1 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984.

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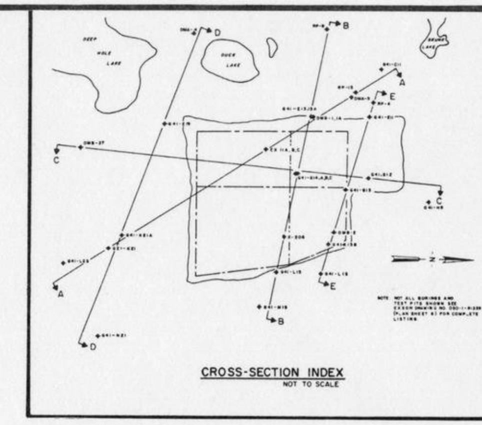
G41-H9	SA-3	18	—	—	SM	T
	SA-5	13	—	—	SM	T
	SA-7	Note 2	—	9.0	SM	T
	SA-8	14	—	—	SM	T
	SA-10	7	—	—	SM-SP	C
	SA-11	Note 2	—	0.9	SP to SM	C
	SA-14	Note 2	—	7.2	SM	T
	SA-15	20	—	—	SM	T
	SA-16	22	—	—	SM	T
	SA-17	Note 2	—	11.0	SM	T
	SA-21	8	—	—	SM-SP	C
	SA-22	Note 2	—	0.8	SM	T
	SA-24	Note 2	—	1.1	SP	C
	SA-26	Note 2	—	1.0	SP-SM	C
	SA-28	Note 2	—	0.3	SM to ML	F
	SA-30	Note 2	—	1.0	SM to ML	F
G41-G11	SA-1	32	240	—	SM	T
	SA-4	17	—	—	SM	T
	SA-6	19	—	—	SM	T
	SA-14	10	18	—	SP-SM	T
	SA-15	21	42	—	SM	T
	SA-17	18	—	—	SM	T
G41-G12	SA-1	80	16	—	ML	L
	SA-4	17	—	—	SM	T
	SA-5	18	—	—	SM	T
G41-13	SA-4	Note 2	—	7.5	SM	T
	SA-10	Note 2	—	3.0	SP	C
	SA-14	Note 2	—	1.0	SM	T
	SA-18	52	—	9.0	SM	T
	SA-22	Note 2	—	7.5	SM	T
	SA-26	Note 2	—	1.2	SP	C
	SA-28	Note 2	—	7.2	SP	C
	SA-30	Note 2	—	12.0	SP to ML	F
G41-G14A	SA-1	6	9	—	SP-SM	T
	SA-2	6	50	—	GP-GM	T
	SA-3	22	33	—	SM	T
	SA-4	21	28	—	SM	T
	SA-5	30	15	—	SM	T
	SA-7	17	13	—	SM	T
	SA-8	13	—	—	SM	T
	SA-9	17	13	—	SM	T
	SA-10	16	9	—	SM	T
	SA-13	8	5	—	SP-SM	C
	SA-14	3	2	—	SP	C
	SA-15	6	4	—	SP-SM	C
	SA-16	6	3	—	SP-SM	C
	SA-17	8	3	—	SP-SM	C
	SA-18	74	3	—	ML	L
G41-G14B	SA-1	22	4	—	SM	F
	SA-2	78	3	—	ML	F
	SA-3	17	14	—	SM	T
	SA-4	23	15	—	SM	T
	SA-5	21	20	—	SM	T
	SA-6	7	68	—	SP-SM	T
	SA-7	13	11	—	SM	T
	SA-9	48	12	—	SM	T
	SA-10	71	16	—	ML	T
	SA-11	19	290	—	SM	T
EX-9A,B	S-A	3	--	--	SP	CD
	SA-2	12	--	--	SM	T
	SA-3	17	--	--	SM	T
	SA-5	11	--	--	SM-SP	CD
	SA-7	6	--	--	SM-SP	CD
	SA-9	5	--	--	GP	CD
	SA-10	9	--	--	SM	T
	SA-12	16	--	--	SM	T
	SA-13	6	--	--	SM-SP	CD
	SA-14	9	--	--	SM-SP	CD
	SA-16	21	--	--	SM	T
	SA-18	11	--	--	SM-SP	CD
	SA-20	13	--	--	SM	CD
	SA-25	17	--	--	SM	FD
EX-10A,B	SA-1	36	--	--	SM	T
	SA-2	4	--	--	SP	CD
	SA-4	6	--	--	SM-SP	CD
	SA-5	24	--	--	SM	T
	SA-6	24	--	--	SM	T
	SA-9	24	--	--	SM	T
	SA-10	14	--	--	SM	T
	SA-13	20	--	--	SM	T
	SA-17	6	--	--	SM-SP	FD
	SA-18	6	--	--	SM-SP	FD
	SA-21	38	--	--	SM	L
	SA-22	93	--	--	ML	L
	SA-23	92	--	--	CL	L
	SA-24	9	--	--	SM-SP	L
EX-12A,B	SA-1	8	--	--	SM-SP	T
	SA-2	31	--	--	SM	T
	SA-3	8	--	--	SM-SP	T
	SA-4	14	--	--	GM	CD
	SA-5	2	--	--	GW	CD
	SA-6	4	--	--	SW-GW	CD
	SA-7	44	--	--	SM	T
	SA-8	15	--	--	SM	T
	SA-9	14	--	--	SM	T
	SA-11	25	--	--	SM	T
	SA-14	14	--	--	SM	T
	SA-19	7	--	--	SM-SP	CD
	SA-20	6	--	--	SM-SP	FD
	SA-21	25	--	--	SM	T
	SA-22	17	--	--	SM	T
	SA-24	17	--	--	SM	FD
	SA-27	25	--	--	SM	T
	SA-28	62	--	--	ML	L
	SA-29	96	--	--	ML	L
EX-13	SA-1	6	--	--	GP-GM	CD
	SA-2	6	--	--	SM-SP	FD
	SA-3	6	--	--	SM-SP	FD
	SA-4	6	--	--	SM-SP	FD
	SA-5	27	--	--	SM	T
	SA-6	25	--	--	SM	T
	SA-7B	5	--	--	SM-SP	T
	SA-8	69	--	--	CL	L
	SA-2A	4	--	--	GW	CD
	SA-3A	46	--	--	SM	T
	SA-5A	11	--	--	SM-SP	T
	SA-8A	21	--	--	SM	T
EX-13B	SA-4A	11	--	--	SM-SP	--
	SA-6A	18	--	--	SM	--
	SA-7A	19	--	--	SM	--
	SA-10A	15	--	--	SM	--
	SA-12A	24	--	--	SM	--
	SA-13A	13	--	--	SM	--
	SA-14A	16	--	--	SM	--
	SA-16A	6	--	--	SM-SP	--



LABORATORY TEST DATA AND CLASSIFICATION OF SAMPLES TESTED

BORING NO.	SAMPLE NO.	% PASSING #200 SIEVE	UNIFORMITY COEFFICIENT D_{60}/D_{10}	PERCENT $CaCO_3$ EQUIVALENT	UNIFIED CLASSIFICATION	GEOLOGIC FORMATION(1)
G41-G15	SA-1	20	230	—	SM	T
	SA-3	10	—	—	GP-GM	T
	SA-5A	26	—	—	SM	T
	SA-5B	30	93	—	SM	T
	SA-6	Note 2	—	0.6	SM	T
	SA-8	23	11	0.8	SM	T
	SA-10	Note 2	—	0.6	SM	T
	SA-12	Note 2	—	0.9	SM	T
	SA-15	17	—	5.5	SM	T
	SA-17	22	19	—	SM	T
	SA-20	13	—	—	SM	T
	SA-21	Note 2	—	0.4	SP to SP-SM	C
	SA-27	35	56	—	SM	T
G41-G15A	SA-3	22	14	—	SM	T
	SA-4	21	23	—	SM	T
	SA-7	27	3600	—	SM	T
	SA-9	27	—	—	SM	T
	SA-10B	23	34	—	SM	T
G41-E17	SA-2	15	—	—	SM	T
	SA-7	21	56	—	SM	T
	SA-8	Note 2	—	0.5	SM	T
	SA-13	Note 2	—	0.6	SM	T
	SA-16	22	—	0.5	SM	T
	SA-21	Note 2	—	0.9	SM	T
	SA-24	9	36	0.6	SP-SM	C
	SA-28	11	—	—	SM-SP	F
	SA-30	90	3	—	ML	L
	SA-31	99	13	—	ML	L
	SA-32	62	—	—	ML	L
	SA-33	20	—	—	SM	T
G41-G19	SA-2	11	—	—	GP-GM	T
	SA-4	28	—	—	SM	T
	SA-9	19	—	—	SM	T
	SA-12	15	—	—	SM	T
	SA-16	9	15	—	SP-SM	C
G41-E19A	SA-3	16	—	—	SM	T
	SA-4	28	—	2.2	SM	T
	SA-7	Note 2	—	0.6	SM	T
	SA-10	17	—	8.4	SM	T
	SA-11	Note 2	—	9.1	SM	T
	SA-12	7	—	—	SM-SP	C
	SA-13A	5	2	—	SP	C
	SA-16	Note 2	—	0.9	SP	C
	SA-17	Note 2	—	1.0	SP	C
	SA-18	3	—	—	SP	C
	SA-19	30	—	12.6	SM	T
	SA-24	7	—	—	SM-SP	C
G41-G21	SA-12	26	20	—	SM	T
	SA-18	6	3	—	SP-SM	C
	SA-20	27	12	—	SM	T
G41-F24	SA-8	Note 2	—	0.4	SP to SP-SM	C
	SA-13	Note 2	—	8.0	SP to SP-SM	C
	SA-15	7	9	3.4	SW-SM	C

(1) T - Till
C - Coarse Grained Stratified Drift
F - Fine Grained Stratified Drift
L - Lacustrine

(2) Grain size determination not made for these samples. Unified Classification from boring log stratigraphy.

WISCONSIN JOHN FRANCIS WALLACE E-23401 HOUSTON TX PROFESSIONAL ENGINEER

PLAN SHEET 9

EXXON MINERALS COMPANY
CRANDON PROJECT

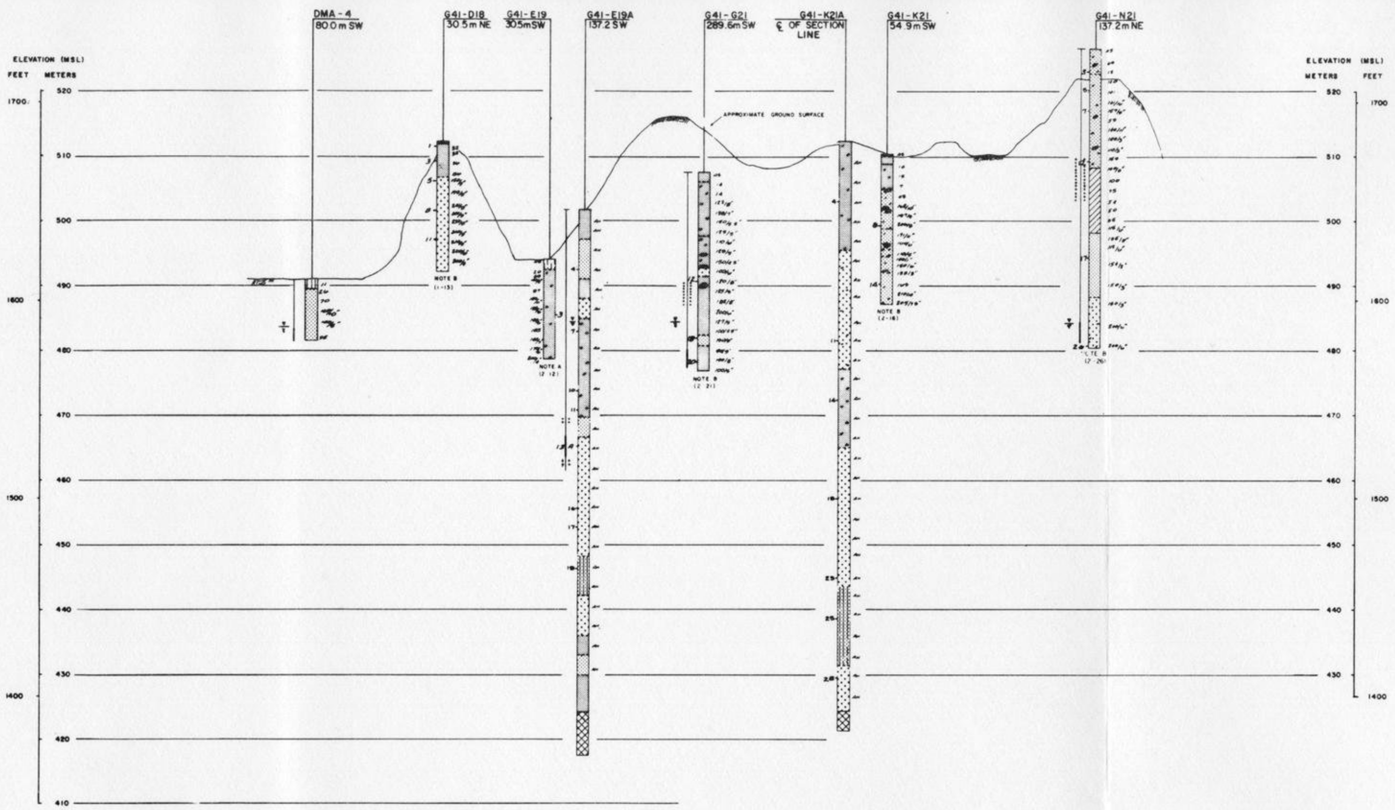
TITLE: BORING AND GEOLOGY PROFILES SECTION C-C

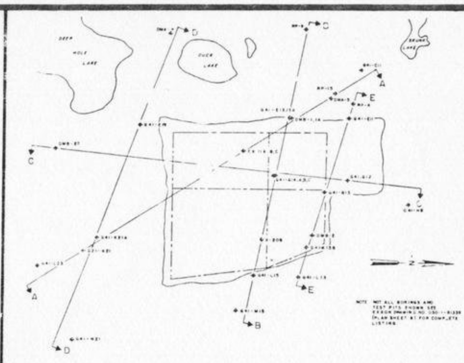
REVISED	DATE	BY	DESCRIPTION
No. 3	9-30-85	KJC	UPDATED CROSS SECTIONS
NO.2	8-31-84	DRS	UPDATED CROSS SECTIONS
NO.1	11-2-82	EXXON	ADDED PLAN SHEET NOS.

Typical Representation: Refinements may be made during final design.

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: SKB	DATE: 10-13-82	CHECKED BY:	DATE: 10-15-82
APPROVED BY:	DATE:	APPROVED BY:	DATE: 11/27/85
APPROVED BY:	DATE:	EXXON: D. E. Moe	DATE: 12/4/85
DRAWING NO.:		SHEET 9 OF 36	REVISION NO. 3

G2B 5/1981





BORING PROFILE LEGEND

NOTE A - STANDARD PENETRATION TEST - DRIVING 2" OD SAMPLER WITH 140lb HAMMER FREELY FALLING 30"

NOTE B - PENETRATION TEST - DRIVING 2" TO 3.25" OD SAMPLER WITH 300lb TO 380lb HAMMER FREELY FALLING 30" TO 25"

(2 - 12) NOTE A OR B APPLIES TO SAMPLE 2 THROUGH SAMPLE 12

SEE BORING LOGS FOR DETAILS

BORING PROFILE SECTION D-D

SCALE IN METERS

SCALE IN FEET

VERTICAL EXAGGERATION: 20x

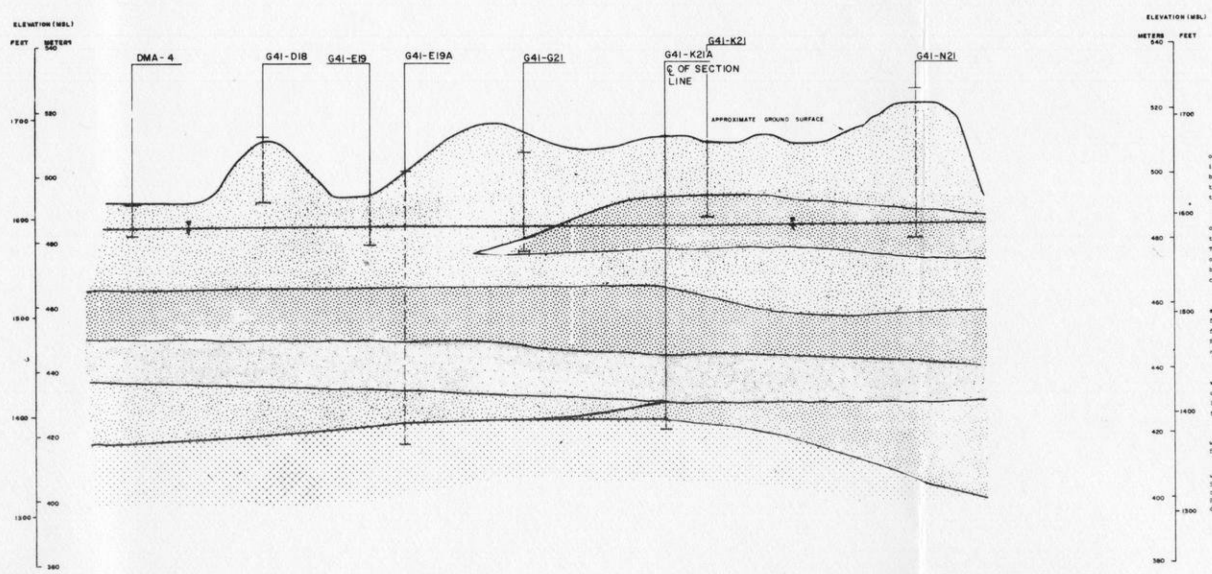
SYMBOL	RANGE OF MATERIAL DESCRIPTIONS	UNIFIED CLASSIFICATION RANGE
	Topsoil and/or Rootmat	-
	Peat, fiberous organic material	PT
	Silty CLAY, trace fine sand to SILT, trace to some clay, trace fine sand	ML- CL,CL ,OL
	Sandy SILT, some clay to clayey SILT, truce fine sand	ML
	Silty fine to coarse SAND to SILT, some fine to coarse sand, trace clay	SM to ML
	Fine to coarse SAND (or GRAVEL), trace silt to clayey SILT, trace fine sand (often layered)	SP to ML
	Fine to coarse SAND, some silt to silty, trace to some fine to coarse gravel to coarse sandy GRAVEL, some silt	SM to GM
	Fine to coarse SAND, trace to some gravel, trace to some silt to gravelly fine to coarse SAND, trace silt	SW, SP, SM, or GW,GP,GM combinations
	Fine to coarse SAND, trace silt to fine to coarse GRAVEL, trace silt	SP, GP, SW, GW
	Cobbles and/or boulders occasionally encountered	-
	Cobbles and/or boulders locations noted	-
	Metavolcanic Tuff, sound and weathered including residual soil	-

LABORATORY TEST DATA AND CLASSIFICATION OF SAMPLES TESTED

BORING NO.	SAMPLE NO.	% PASSING #200 SIEVE	UNIFORMITY COEFFICIENT D_{60}/D_{10}	PERCENT $CaCO_3$ EQUIVALENT	UNIFIED CLASSIFICATION	GEOLOGIC FORMATION(1)
G41-D18	SA-1	19	—	—	SM	T
	SA-3	16	—	—	SM	T
	SA-5	10	—	—	SP-SM	T
	SA-8	14	—	—	SM	T
	SA-11	18	—	—	SM	T
G41-E19	SA-3	28	—	—	SM	T
G41-E19A	SA-3	16	—	—	SM	T
	SA-4	28	—	2.2	SM	T
	SA-7	Note 2	—	0.6	SM	T
	SA-10	17	—	8.6	SM	T
	SA-11	Note 2	—	9.1	SM	T
	SA-12	7	—	—	SM-SP	C
	SA-13A	5	—	—	SP	C
	SA-16	Note 2	—	0.9	SP	C
	SA-17	Note 2	—	1.0	SP	C
	SA-18	3	—	—	SP	F
	SA-19	30	—	12.6	SM	T
	SA-24	7	—	—	SM-SP	L
G41-H21	SA-12	26	30	—	SM	T
	SA-18	6	3	—	SP-SM	C
	SA-20	17	12	—	SM	T
G41-K21	SA-8	13	40	—	SM	T
	SA-14	5	4	—	SP	C
G41-K21A	SA-4	Note 2	—	1.8	SM	T
	SA-11	Note 2	—	0.8	SP	C
	SA-14	Note 2	—	0.4	SM	T
	SA-19	Note 2	—	3.2	SP	C
	SA-23	Note 2	—	1.2	SM	C
	SA-25	Note 2	—	8.0	SP to ML	F
	SA-28	Note 2	—	3.6	SP	C
G41-N21	SA-3	11	29	—	SP-SM	T
	SA-5	Note 2	—	0.4	SP to SP-SM	T
	SA-7	Note 2	—	2.2	SP to SP-SM	T
	SA-12	Note 2	—	2.4	SP to SP-SM	T
	SA-16	Note 2	—	6.3	ML or CL	L
	SA-17	51	—	—	ML-CL	L
	SA-26	6	4	—	SP-SM	C

(1) T - Till
C - Coarse Grained Stratified Drift
F - Fine Grained Stratified Drift
L - Lacustrine

(2) Grain size determination not made for these samples. Unified Classification from boring log stratigraphy.



MAJOR GLACIAL FORMATION CATEGORIES

The Geologic Profiles are for illustrative purposes only. The distribution of the glacial formations has been inferred from the test borings shown on this section, test borings from the general site area, and trends implied from the glacial history and boring data. The actual distribution of materials may vary from that shown.

Categorization of the overburden soils into the various major glacial formations has been primarily based on the shape of the grain size curves of the samples tested. The various glacial formations do not correlate on a direct one-to-one basis with the classification of the materials by the Unified Soil Classification System. The major glacial formations are briefly described as follows:

Till: Deposited directly by a glacier, not water sorted. Fairly well graded (poorly sorted) with the uniformity coefficient (D_{60}/D_{10}) of samples tested ranging from 4 to 290 with all but nine samples being above 10. Primarily in the Unified Soil Classification System designations SM and SP-SM.

Coarse-Grained Stratified Drift: Deposited by meltwater. Moderately uniformly graded (well sorted) with the uniformity coefficient of samples tested ranging from 2 to 15 with all but four being below 8. Primarily in the Unified Soil Classification System designations SP and SP-SM.

Fine-Grained Stratified Drift: Deposited by meltwater. Uniformly graded (well sorted) fine sand. Unified Soil Classification System designation SP.

Lacustrine Deposits: Deposited in bodies of still water. Commonly moderately uniformly graded (well sorted). Similar to fine grained stratified drift in the shape of the grain size curve but finer in overall grain size. Primarily in the Unified Soil Classification System designation ML.

LEGEND

GEOLOGICAL DEPOSIT SYMBOLS

- WETLAND AND MARSH
- FINE-GRAINED STRATIFIED DRIFT
- COARSE-GRAINED STRATIFIED DRIFT
- TILL
- LACUSTRINE
- BEDROCK
- INTERPRETED STRATA BOUNDARIES
- STRATA BOUNDARIES UNKNOWN

G41-H18
GROUND SURFACE AT BORING LOCATION
BOREHOLE ON LINE OF SECTION
BOTTOM OF BOREHOLE

DMA-5
GROUND SURFACE AT BORING LOCATION
BOREHOLE OFF LINE OF SECTION
BOTTOM OF BOREHOLE

GROUNDWATER LEVEL

GEOLOGIC PROFILE SECTION D-D

SCALE IN METERS

SCALE IN FEET

VERTICAL EXAGGERATION: 10x

NOTES

1. PROFILE SECTION LOCATIONS SHOWN ON BORING AND GEOLOGY SECTION PLAN, DRAWING NO 050-1-81339 (PLAN SHEET 6)
2. GROUNDWATER LEVEL PROFILE FROM GROUNDWATER POTENTIOMETRIC CONTOURS, DRAWING NO 050-1-81117 (PLAN SHEET 12)
3. BEDROCK PROFILE FROM BEDROCK CONTOURS, STS Dwg 12959-6 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984)
4. FOR BORING LOCATIONS AT EXTREME ENDS OF SECTIONS REFER TO SOIL BORING AND PIEZOMETER LOCATION MAP, STS DRAWING 12959-1 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984.

NO.2	8-31-84	DLS	UPDATED CROSS SECTIONS
NO.1	11-3-82	EXXON	ADDED PLAN SHEET NOS.
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

PLAN SHEET 10

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
BORING AND GEOLOGY PROFILES
SECTION D-D

SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST

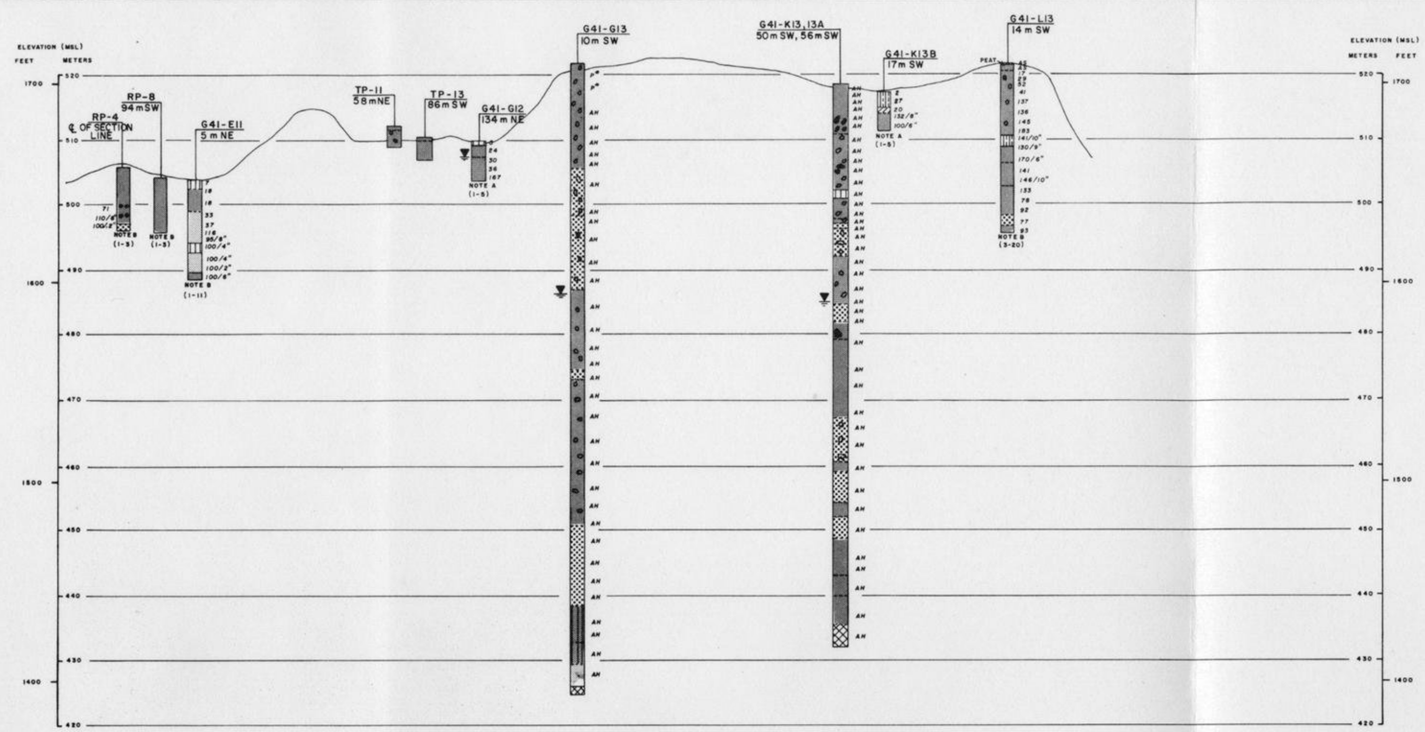
DRAWN BY: SKB | DATE: 10-13-82 | CHECKED BY

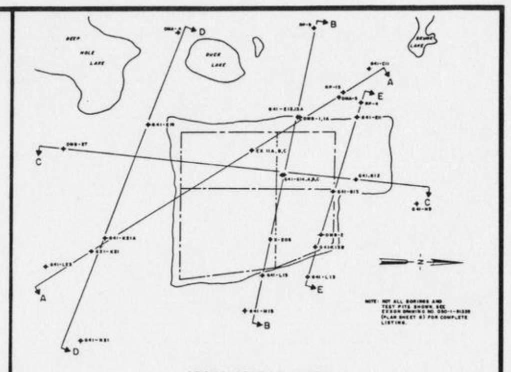
APPROVED BY | DATE | APPROVED BY

APPROVED BY | DATE | EXXON: D.E. Moe

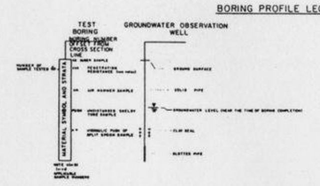
DRAWING NO. | SHEET 10 OF 36 | REVISION NO. 2

GBS 5/1981





BORING PROFILE LEGEND



NOTE A - STANDARD PENETRATION TEST - DRIVING 2" OD SAMPLER WITH 140lb HAMMER FREELY FALLING 30"

NOTE B - PENETRATION TEST - DRIVING 2" TO 3.25" OD SAMPLER WITH 300lb TO 380lb HAMMER FREELY FALLING 20" TO 25"

(2 - 12) NOTE A OR B APPLIES TO SAMPLE 2 THROUGH SAMPLE 12

SEE BORING LOGS FOR DETAILS

BORING PROFILE SECTION E-E

SCALE IN METERS: 0 50 100 150 200 250

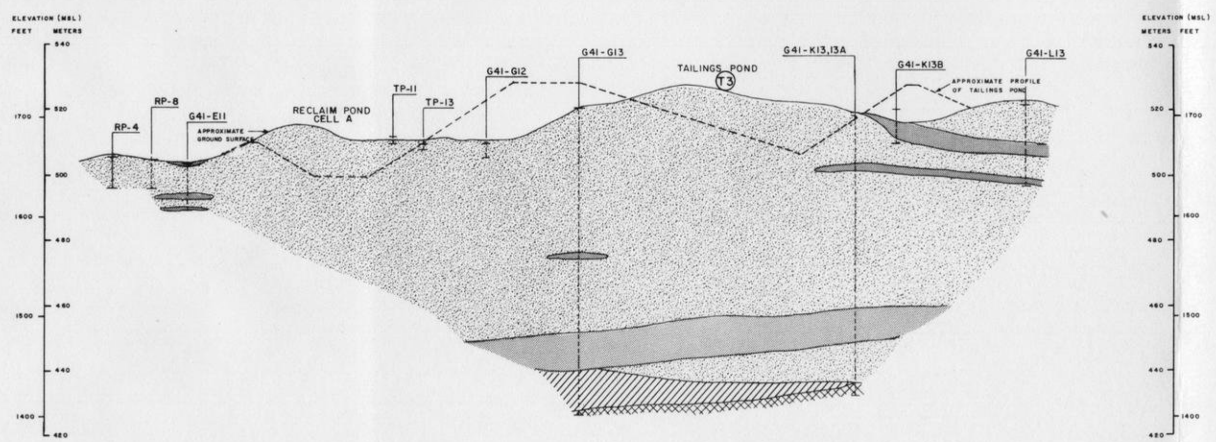
SCALE IN FEET: 0 500 1000 1500

VERTICAL EXAGGERATION: 10x

SYMBOL	RANGE OF MATERIAL DESCRIPTIONS	UNIFIED CLASSIFICATION RANGE
	- Topsoil and/or Rootmat	-
	- Peat, fiberous organic material	PT
	- Silty CLAY, trace fine sand to SILT, trace to some clay, trace fine sand	ML- CL,CL ,OL
	- Sandy SILT, some clay to clayey SILT, trace fine sand	ML
	- Silty fine to coarse SAND to SILT, some fine to coarse sand, trace clay	SM to ML
	- Fine to coarse SAND (or GRAVEL), trace silt to clayey SILT, trace fine sand (often layered)	SP to ML
	- Fine to coarse SAND, some silt to silty, trace to some fine to coarse gravel to coarse sandy GRAVEL, some silt	SM to GM
	- Fine to coarse SAND, trace to some gravel, trace to some silt to gravelly fine to coarse SAND, trace silt	SW, SP, SM, or GW,GP,GM combinations
	- Fine to coarse SAND, trace silt to fine to coarse GRAVEL, trace silt	SP, GP, SW, GW
	- Cobbles and/or boulders occasionally encountered	-
	- Cobbles and/or boulders locations noted	-
	- Metavolcanic Tuff, sound and weathered including residual soil	-

LABORATORY TEST DATA AND CLASSIFICATION OF SAMPLES

BORING NO.	SAMPLE NO.	% PASSING #200 SIEVE	UNIFIED SOIL CLASSIFICATION	GEOLOGIC FORMATION(1)
G41-G12	SA-1	82	ML	-
	SA-4	16	SM	T
	SA-5	18	SM	T
G41-K13	SA-1	18	SM	T
	SA-3	21	SM	T
	SA-5	19	SM	T
	SA-6	13	SM	T
	SA-8	13	SM	T
	SA-9A, 9B	9	SW-SM	T
	SA-10	32	SM	T
	SA-11	10	SP-SM	T
	SA-12	22	SM	F
	SA-13	22	SM	F
	SA-14	17	SM	F
G41-K13A	SA-2	23	SM	T
	SA-8	21	SM	T
	SA-13	13	SM	T
	SA-15	13	GM	T
	SA-16	10	SP-SM	T
	SA-20	20	SM	T
	SA-23A	10	SP-SM	T
G41-K13B	SA-1	63	ML	-
	SA-3	88	CL-ML	T
	SA-5	17	SM	T



MAJOR GLACIAL FORMATION CATEGORIES

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Till: Deposited directly by a glacier, not water sorted. Fairly well graded (poorly sorted) with the uniformity coefficient (D_{60}/D_{10}) of samples tested ranging from 6 to 290 with all but nine samples being above 10. Primarily in the Unified Soil Classification System designations SM and SP-SM.

Coarse Grained Stratified Drift: Deposited by meltwater. Moderately uniformly graded (well sorted) with the uniformity coefficient of samples tested ranging from 3 to 15 with all but four being below 8. Primarily in the Unified Soil Classification System designations SP and SP-SM.

Fine-Grained Stratified Drift: Deposited by meltwater. Uniformly graded (well sorted) fine sand. Unified Soil Classification System designation SP.

Lacustrine Deposits: Deposited in bodies of still water. Commonly moderately uniformly graded (well sorted). Similar to fine grained stratified drift in the shape of the grain size curve but finer in overall grain size. Primarily in the Unified Soil Classification System designation ML.

LEGEND

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- FINE-GRAINED STRATIFIED DRIFT
- COARSE-GRAINED STRATIFIED DRIFT
- TILL
- LACUSTRINE
- BEDROCK
- INTERPRETED STRATA BOUNDARIES
- STRATA BOUNDARIES UNKNOWN

G41-H18B
- GROUND SURFACE AT BORING LOCATION
- BOREHOLE ON LINE OF SECTION
- BOTTOM OF BOREHOLE

DMA-5
- GROUND SURFACE AT BORING LOCATION
- BOREHOLE OFF LINE OF SECTION
- BOTTOM OF BOREHOLE

GROUNDWATER LEVEL

GEOLOGIC PROFILE SECTION E-E

SCALE IN METERS: 0 50 100 150 200 250

SCALE IN FEET: 0 500 1000 1500

VERTICAL EXAGGERATION 5x

NOTES

1. PROFILE SECTION LOCATIONS SHOWN ON BORING AND GEOLOGY SECTION PLAN, DRAWING NO. 050-1-81339 (PLAN SHEET 6)
2. GROUNDWATER LEVEL PROFILE FROM GROUNDWATER POTENTIOMETRIC CONTOURS, DRAWING NO. 050-1-81118 (PLAN SHEET 12)
3. BEDROCK PROFILE FROM BEDROCK CONTOURS, DRAWING NO. 050-1-80927. (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984
4. FOR BORING LOCATIONS AT EXTREME ENDS OF SECTIONS REFER TO SOIL BORING AND PIEZOMETER LOCATION MAP, STS DRAWING 12959-1 (STS LTD., "HYDROLOGIC STUDY UPDATE" JUNE 1984.

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

PLAN SHEET 11

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE: BORING AND GEOLOGY PROFILES SECTION E-E

SCALE	STATE	COUNTY	
AS SHOWN	WISCONSIN	FOREST	
DRAWN BY K.J.C.	DATE 10-1-85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY [signature]	11/27/85
APPROVED BY	DATE	EXXON D.F. Moe	12/4/85
DRAWING NO.		SHEET 11 OF 36	REVISION NO. 0

DESIGN PRODUCTS CO.—

LEGEND

—485— GROUNDWATER CONTOURS IN METERS ABOVE MSL 1929 ADJUSTMENT. CONTOURS BASED ON JULY 1985 MEASUREMENTS.

(T2) POND NUMBER

GENERAL NOTES

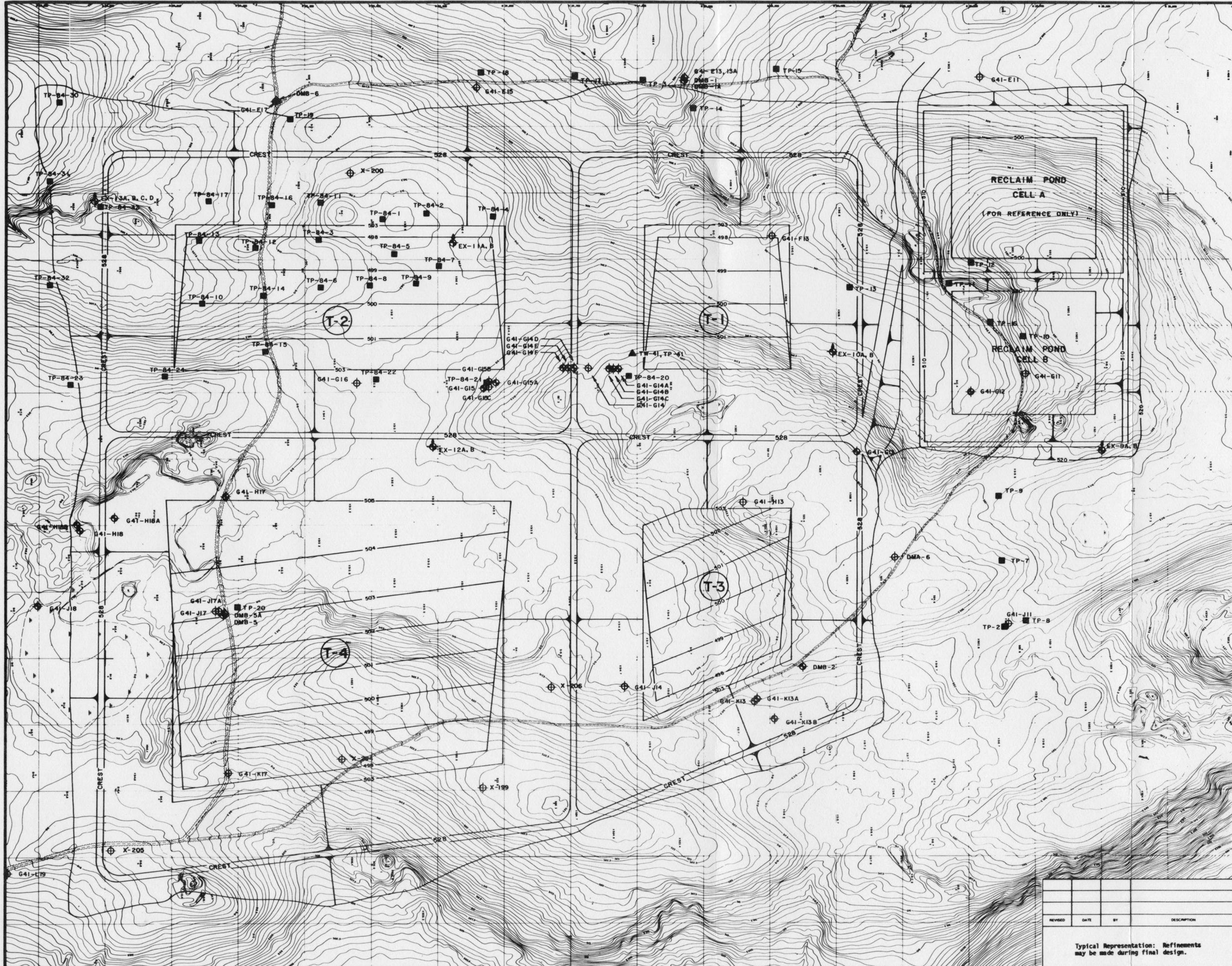
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

PLAN SHEET 12

EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE: GROUNDWATER POTENTIOMETRIC CONTOURS			
SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: J.J.T.	DATE: 9-27-85	CHECKED BY: C.C. Schroeder	DATE: 12/9/85
APPROVED BY:	DATE:	APPROVED BY: J. Waller	DATE: 11-27-85
APPROVED BY:	DATE:	EXXON: D.E. Moe	DATE: 12/2/85
DRAWING NO:		SHEET 12 OF 36	REVISION NO: 0



LEGEND

- TEST BORING
- TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
- TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELLS
- GOLDER ASSOCIATES & STS LTD, TEST PIT LOCATION
- GOLDER ASSOCIATES TEST WELL LOCATION
- T-1 POND NUMBER
- EMBANKMENT SLOPE

NOTES:

1) REFER TO DRAWING NUMBER 050-1-81339 (PLAN SHEET 6) FOR BORING DESIGNATION NUMBER.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

Z

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN
JOHN FRANCIS WALLACE
E-23001
HOUSTON, TX
PROFESSIONAL ENGINEER

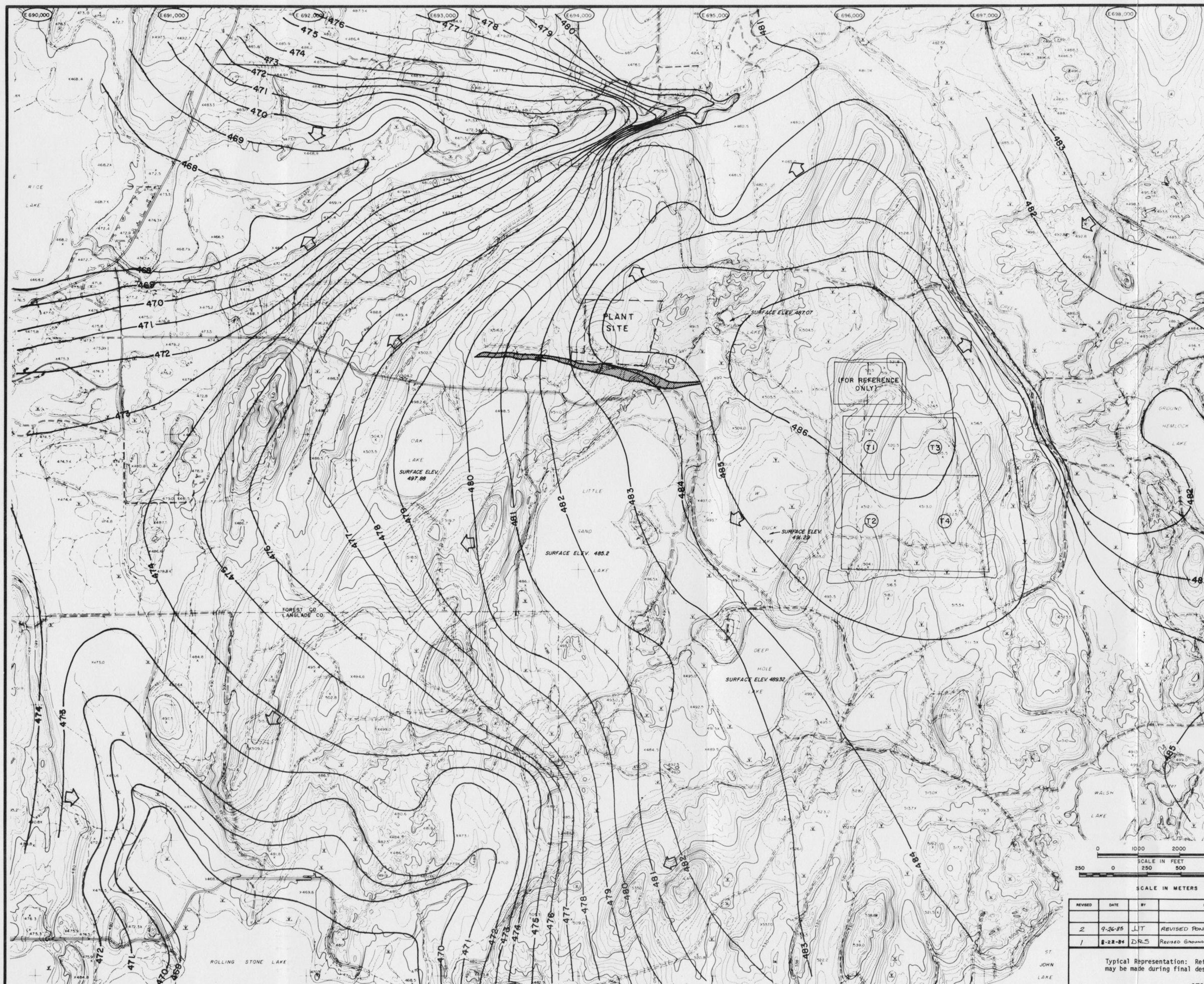
PLAN SHEET 13

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
BORING LOCATION MAP

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY JJT	DATE 9-25-85	CHECKED BY CC Schroeder	DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J.F. Wallace	DATE 11-27-85
APPROVED BY	DATE	EXXON D.E. Moe	DATE 12/4/85
DRAWING NO		SHEET 13 OF 36	REVISION NO 0

REVISED	DATE	BY	DESCRIPTION



LEGEND

- 482 — GROUNDWATER CONTOURS IN METERS ABOVE MSL 1929 ADJUSTMENT. CONTOURS BASED ON APRIL 1984 MEASUREMENTS. SEE STS LTD. REPORT "HYDROGEOLOGICAL STUDY UPDATE", JUNE 1984.
- (T1) POND NUMBER
- CRANDON FORMATION
- GROUNDWATER FLOW DIRECTION

NOTE: DATA FROM APRIL 27, 1984 FOR OLDER WELLS
DATA FROM MAY 24, 1984 FOR EX WELLS

WISCONSIN PROFESSIONAL ENGINEER

SCALE IN FEET: 0 1000 2000 3000

SCALE IN METERS: 250 0 250 500 750 1000

REVISED	DATE	BY	DESCRIPTION
2	9-26-85	JJT	Revised Pond Locations
1	8-22-84	DRS	Revised Groundwater Contours

Typical Representation: Refinements may be made during final design.

STS DRWG. 12959 - 9

PLAN SHEET 14

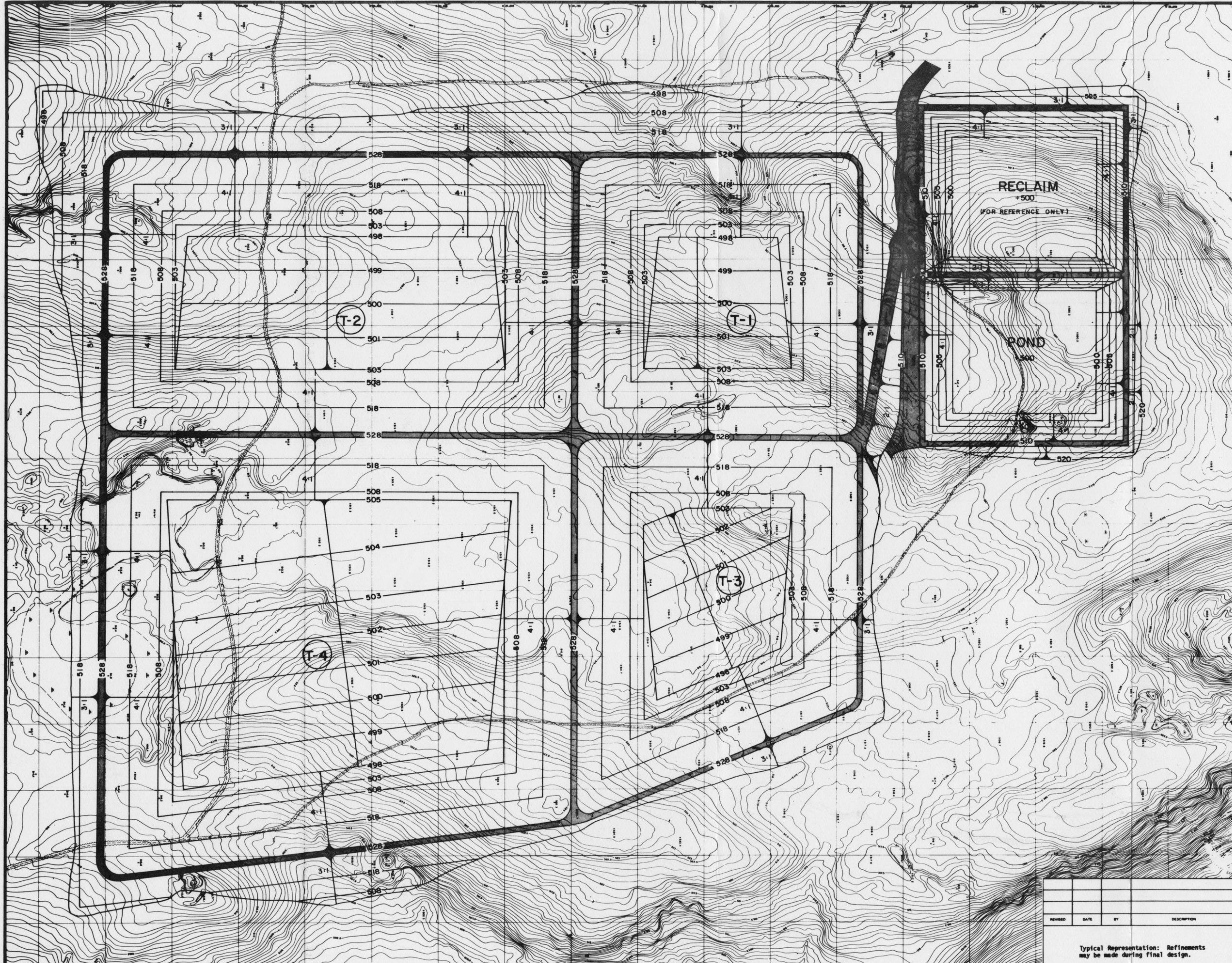
EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE: AREA GROUNDWATER POTENTIOMETRIC CONTOURS

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST, LANGLADE	
DRAWN BY J.J.T.	DATE 6-20-84	CHECKED BY	DATE
APPROVED BY J.A.S.	DATE	APPROVED BY	DATE 11/20/85
APPROVED BY R. ROWE	DATE		DATE 12/4/85
DRAWING NO		SHEET 14 OF 36	REVISION NO 2

DESIGN PRODUCTS CO.



LEGEND

- ACCESS ROAD
- (T-1) POND NUMBER
- EMBANKMENT SLOPE

NOTES:

1) BASE GRADE ELEVATIONS SHOWN ARE TO TOP OF FINAL CONSTRUCTED SURFACE. SUBTRACT ROCK, FILTER, DRAIN, AND LINER THICKNESS TO DETERMINE SUBGRADE ELEVATIONS.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN
JOHN FRANCIS WALLACE
HOUSTON TX
PROFESSIONAL ENGINEER

PLAN SHEET 15

EXXON MINERALS COMPANY
CRANDON PROJECT

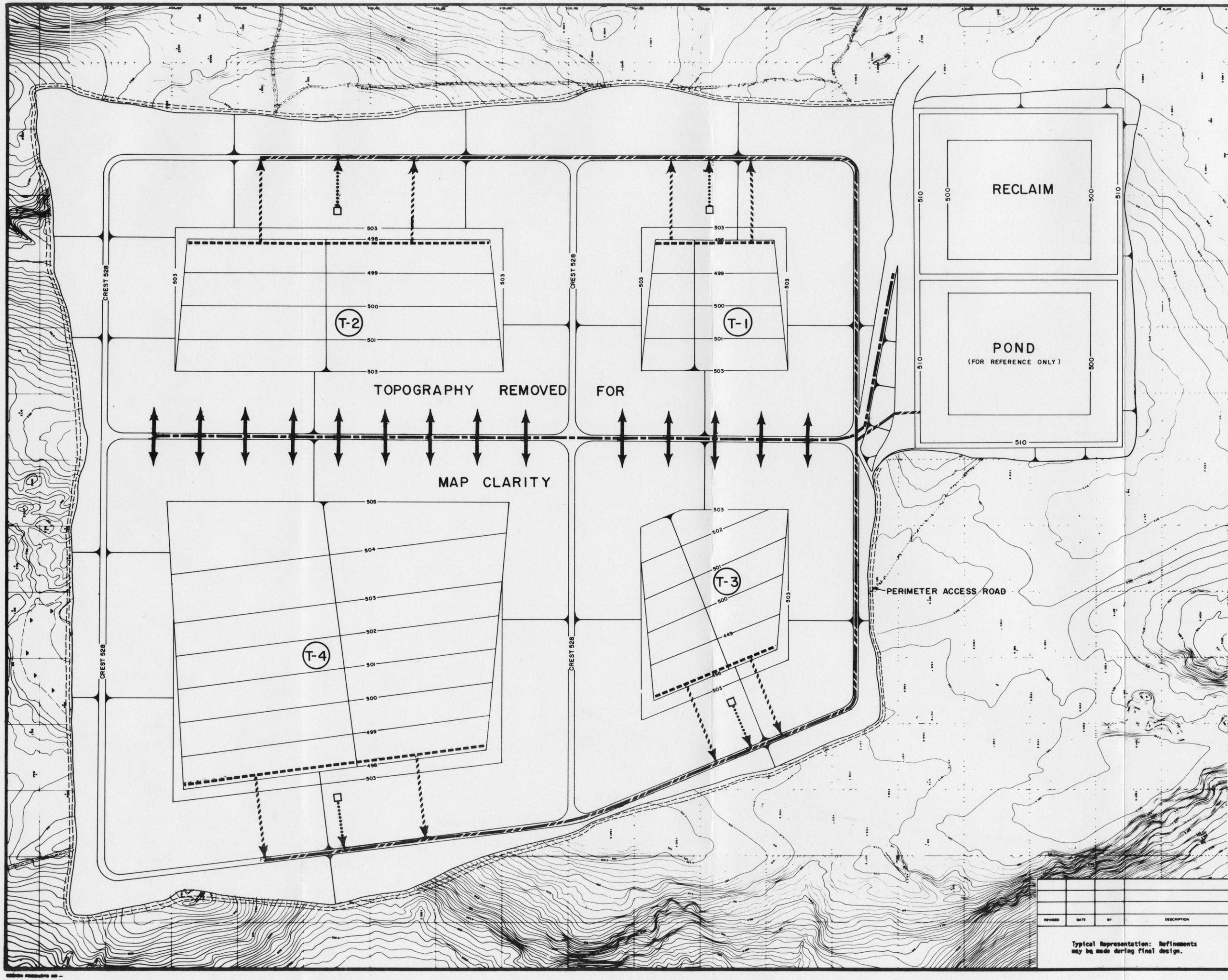
TITLE
BASE GRADE PLAN

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J.J.T	DATE 9-25-85	CHECKED BY CC Schroeder	DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY J.F. Wallace	DATE	
APPROVED BY	DATE	EXXON D.E. Mc	DATE	
DRAWING NO		SHEET 19 OF 36	REVISION NO 0	

DESIGN PRODUCTS CO —



LEGEND

- UNDERDRAIN COLLECTION PIPE
- UNDERDRAIN DISCHARGE PIPE
- DECANT PIPELINE FROM FLOATING BARGE
- DECANT AND UNDERDRAIN RETURN PIPELINE
- TAILINGS PIPELINE
- TAILINGS DISCHARGE POINTS
- (T1) POND NUMBER
- ACCESS ROAD

NOTES:

1) HAUL ROAD AND CREST WIDTH DETAILS SHOWN ON PLAN SHEET 23.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

Z

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER
JOHN ... E-23401 ...

PLAN SHEET 16

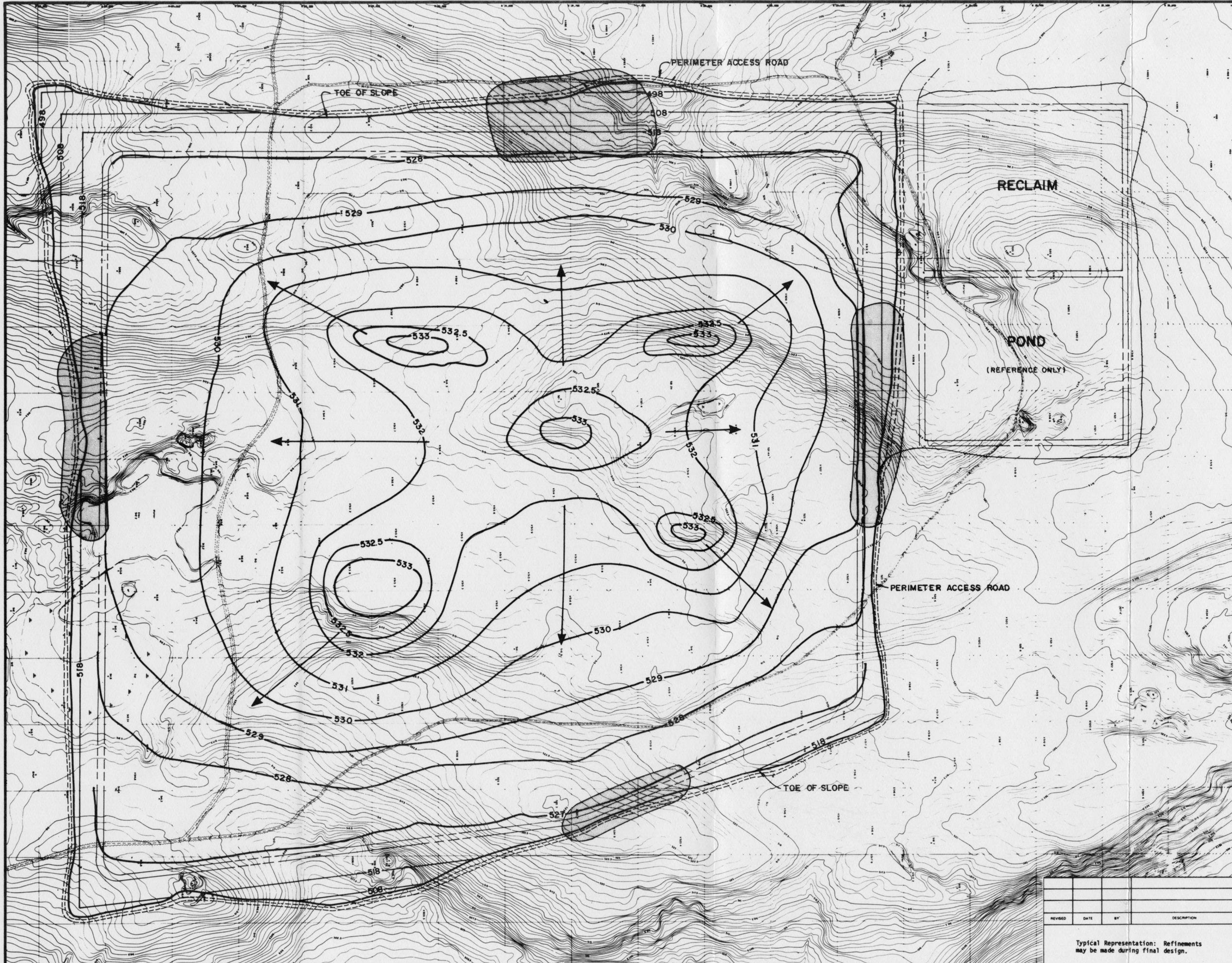
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PIPELINE AND ACCESS ROAD ALIGNMENT

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J. J. T.	DATE 10-5-85	CHECKED BY E. E. Schroeder		DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J. R. Wilken		DATE 12/12/85
APPROVED BY	DATE	DESIGN D. E. Moe		DATE 12/7/85
DRAWING NO			SHEET 16 OF 36	REVISION NO 0



LEGEND

AREAS POTENTIALLY REQUIRING SPECIAL EROSION CONTROL

DIRECTION OF SURFACE WATER RUN-OFF

NOTES:

1) SEE DETAIL B, FOR TYPICAL RECLAMATION COVER PLAN SHEET 25.

2) SEE PLAN SHEET 25 FOR CROSS-SECTION THROUGH ENTIRE FACILITY.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/ TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

Z

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER

PLAN SHEET 17

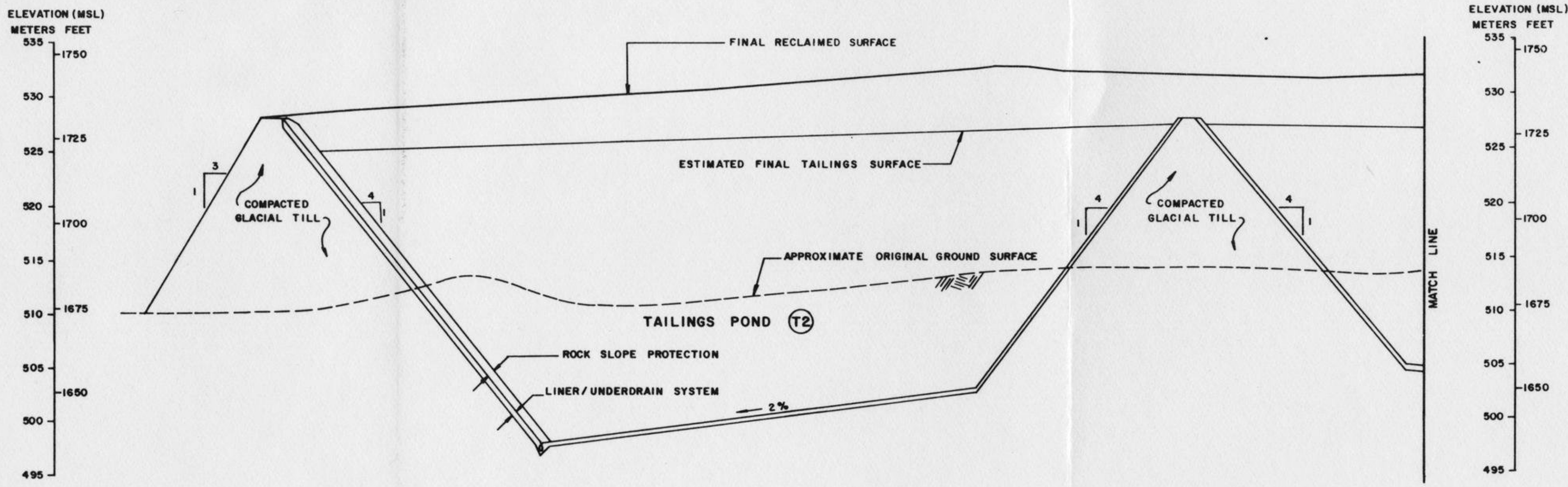
EXXON MINERALS COMPANY
CRANDON PROJECT

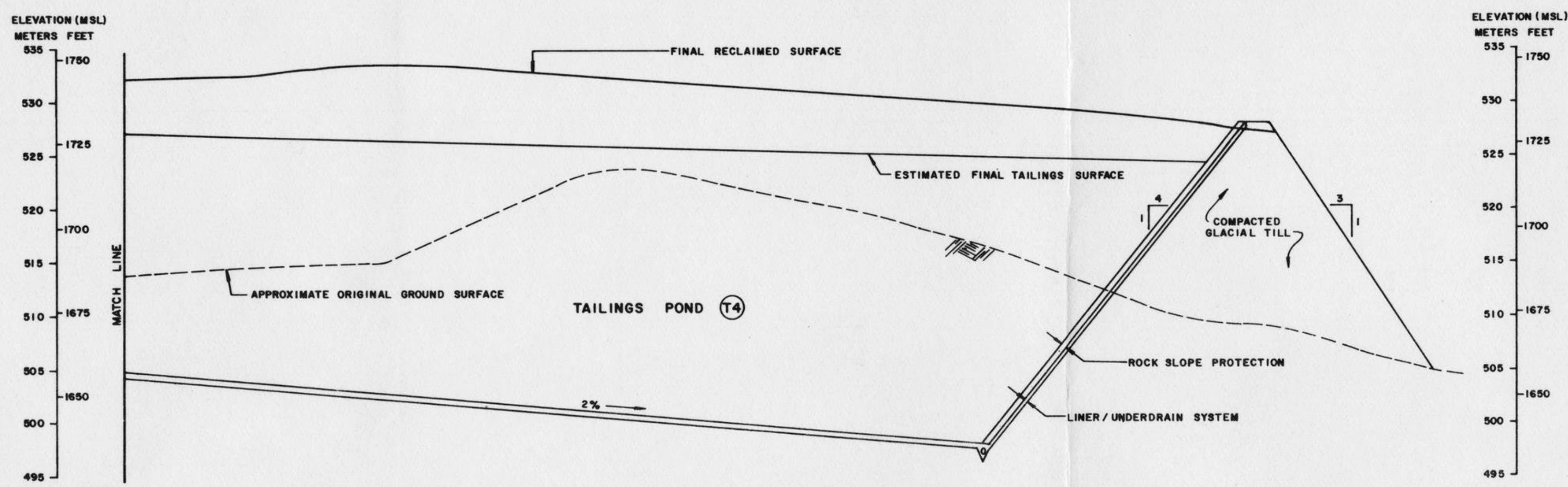
TITLE
FINAL GRADE PLAN

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-7-85	CHECKED BY CCSchroeder	DATE 12/6/85
APPROVED BY	DATE	APPROVED BY JRWallace	DATE [illegible]
APPROVED BY	DATE	EXXON D.E. Moe	DATE [illegible]
DRAWING NO		SHEET 17 OF 36	REVISION NO 0

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.



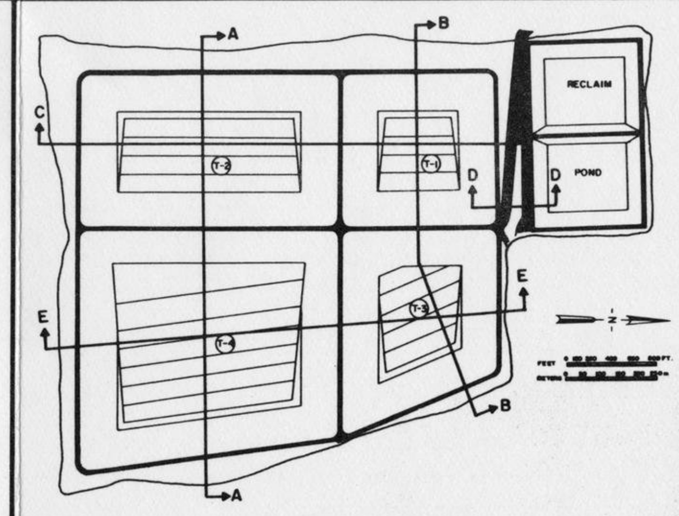


SECTION A-A

0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5 x



CROSS-SECTION INDEX

NOTE: FOR TYPICAL DETAILS AND REFERENCE NOTES SEE PLAN SHEET 23.

PLAN SHEET 18

REVISED	DATE	BY	DESCRIPTION

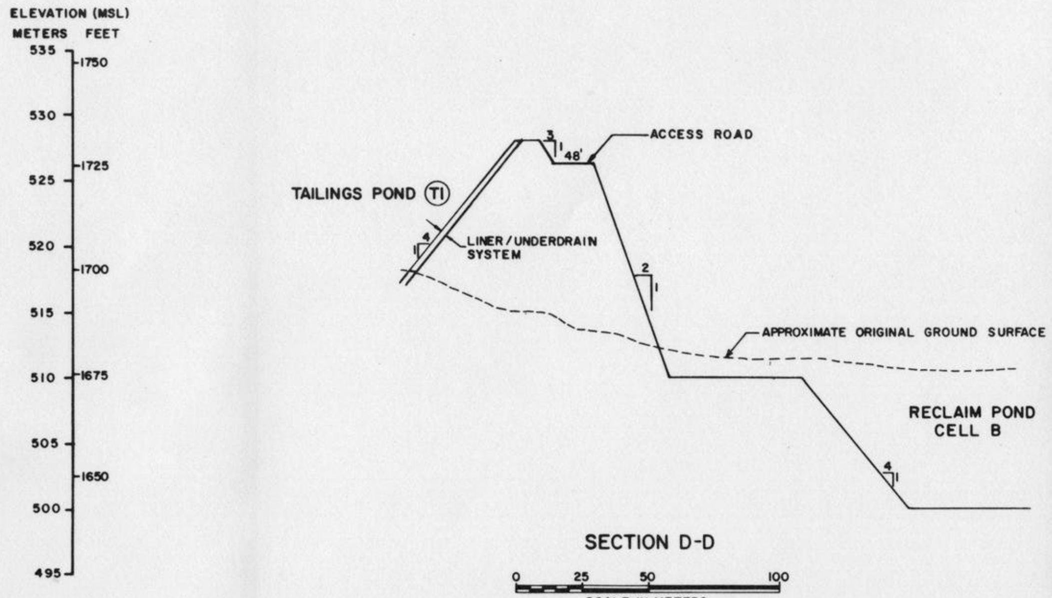
Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: FACILITY CROSS SECTION A-A

SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST
DRAWN BY: P.D.P. | DATE: 10-14-85 | CHECKED BY: E.C. Schroeder
APPROVED BY: | DATE: | APPROVED BY:
DRAWING NO. | SHEET 18 OF 36 | REVISION NO. 0

DESIGN PRODUCTS CO. —

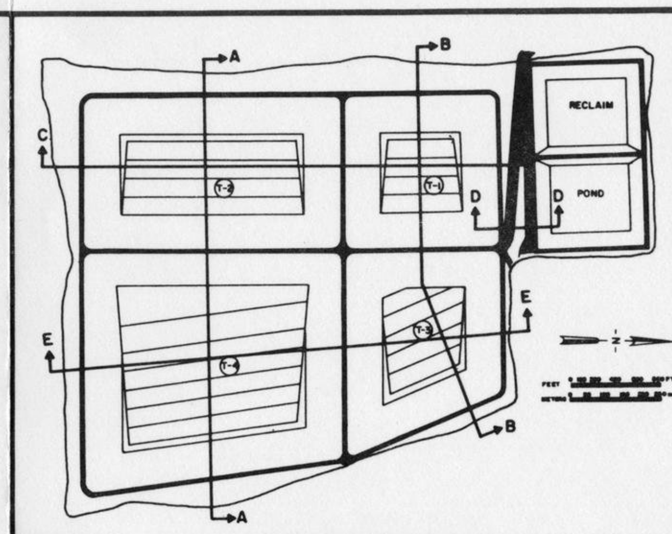


SECTION D-D

0 25 50 100
SCALE IN METERS

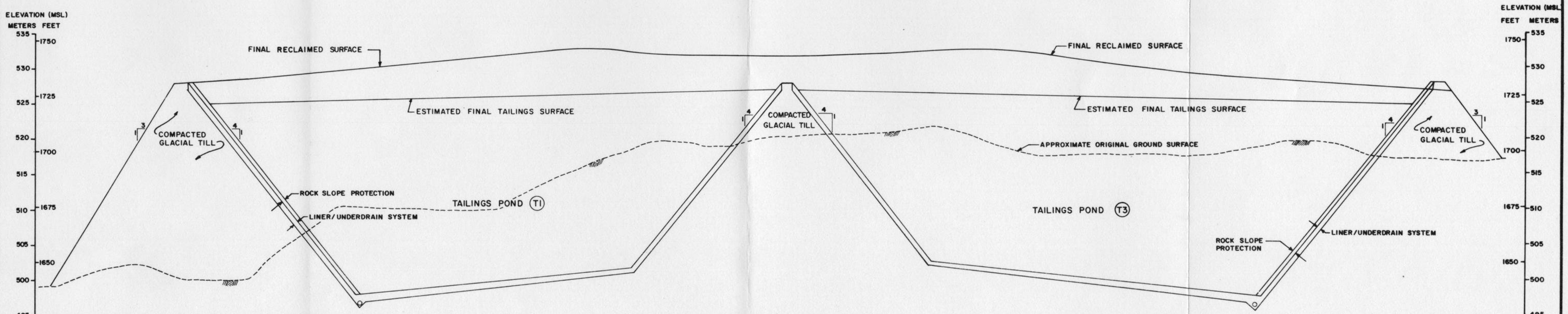
0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5 x



CROSS-SECTION INDEX

NOTE: FOR TYPICAL DETAILS AND REFERENCE NOTES SEE PLAN SHEET 23.



SECTION B-B

0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5 x

PLAN SHEET 19

EXXON MINERALS COMPANY
CRANDON PROJECT

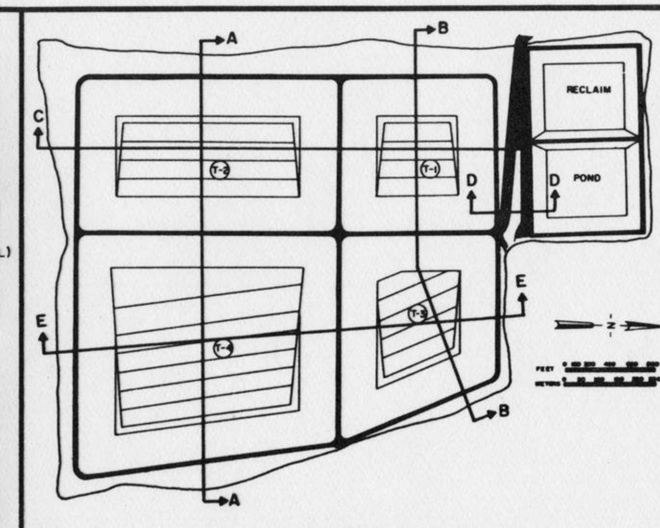
TITLE
FACILITY CROSS SECTION B-B & D-D

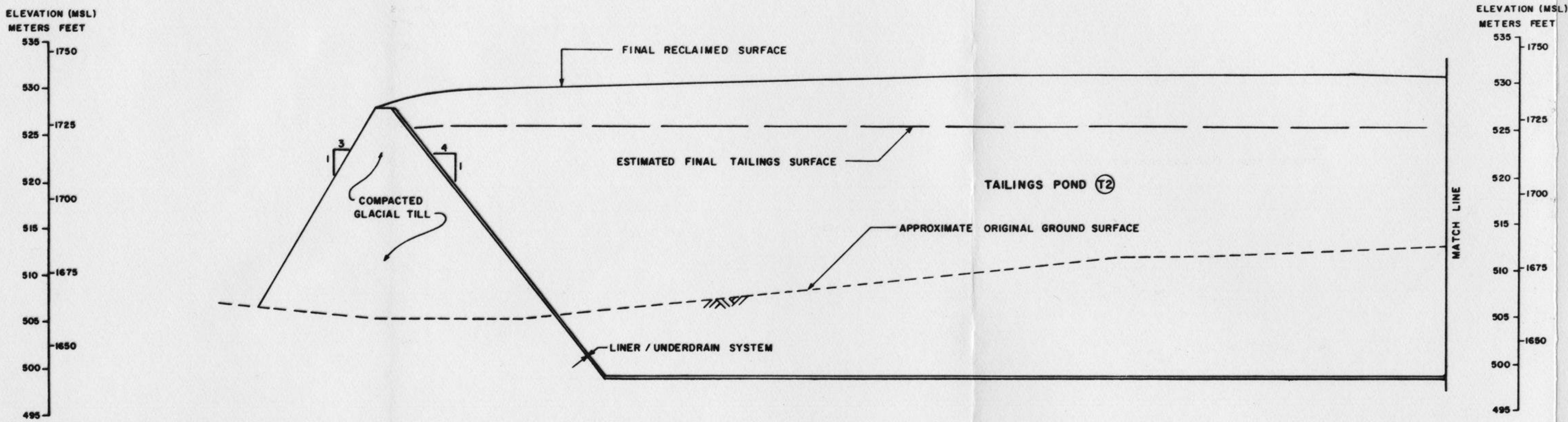
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY K.J.C.	DATE 10-11-85	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY		DATE	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO		SHEET 19 OF 36		REVISION NO 0	

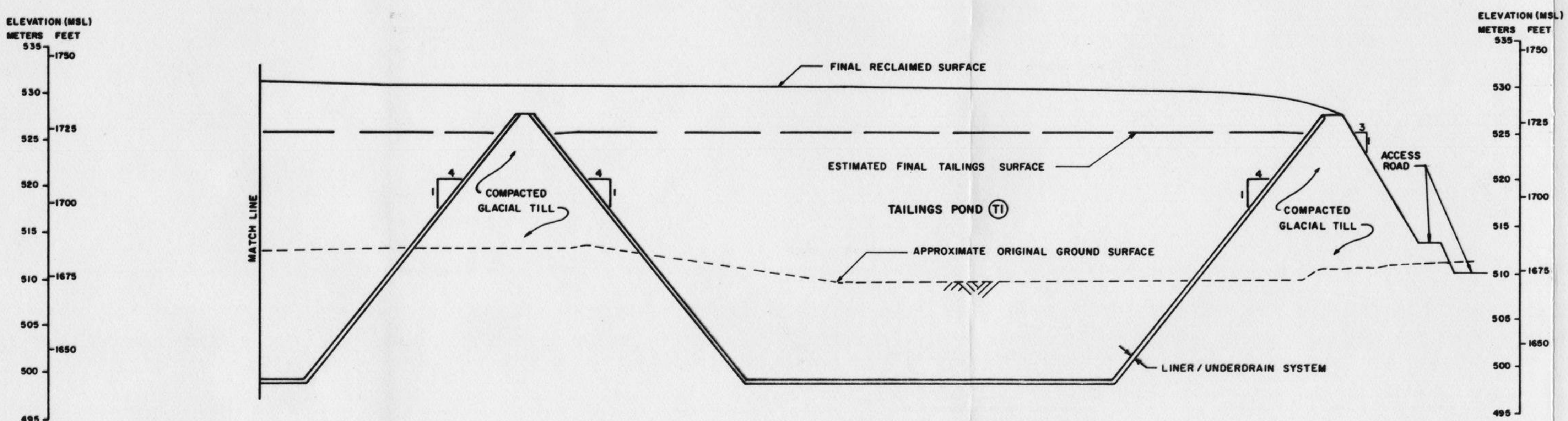
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

DESIGN PRODUCTS CO. —







NOTE: FOR TYPICAL DETAILS AND REFERENCE NOTES SEE PLAN SHEET 23.

SECTION C-C

0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5x

Typical Representation: Refinements may be made during final design.

REVISED	DATE	BY	DESCRIPTION

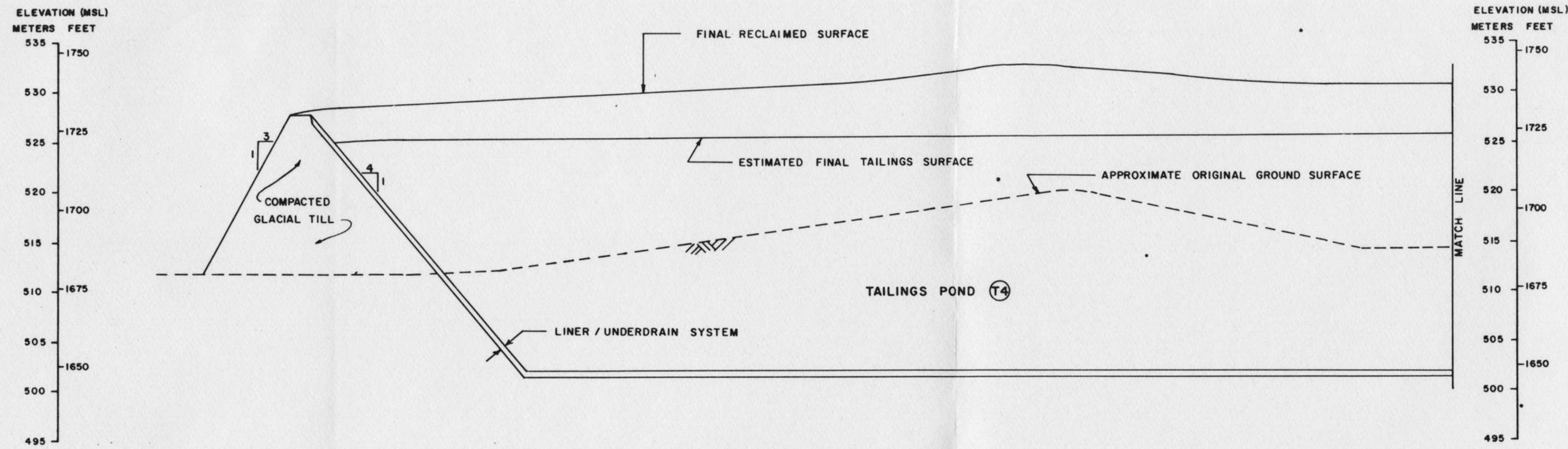
PLAN SHEET 20

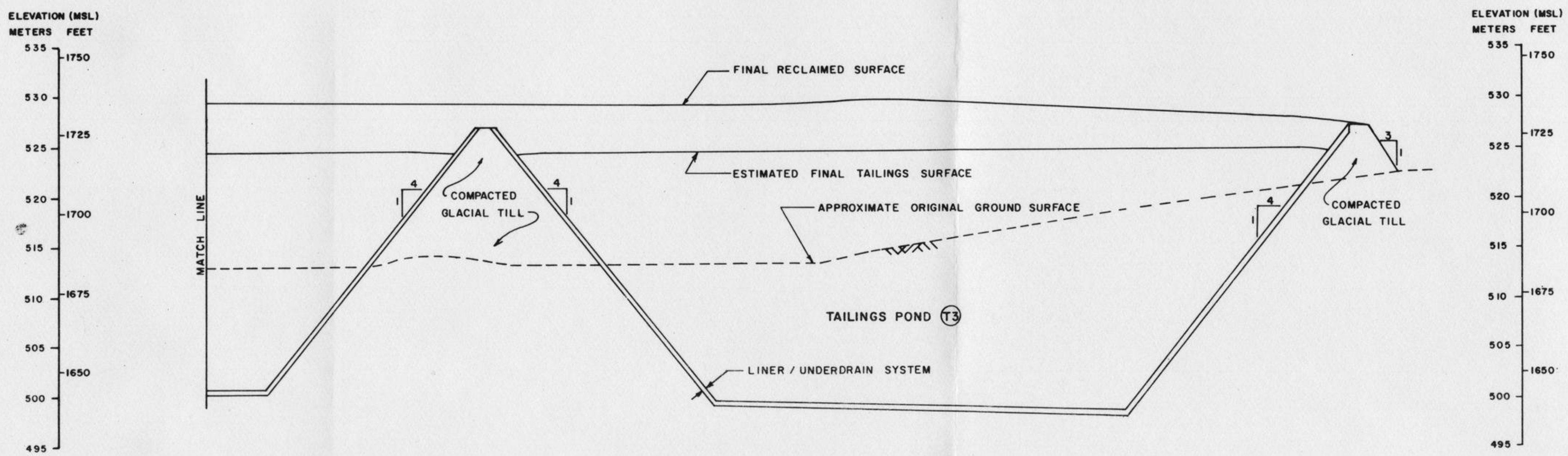
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: FACILITY CROSS SECTION C-C

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: K.J.C.	DATE: 10-9-85	CHECKED BY: C.C. Schroeder	DATE: 12/6/85
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON: D.E. Moe	DATE: 12/7/85
DRAWING NO		SHEET 20 OF 36	REVISION NO 0

DESIGN PRODUCTS CO.—



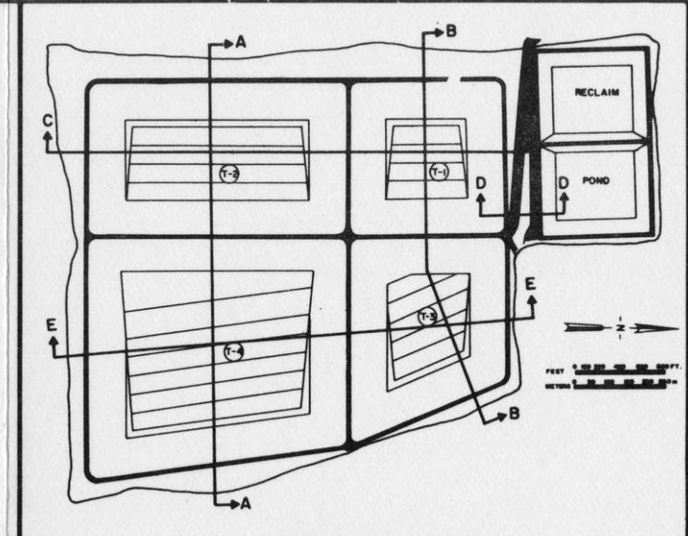


SECTION E-E

0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5X



CROSS-SECTION INDEX

NOTE: FOR TYPICAL DETAILS AND REFERENCE NOTES SEE PLAN SHEET 23.

PLAN SHEET 21

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: FACILITY CROSS SECTION E-E

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

DRAWN BY	DATE	CHECKED BY	DATE
K.J.C.	10-9-85	C.C. Schroeder	12/6/85

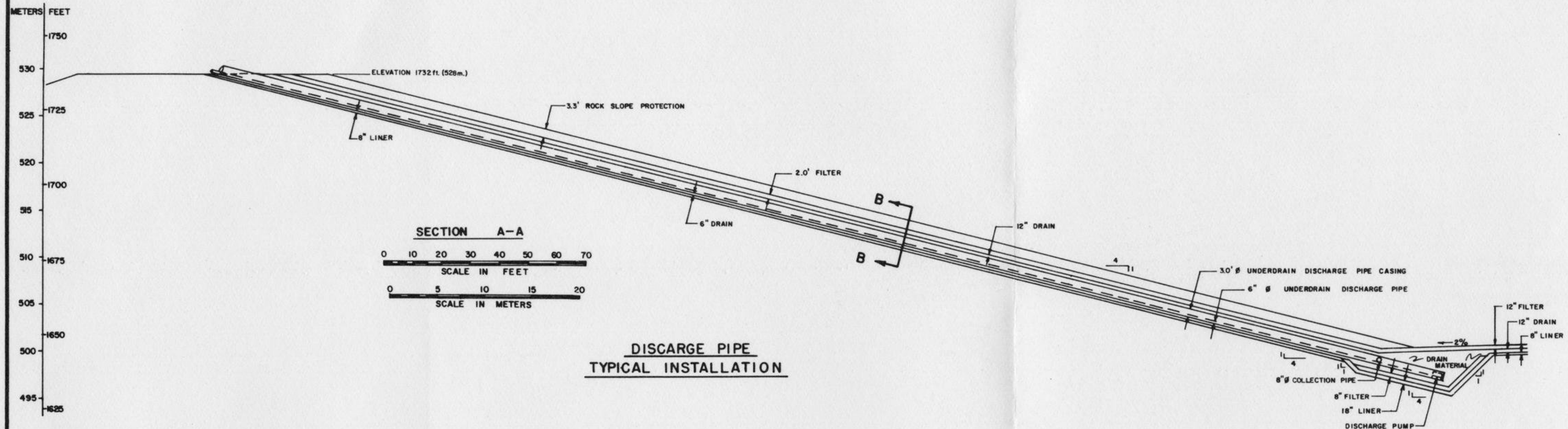
APPROVED BY / APPROVED BY / EXXON / DRAWING NO

SHEET 21 OF 34

REVISION NO. 0

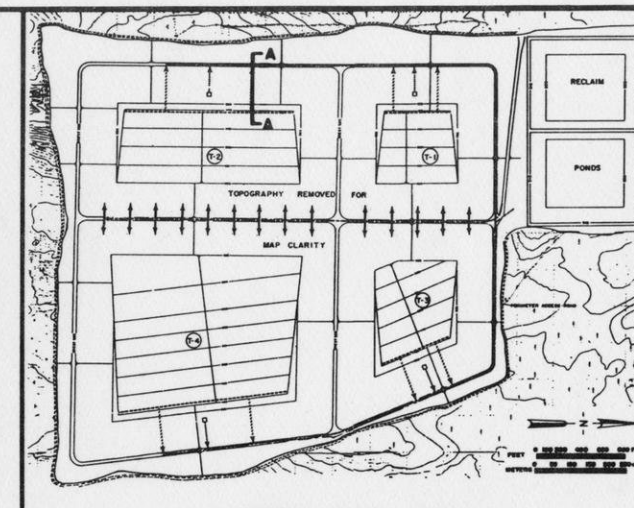
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

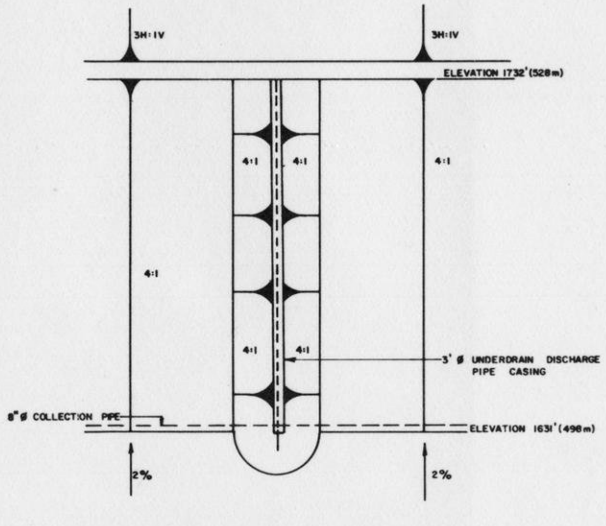


SECTION A-A

DISCARGE PIPE
TYPICAL INSTALLATION

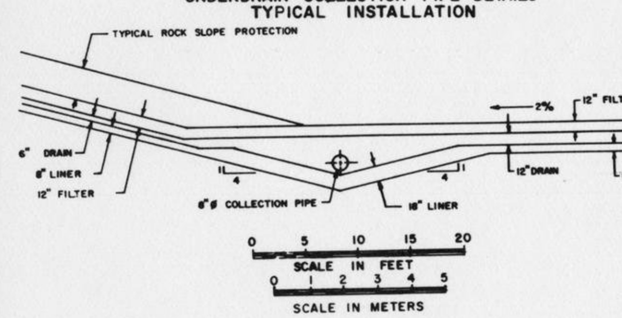


CROSS-SECTION INDEX

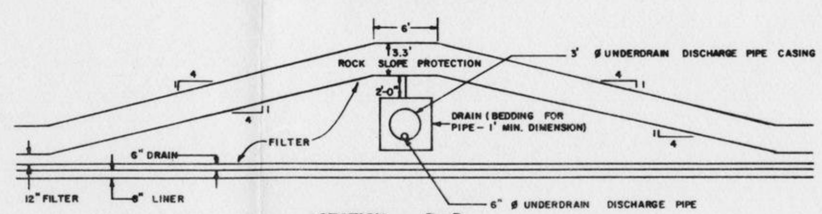


PLAN VIEW SECTION A-A

UNDERDRAIN COLLECTION PIPE DETAILS
TYPICAL INSTALLATION



DISCHARGE PIPE DETAILS



SECTION B-B

COLLECTION AND DISCHARGE PIPE NOTES

1. Underdrain collection pipe shall be 8 in. diameter with bottom perforations no larger than 0.25 in. diameter.
2. Underdrain discharge pipe casing shall be 3 ft. diameter with the lowest 5 ft. in the sump area perforated. Perforations shall be no larger than 0.25 in. diameter. The discharge pipe casing shall be fitted with an end cap or plate at the sump end of the pipe.
3. Underdrain discharge pipe shall be 6 in. diameter. The underdrain discharge pipe will be connected to a pump in the sump end of the discharge pipe casing.

NOTES AND PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 6 in. and compacted to 95% maximum dry density, within ±3% of optimum moisture content as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 0.75 in. modified with bentonite. Liner shall be compacted to 95% maximum dry density, at 3% above optimum moisture content, as determined by ASTM D-698
3. Drain material shall be finer than 2 in. and coarser than No. 40 U.S. Standard Sieve.
4. Filter material shall be glacial till finer than 6 in. and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

NOTE:
SEE PLAN SHEET 16
FOR LOCATION OF UNDERDRAIN
DISCHARGE AND COLLECTION PIPES.

REVISED	DATE	BY	DESCRIPTION

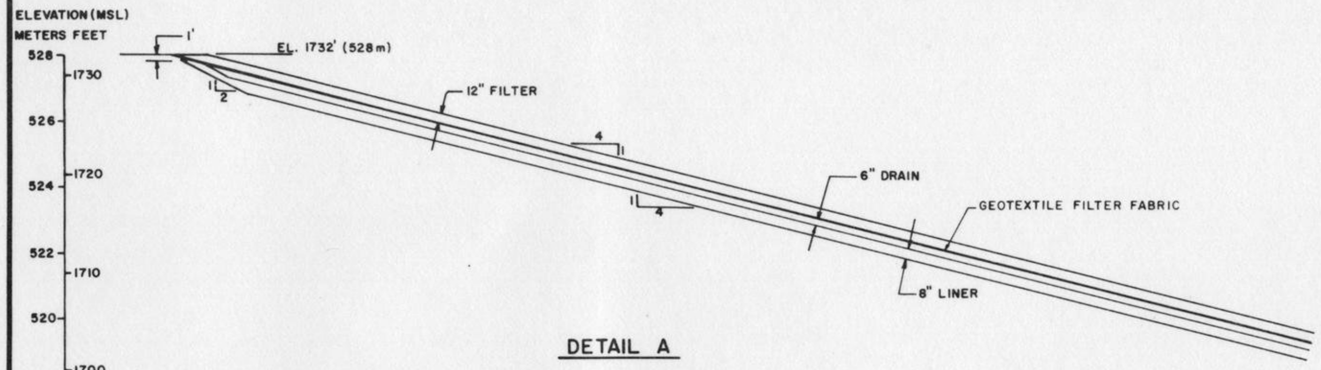
Typical Representation: Refinements may be made during final design.

PLAN SHEET 22

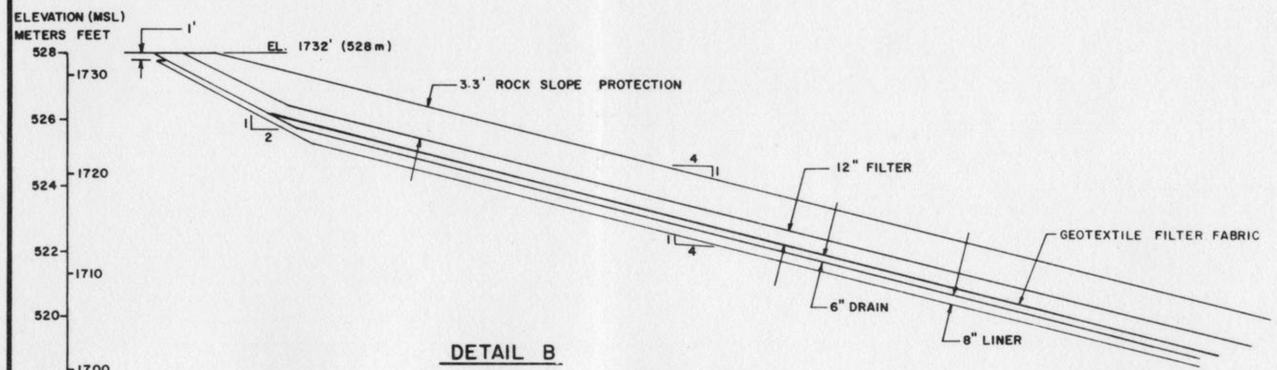
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
UNDERDRAIN AND COLLECTION PIPE DETAILS

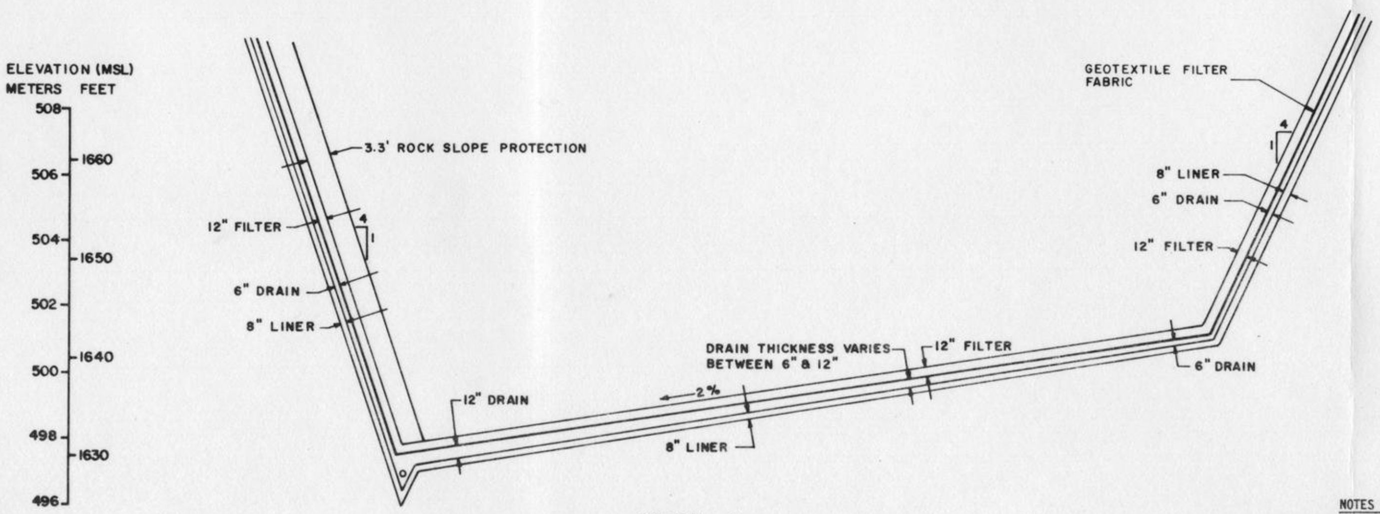
SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY M.M.A.	DATE 10-8-85	CHECKED BY C.C. Schroeder	DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J. Wallace	DATE
APPROVED BY	DATE	EXXON D.E. Moe	DATE 12/7/85
DRAWING NO		SHEET 22 OF 36	REVISION NO 0



DETAIL A

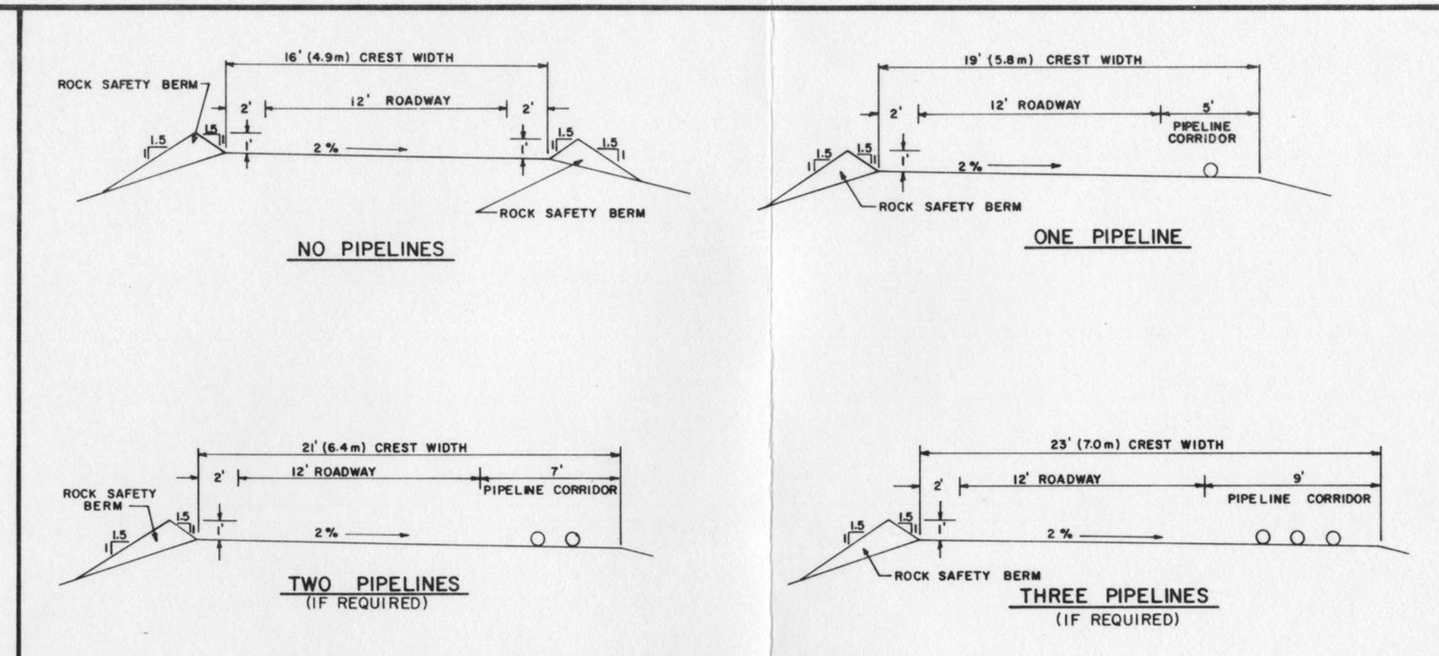


DETAIL B

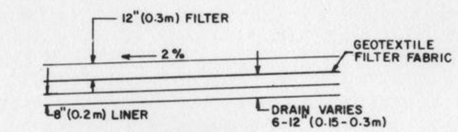


DETAIL C

UNDERDRAIN AND LINER DETAIL - TYPICAL POND BASE



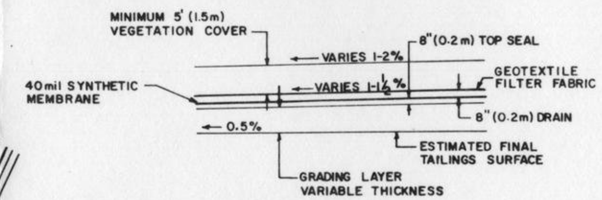
CREST WIDTH DETAILS



DETAIL D

TYPICAL BOTTOM UNDERDRAIN AND LINER

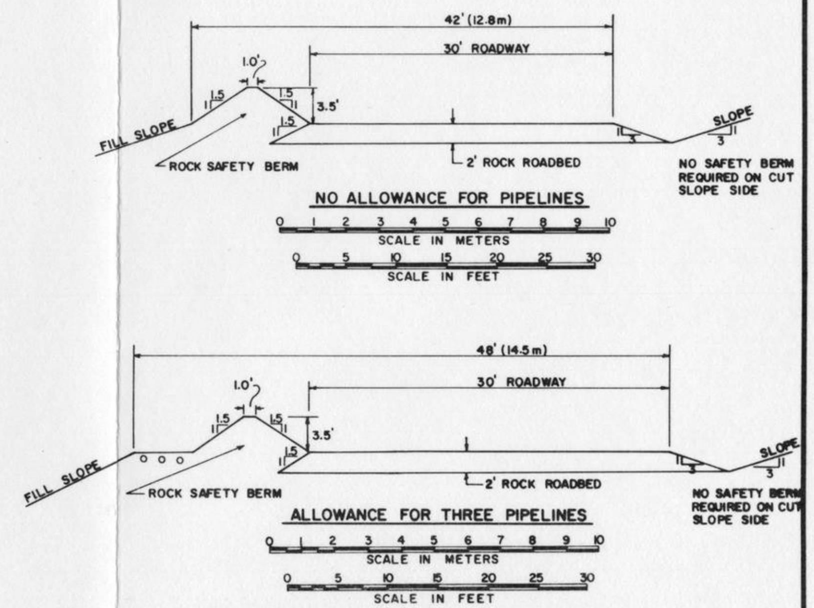
DIMENSIONS AS SHOWN



DETAIL E

TYPICAL RECLAMATION COVER

DIMENSIONS AS SHOWN



MWDF ACCESS ROAD DETAILS

NOTES AND PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 6 in. and compacted to 95% maximum dry density, within ±3% of optimum moisture content as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 0.75 in. modifided with bentonite. Liner shall be compacted to 95% maximum dry density, at 3% above optimum moisture content, as determined by ASTM D-698
3. Drain material shall be finer than 2 in. and coarser than No. 40 U.S. Standard Sieve.
4. Filter material shall be glacial till finer than 6 in. and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

Typical Representation: Refinements may be made during final design.

REVISED	DATE	BY	DESCRIPTION

PROFESSIONAL ENGINEER

PLAN SHEET 23

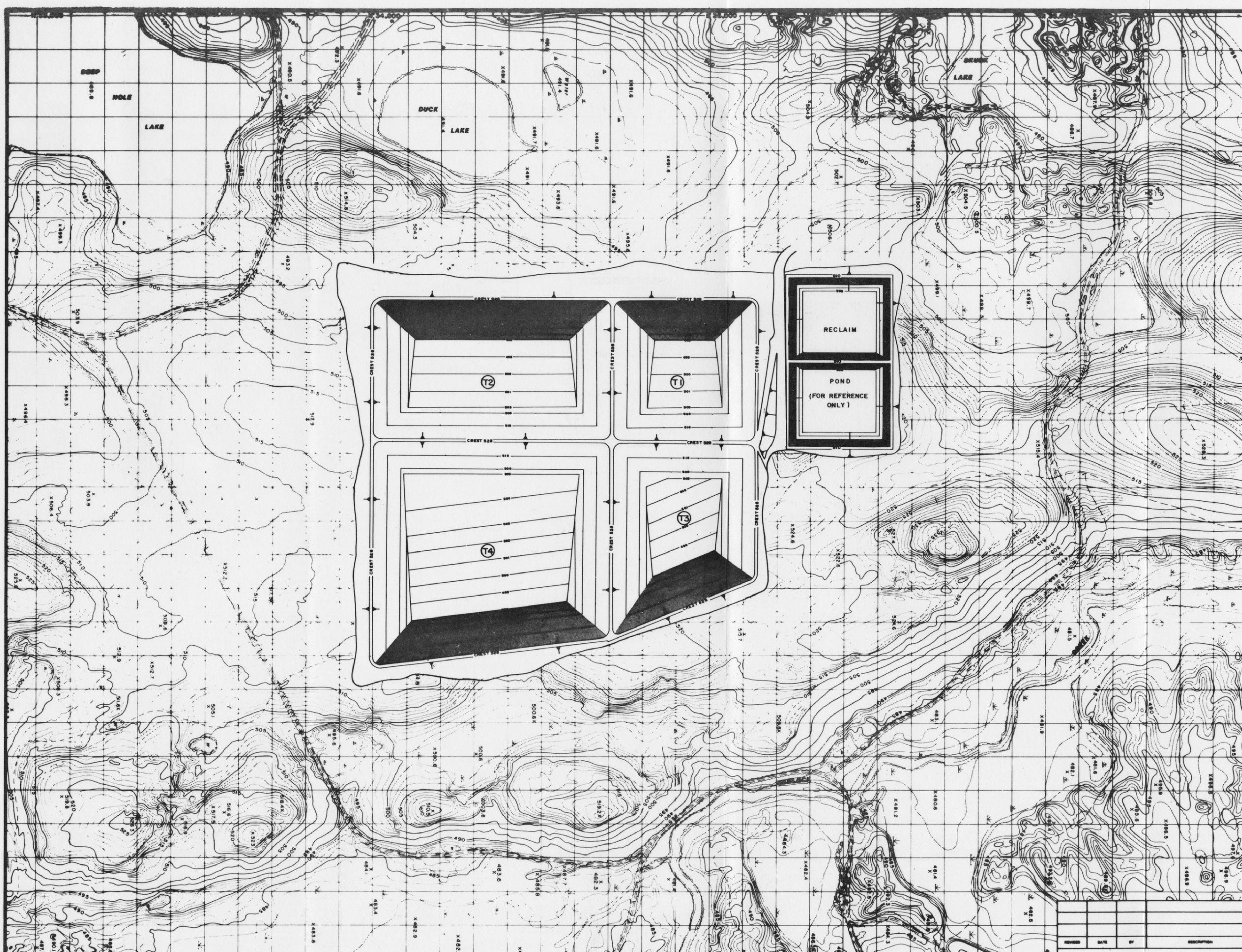
EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE: UNDERDRAIN, COVER, ACCESS ROAD & CREST DETAILS

SCALE: AS SHOWN	STATE: WISCONSIN		COUNTY: FOREST	
DRAWN BY: K.J.C.	DATE: 10-8-85	CHECKED BY: CC Schroeder		DATE: 12/6/85
APPROVED BY	DATE	APPROVED BY: R Wallace		DATE: 12/6/85
APPROVED BY	DATE	EXXON: D.E. Moe		DATE: 12/9/85
DRAWING NO		SHEET 23 OF 36		REVISION NO: 0

DESIGN PRODUCTS CO —



Typical Representation: Refinements may be made during final design.

LEGEND

- ROCK SLOPE PROTECTION
- (T2) POND NUMBER
- EMBANKMENT SLOPE

NOTE:

1) ROCK SLOPE PROTECTION DETAILS SHOWN ON PLAN SHEETS 22 & 23.

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

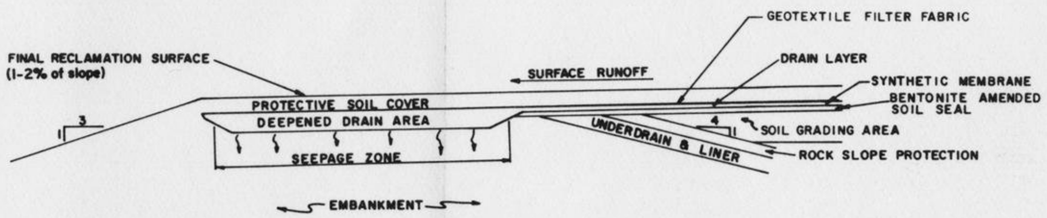
PLAN SHEET 24

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
ROCK SLOPE PROTECTION PLAN

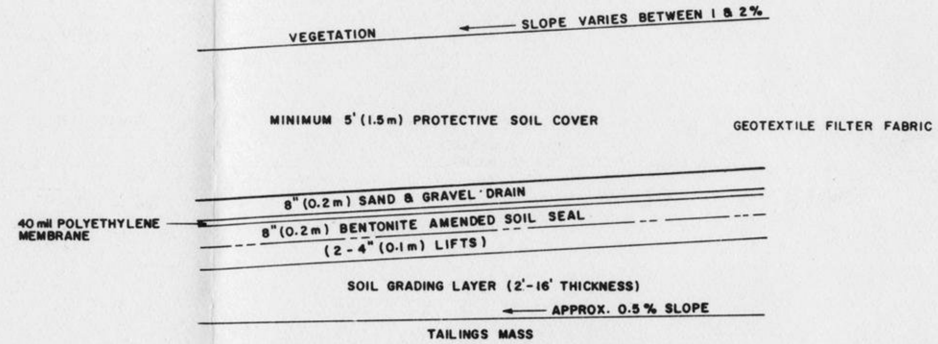
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST
DRAWN BY J.J.T.	DATE 10-4-85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE		
DRAWING NO		SHEET 24 OF 36	

REVISED	DATE	BY	DESCRIPTION



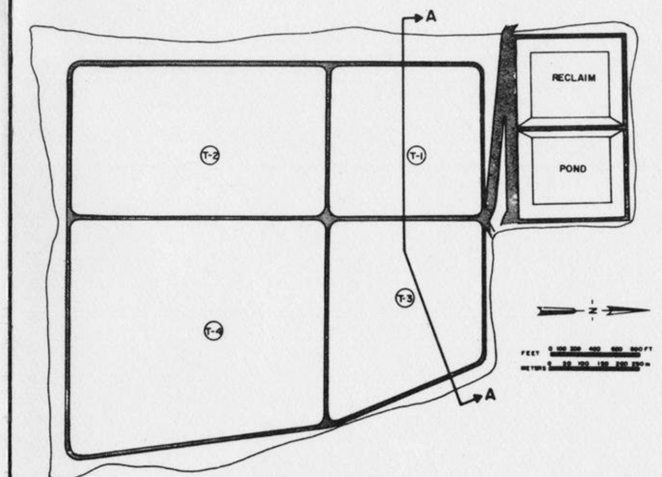
TYPICAL RECLAMATION EMBANKMENT DRAINAGE DETAIL
NOT TO SCALE

DETAIL A

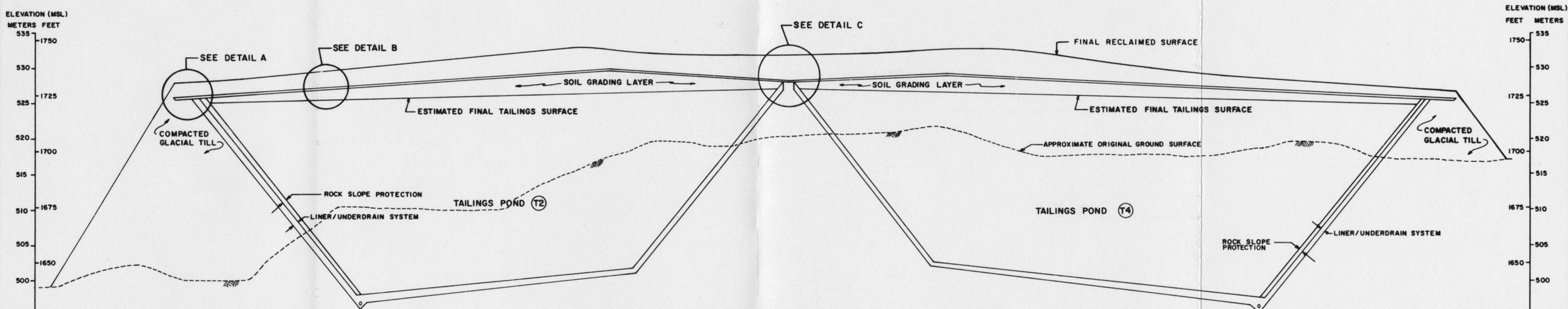


TYPICAL RECLAMATION COVER DETAIL
NOT TO SCALE

DETAIL B



CROSS-SECTION INDEX

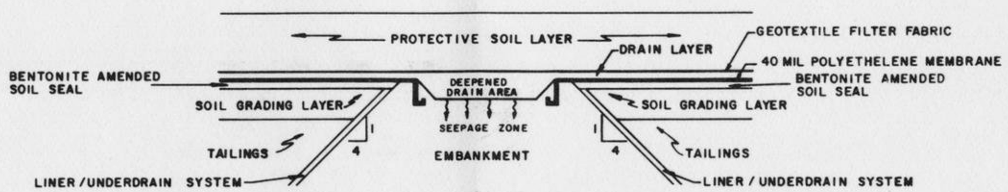


RECLAMATION COVER SECTION A-A

0 25 50 100
SCALE IN METERS

0 50 100 200 300
SCALE IN FEET

VERTICAL EXAGGERATION: 5 x



TYPICAL RECLAMATION CENTRAL EMBANKMENT DRAINAGE DETAIL
NOT TO SCALE

DETAIL C

PLAN SHEET 25

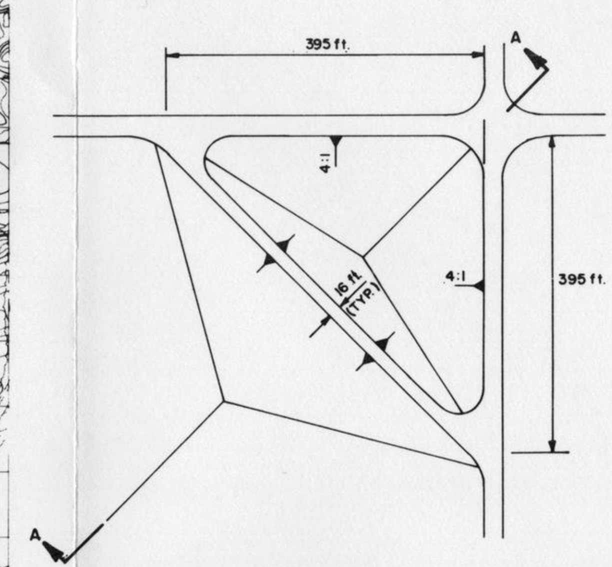
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RECLAMATION COVER SYSTEM & DETAILS

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY K.J.C.	DATE 10-7-85	CHECKED BY C.C. Schroeder		DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY J. Wallace		DATE 12/?/85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 12/9/85	
DRAWING NO			SHEET 25 OF 36	REVISION NO 0	

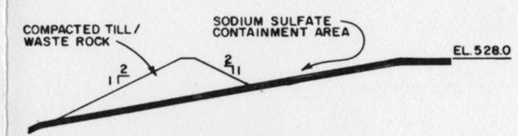


ENLARGED DETAIL

(POND T4 SHOWN, OTHER PONDS TYPICAL)

0 25 50 100
SCALE IN METERS

0 100 200 300
SCALE IN FEET



SECTION A-A

(TYPICAL)

0 25 50 100
SCALE IN METERS

0 100 200 300
SCALE IN FEET

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AEROMETRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE/TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

PLAN SHEET 26

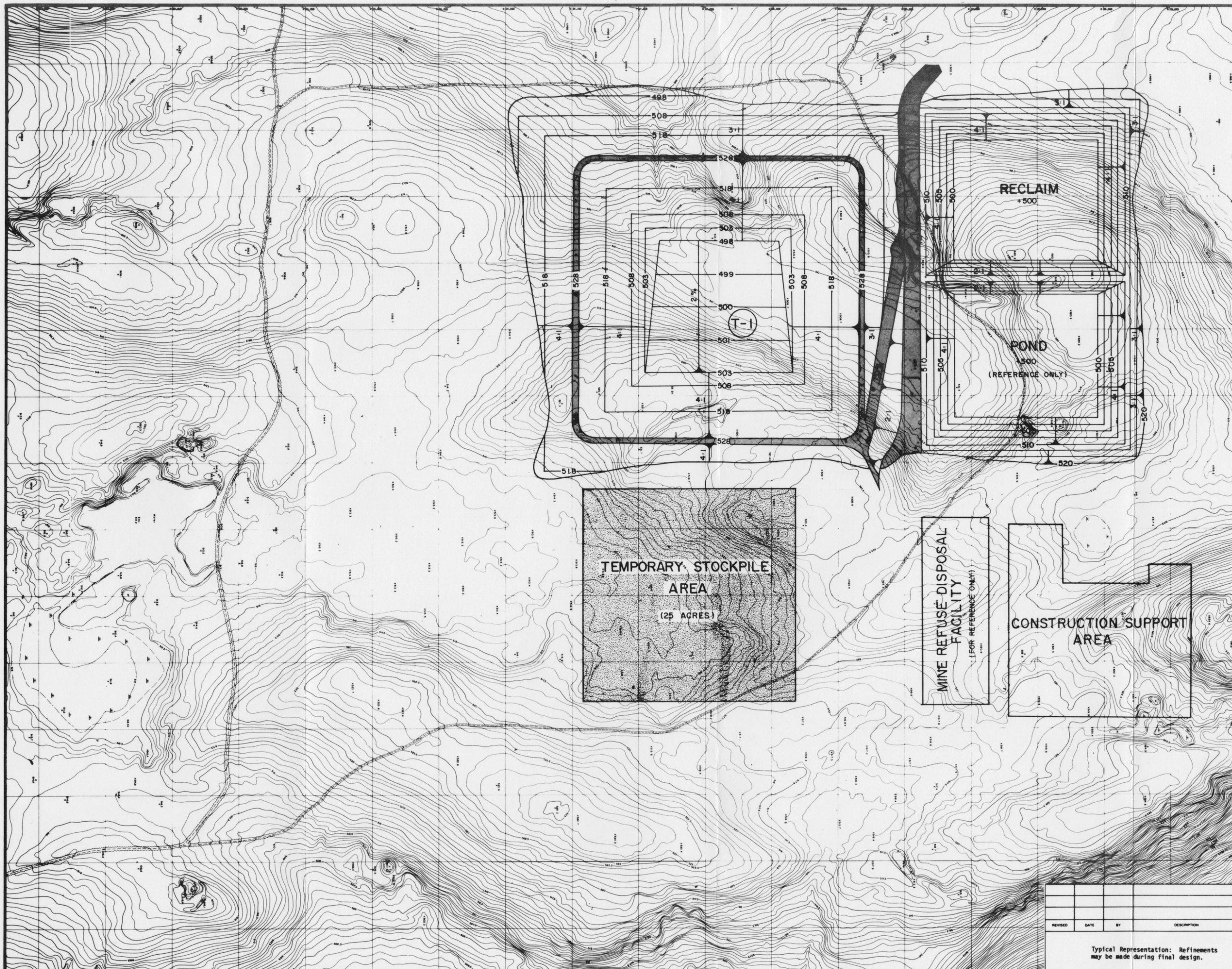
EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

SODIUM SULFATE STORAGE

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J.J.T.	DATE 9-27-85	CHECKED BY C. Schroeder	DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J.F. Wallace	DATE 12/?/85
APPROVED BY	DATE	EXXON D.E. Moe	DATE 12/?/85
DRAWING NO		SHEET 26 OF 36	REVISION NO 0



LEGEND

- CREST ROAD
- T-1 POND NUMBER
- EMBANKMENT SLOPE

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

Z

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN
JOHN FRANCIS WALLACE
E-23481
HOUSTON TX
PROFESSIONAL ENGINEER

PLAN SHEET 27

EXXON MINERALS COMPANY
CRANDON PROJECT

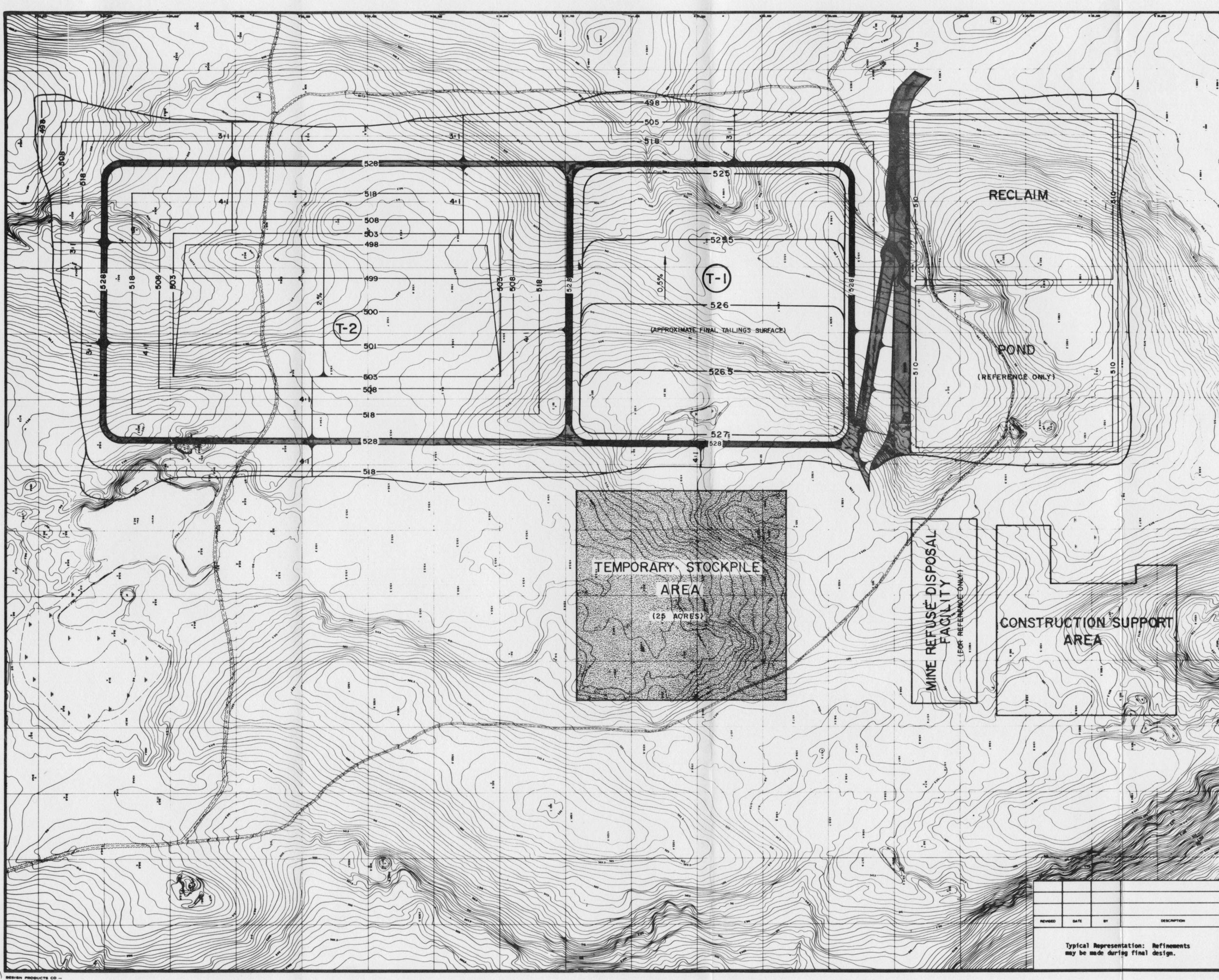
TITLE
PHASE I
POND T-I CONSTRUCTED

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-13-85	CHECKED BY C. Schroeder		DATE 12/1/85
APPROVED BY	DATE	APPROVED BY J. Wallace		DATE
APPROVED BY	DATE	EXXON D.E. Moe		DATE
DRAWING NO		SHEET 27 OF 38		REVISION NO 0

DESIGN PRODUCTS CO —



LEGEND

- CREST ROAD
- (T-1) POND NUMBER
- EMBANKMENT SLOPE

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER
JOHN FRANCIS WALLACE
E-23401
HOUSTON TX

PLAN SHEET 28

REVISED	DATE	BY	DESCRIPTION

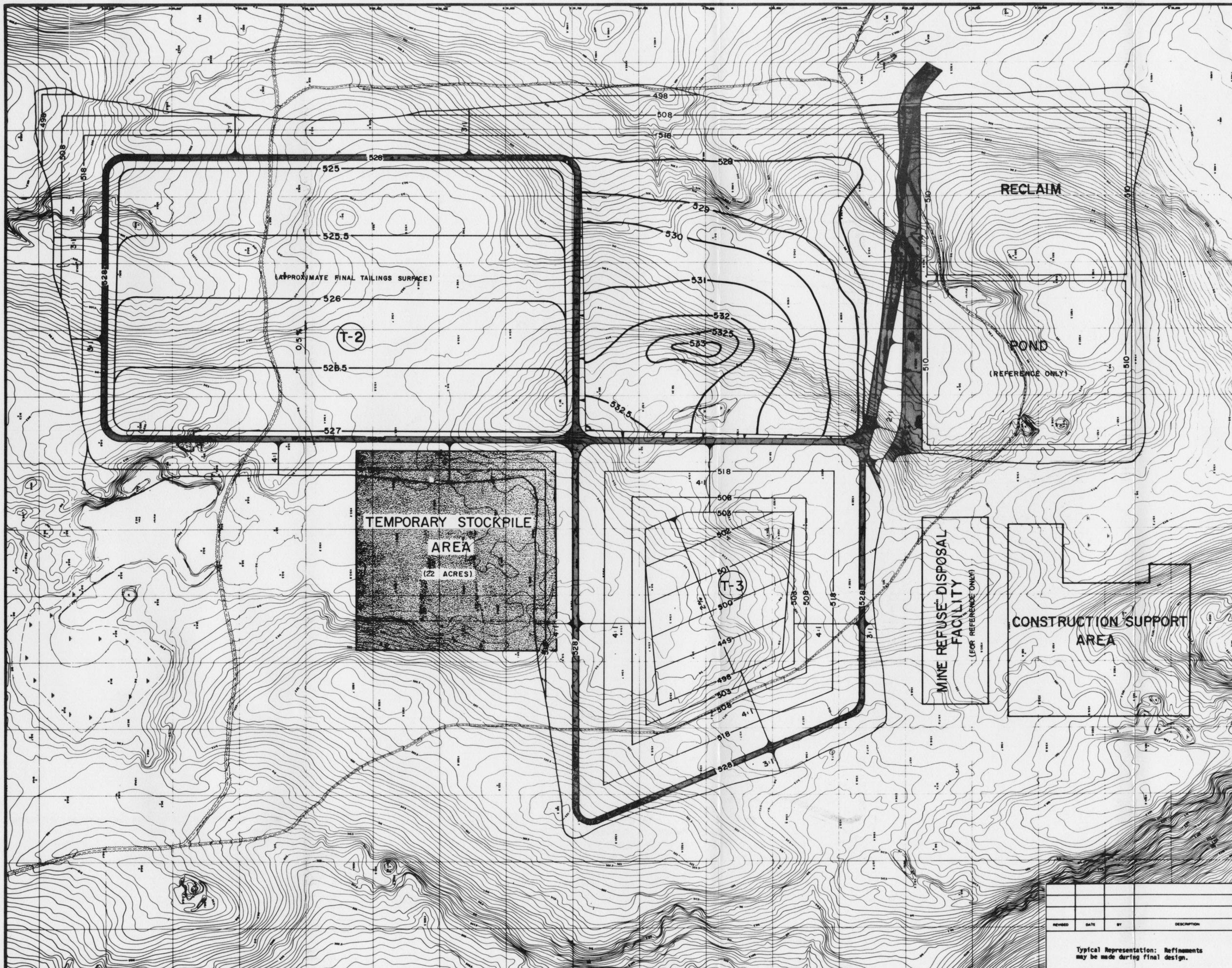
Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE
PHASE 2
POND T-2 CONSTRUCTED, POND
T-1 FILLED

SCALE	STATE	COUNTY	
AS SHOWN	WISCONSIN	FOREST	
DRAWN BY J.J.T.	DATE 10-7-85	CHECKED BY C.C. Schroeder	DATE 12/10/85
APPROVED BY	DATE	APPROVED BY J.F. Wallace	DATE 12/16
APPROVED BY	DATE	EXEC. D.E. Moe	DATE [illegible]
DRAWING NO		SHEET 28 OF 36	REVISION NO



LEGEND

CREST ROAD

T-1 POND NUMBER

EMBANKMENT SLOPE

531 FINAL RECLAMATION SURFACE CONTOUR

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

Z

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN
JOHN FRANCIS [illegible]
[illegible]
HOUSTON
TX
PROFESSIONAL ENGINEER

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

PLAN SHEET 29

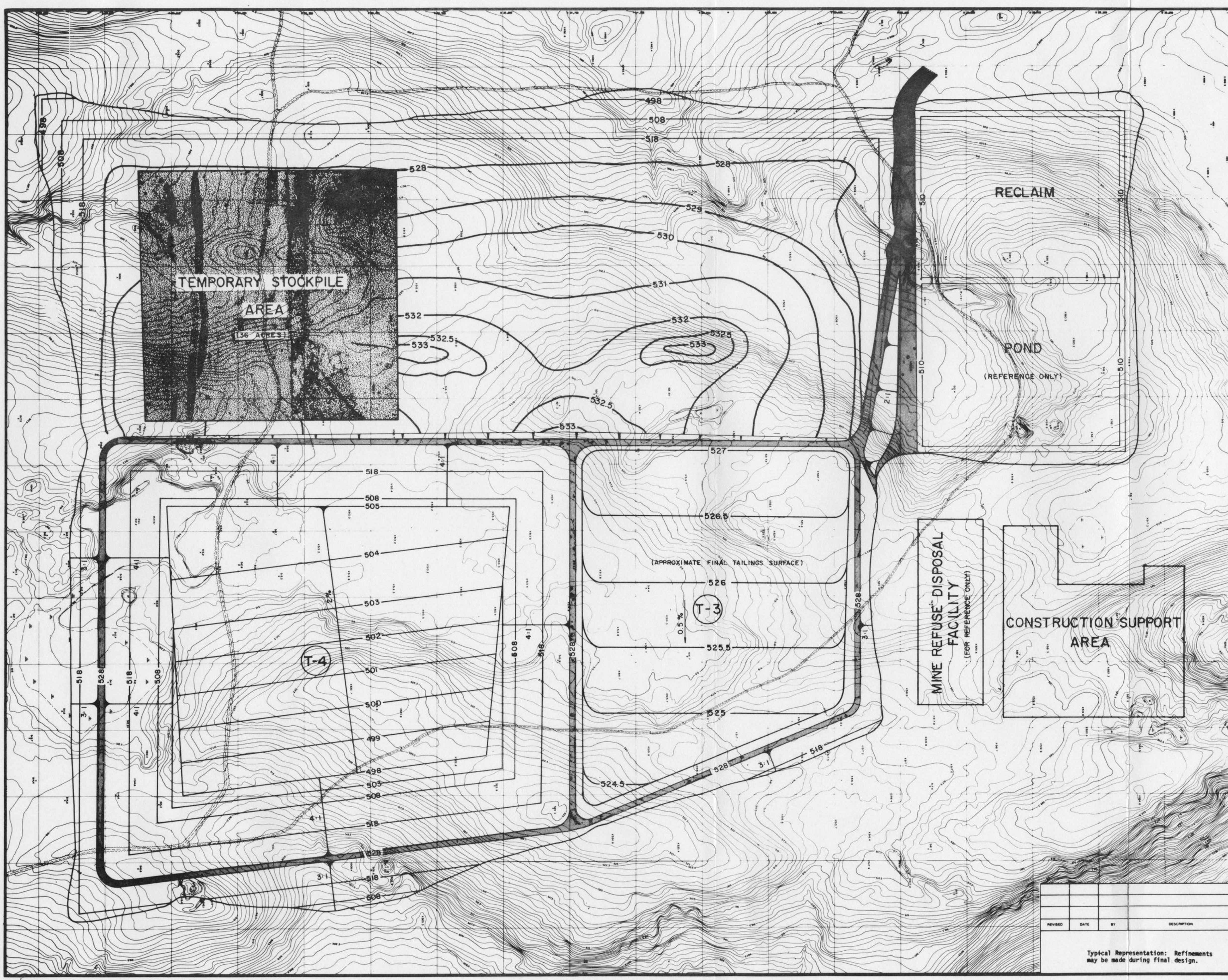
EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE
PHASE 3
POND T-3 CONSTRUCTED, POND T-2 FILLED, POND T-1 RECLAIMED

SCALE AS NOTED	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-12-85	CHECKED BY C C Schroeder	DATE [illegible]
APPROVED BY	DATE	APPROVED BY [illegible]	DATE [illegible]
APPROVED BY	DATE	EXXON D.E. [illegible]	DATE [illegible]
DRAWING NO		SHEET 29 OF [illegible]	REVISION NO 0

DESIGN PRODUCTS CO —



LEGEND

- CREST ROAD
- (T-1) POND NUMBER
- EMBANKMENT SLOPE
- ~531~ FINAL RECLAMATION SURFACE CONTOURS

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 100 200 400 600 800
SCALE IN FEET

0 50 100 150 200 250
SCALE IN METERS

WISCONSIN PROFESSIONAL ENGINEER
JOHN FRANK WALLACE
E 20001
HOUSTON TX

PLAN SHEET 30

EXXON MINERALS COMPANY
CRANDON PROJECT

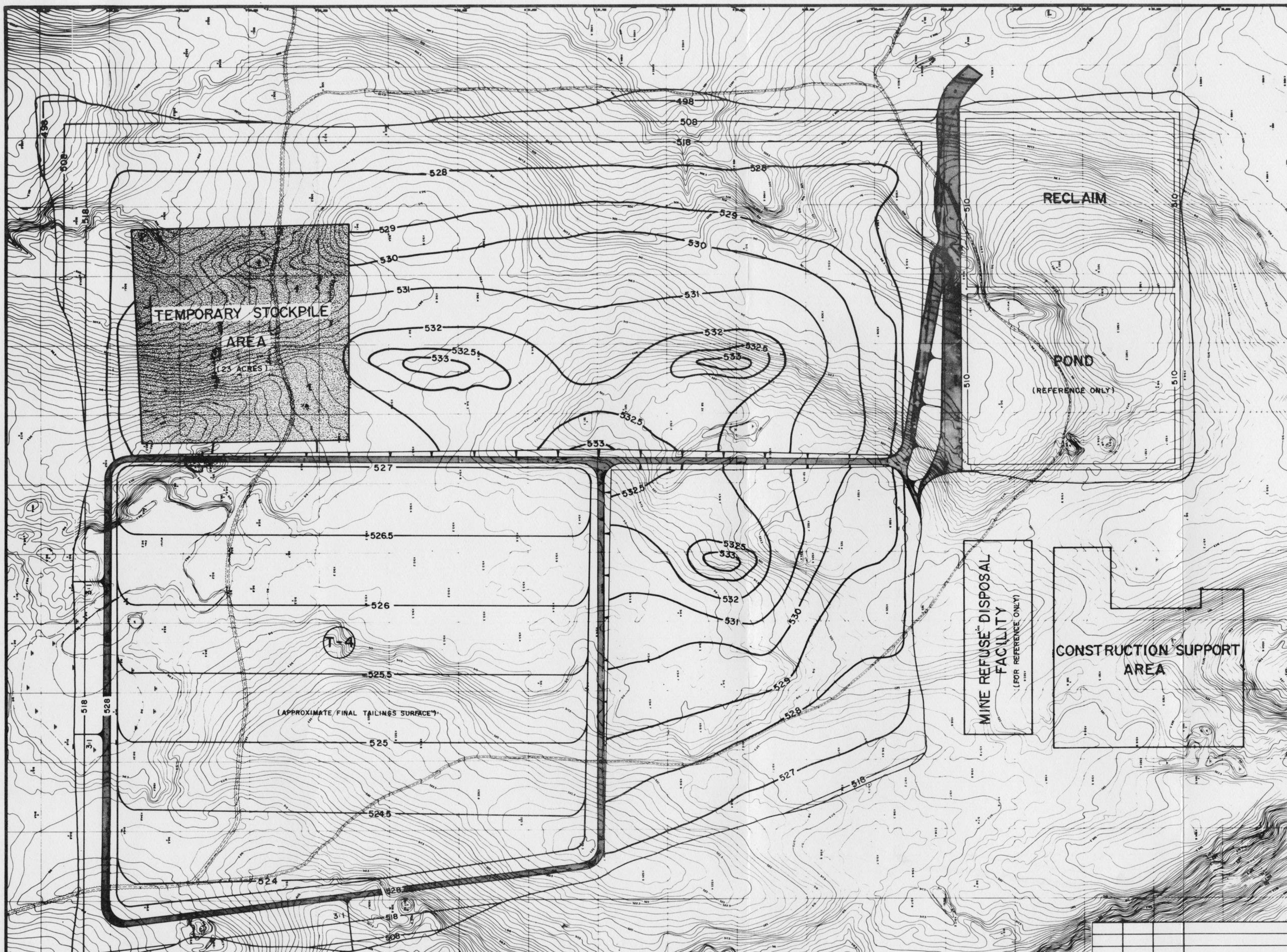
TITLE
PHASE 4
POND T-4 CONSTRUCTED, POND T-3 FILLED, POND T-1 & T-2 RECLAIMED

SCALE AS NOTED	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY J.J.T.	DATE 10-12-85	CHECKED BY C C Schroeder		DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY J.F. Wallace		DATE	
APPROVED BY	DATE	EXXON D.E. Moe		DATE	
DRAWING NO			SHEET 30 OF 36	REVISION NO 0	

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

DESIGN PRODUCTS CO —



LEGEND

- CREST ROAD
- T-1 POND NUMBER
- EMBANKMENT SLOPE
- 531 FINAL RECLAMATION SURFACE CONTOURS

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
4. CONTOURS SHOWN WITHIN THE POND CONFINES ARE FINISHED GRADE / TOP OF FILTER LAYER UNLESS OTHERWISE INDICATED.

0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS

WISCONSIN
JOHN FRANCIS WALLACE
E-
HOUSTON TX
PROFESSIONAL ENGINEER

PLAN SHEET 31

EXXON MINERALS COMPANY
CRANDON PROJECT

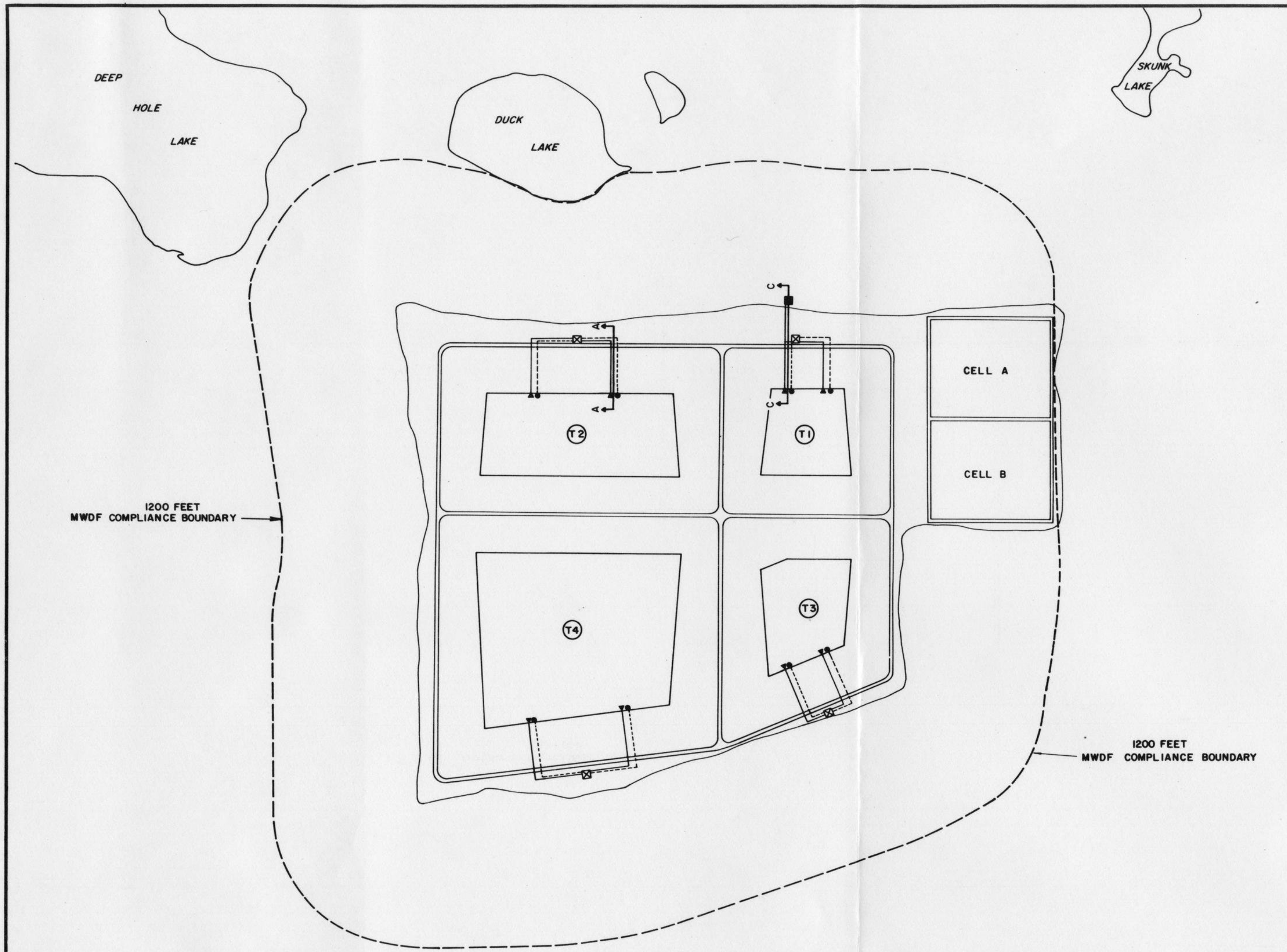
TITLE
PHASE 5
POND T-4 FILLED, PONDS T-1, T-2 & T-3 RECLAIMED

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-12-85	CHECKED BY CC Schroeder	DATE	
APPROVED BY	DATE	APPROVED BY	DATE	
APPROVED BY	DATE	D. C. Moe	DATE 12/	
DRAWING NO			SHEET 31 OF 36	REVISION NO 0

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

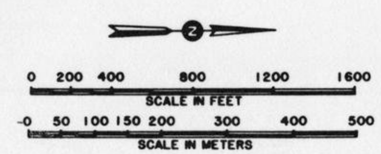
DESIGN PRODUCTS CO —



LEGEND

- ▲ COLLECTION LYSIMETER
- ● LEACHATE HEAD WELLS
- ⊠ INSTRUMENTATION SHELTER
- ■ SUMP

NOTE: SECTIONS A-A & C-C ARE PRESENTED ON PLAN SHEET 35.



PLAN SHEET 32

REVISED	DATE	BY	DESCRIPTION

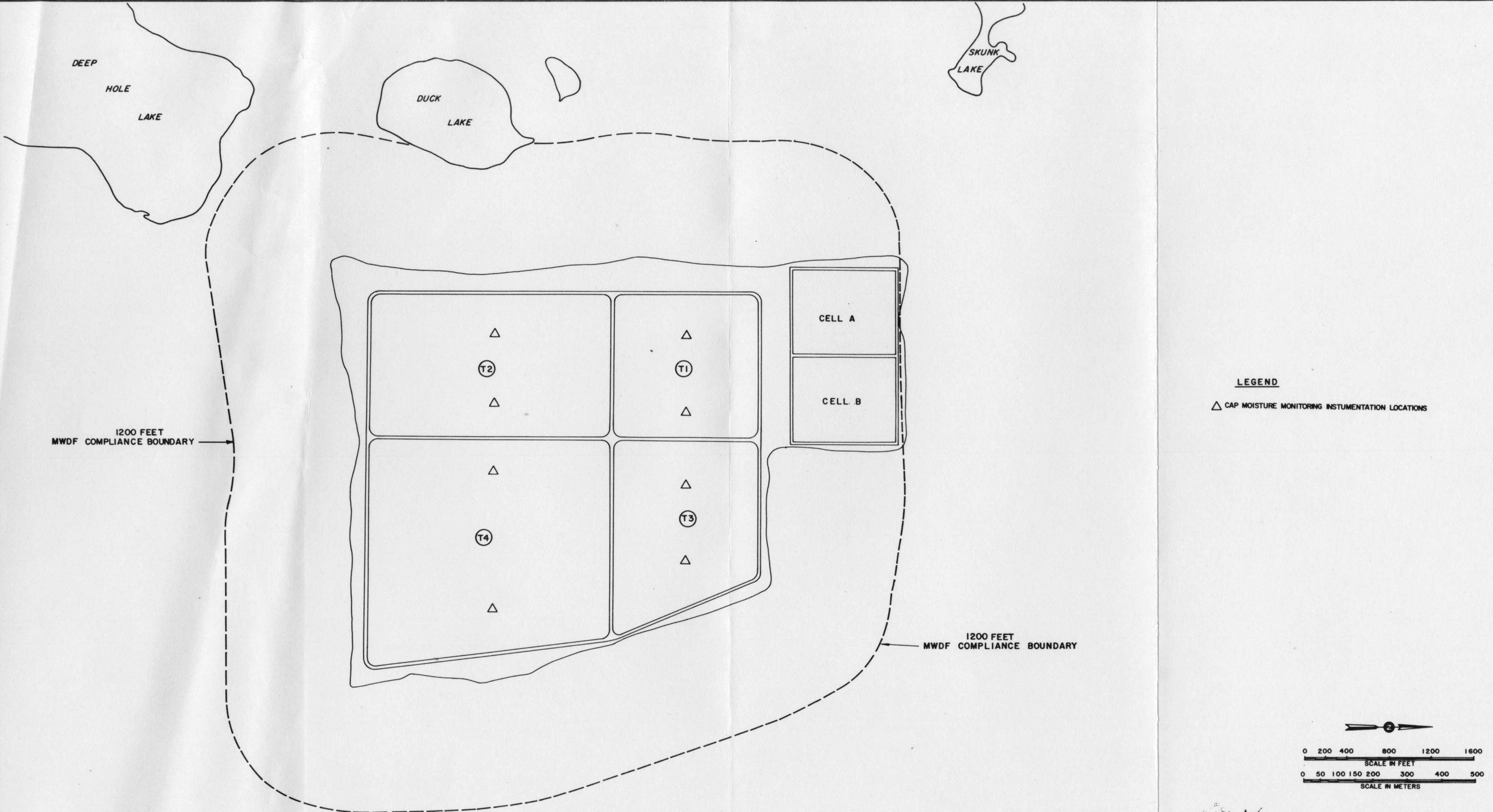
Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
LINER PERFORMANCE, AND LEACHATE HEAD MONITORING LOCATIONS

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J.J.T.	DATE 9-30-85	CHECKED BY C.C. Schroeder		DATE 12/6/85
APPROVED BY	DATE	APPROVED BY J. Walton		DATE 12/2/85
APPROVED BY	DATE	EXXON D.E. Moe		DATE 12/9/85
DRAWING NO			SHEET 32 OF 36	REVISION NO 0

DESIGN PRODUCTS CO —



PLAN SHEET 33

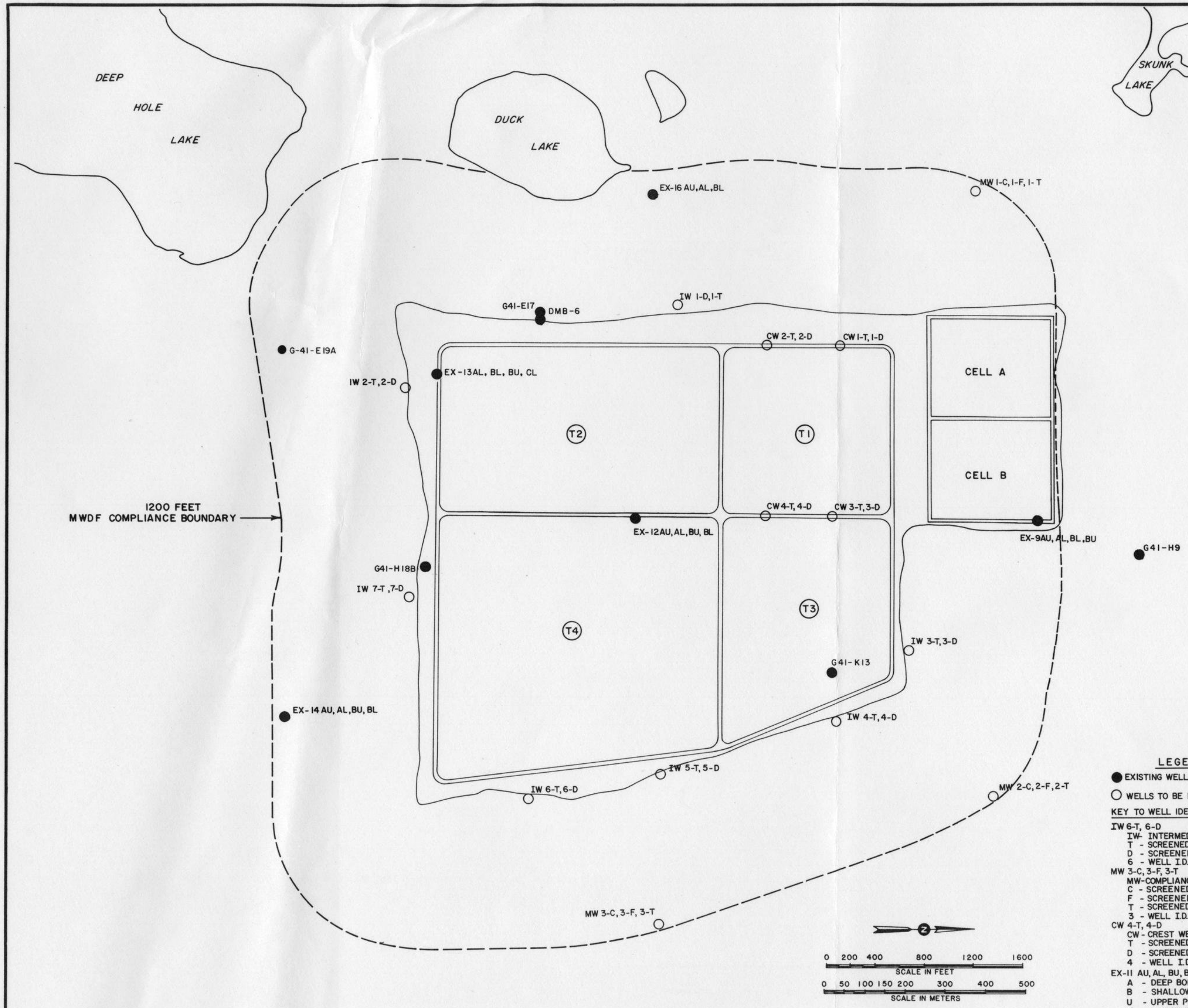
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RECLAMATION CAP (COVER)
PERFORMANCE MONITORING LOCATIONS

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY J.J.T.	DATE 9-30-85	CHECKED BY C.C. Schroeder		DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY J.F. Wallen		DATE [illegible]	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 12/9/[illegible]	
DRAWING NO			SHEET 33 OF 36	REVISION NO 0	



LEGEND

● EXISTING WELLS

○ WELLS TO BE INSTALLED

KEY TO WELL IDENTIFICATION

IW 6-T, 6-D
- IW - INTERMEDIATE WELL
- T - SCREENED IN TILL
- D - SCREENED IN DRIFT
- 6 - WELL I.D. NUMBER

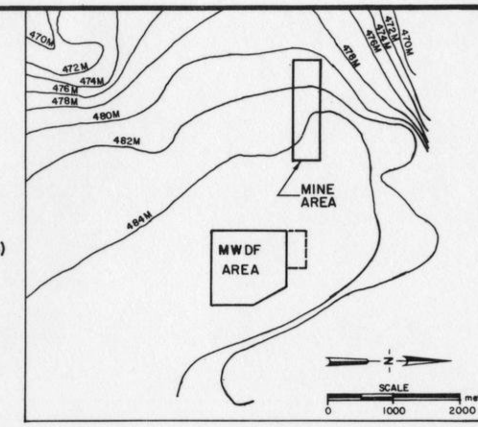
MW 3-C, 3-F, 3-T
- MW - COMPLIANCE BOUNDARY MONITORING WELL
- C - SCREENED IN COARSE DRIFT
- F - SCREENED IN FINE DRIFT
- T - SCREENED IN TILL
- 3 - WELL I.D. NUMBER

CW 4-T, 4-D
- CW - CREST WELL
- T - SCREENED IN TILL
- D - SCREENED IN DRIFT
- 4 - WELL I.D. NUMBER

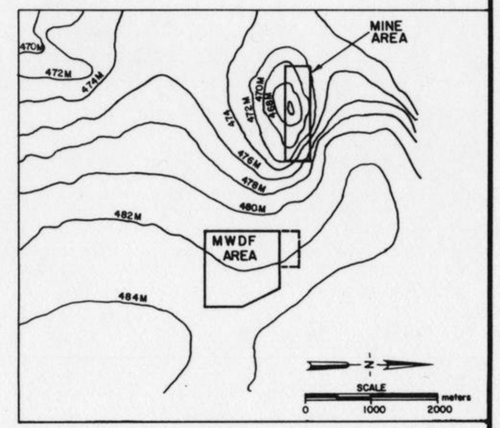
EX-11 AU, AL, BU, BL
- A - DEEP BORE HOLE
- B - SHALLOW BORE HOLE
- U - UPPER PIEZOMETER SCREEN
- L - LOWER PIEZOMETER SCREEN

(REF. STS, 1984)

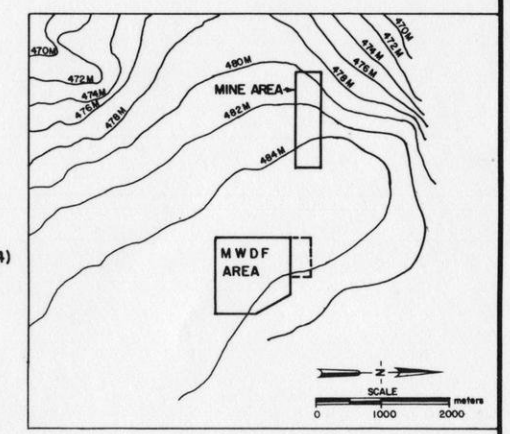
PRECONSTRUCTION GROUNDWATER CONTOURS (D'APPOLONIA, 1984)



GROUNDWATER CONTOURS AT YEAR 28 (D'APPOLONIA, 1984)



GROUNDWATER CONTOURS AT YEAR 60 (D'APPOLONIA, 1984)



LEGEND

470M POTENTIOMETRIC SURFACE (IN METERS)

WISCONSIN JOHN FRANKLIN WALLACE PROFESSIONAL ENGINEER

PLAN SHEET 34

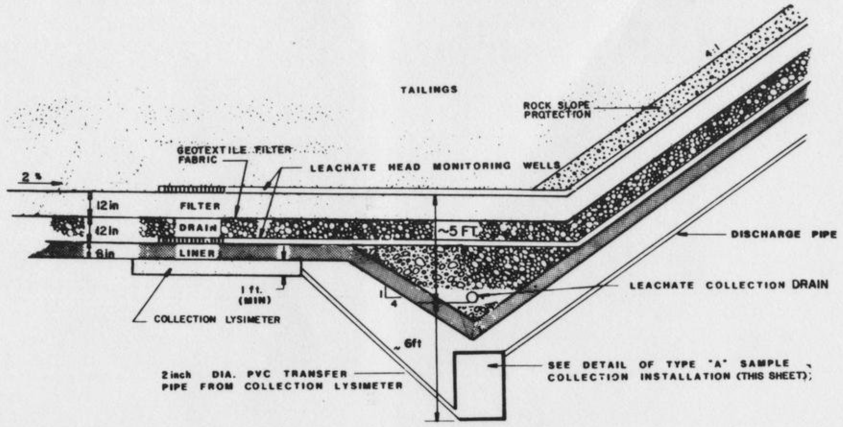
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
OPERATION MONITORING WELL LOCATIONS (SUBPROGRAM)

1	1-2-86	DRS	Updated Wells
REVISED	DATE	BY	DESCRIPTION

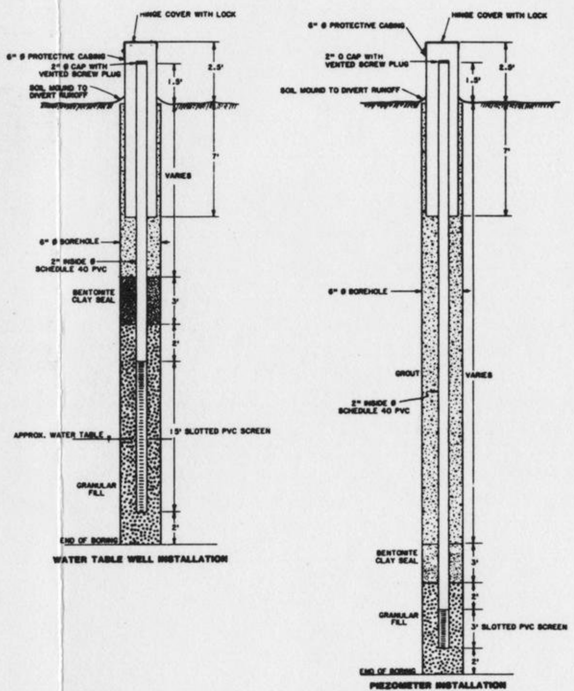
Typical Representation: Refinements may be made during final design.

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J. J. T.	DATE 9-30-85	CHECKED BY J. F. Wallace	DATE 1/2/86
APPROVED BY	DATE	APPROVED BY D.E. Moe	DATE 12/4/85
APPROVED BY	DATE		
DRAWING NO		SHEET 34 OF 36	REVISION NO 0

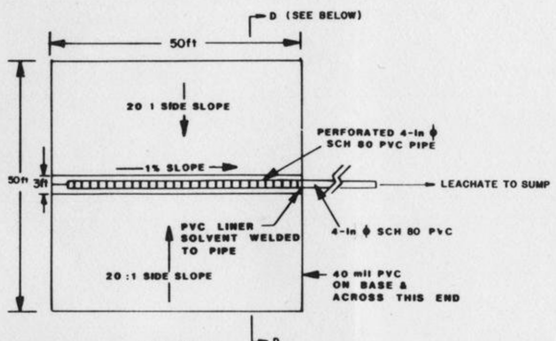


SECTION A-A (FROM SHEET 32)

TYPICAL LINER PERFORMANCE & LEACHATE HEAD MONITORING INSTRUMENTATION INSTALLATION

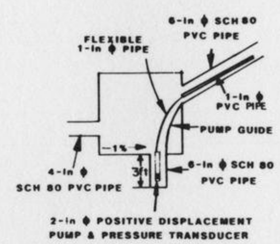


TYPICAL MONITORING WELL INSTALLATIONS

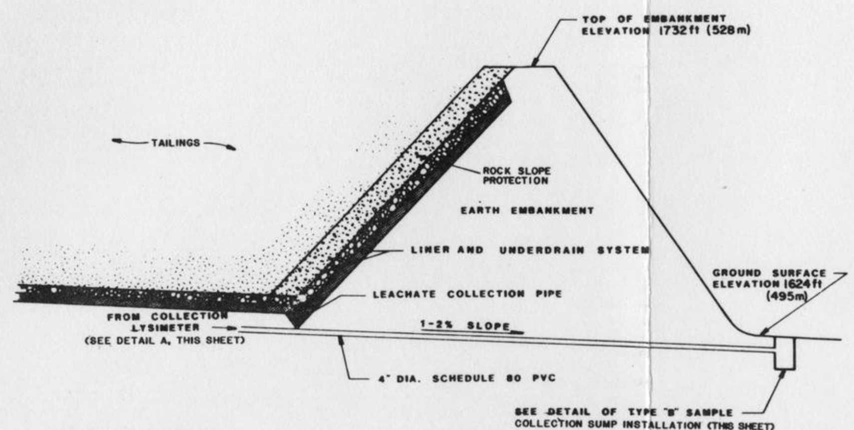


DETAIL A

PLAN VIEW

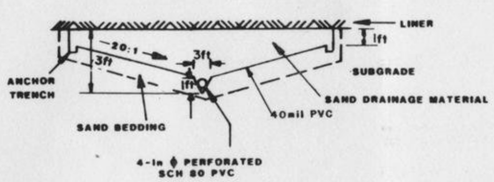


TYPE "A" SAMPLE COLLECTION SUMP INSTALLATION



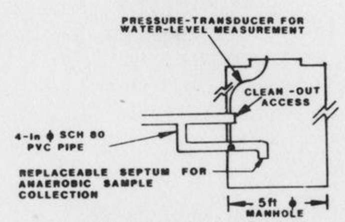
SECTION C-C (FROM SHEET32)

GRAVITY DRAIN LYSIMETER, POND T1



SECTION D-D

COLLECTION LYSIMETER CROSS SECTION



TYPE "B" SAMPLE COLLECTION SUMP INSTALLATION

Typical Representation: Refinements may be made during final design.

REVISED	DATE	BY	DESCRIPTION

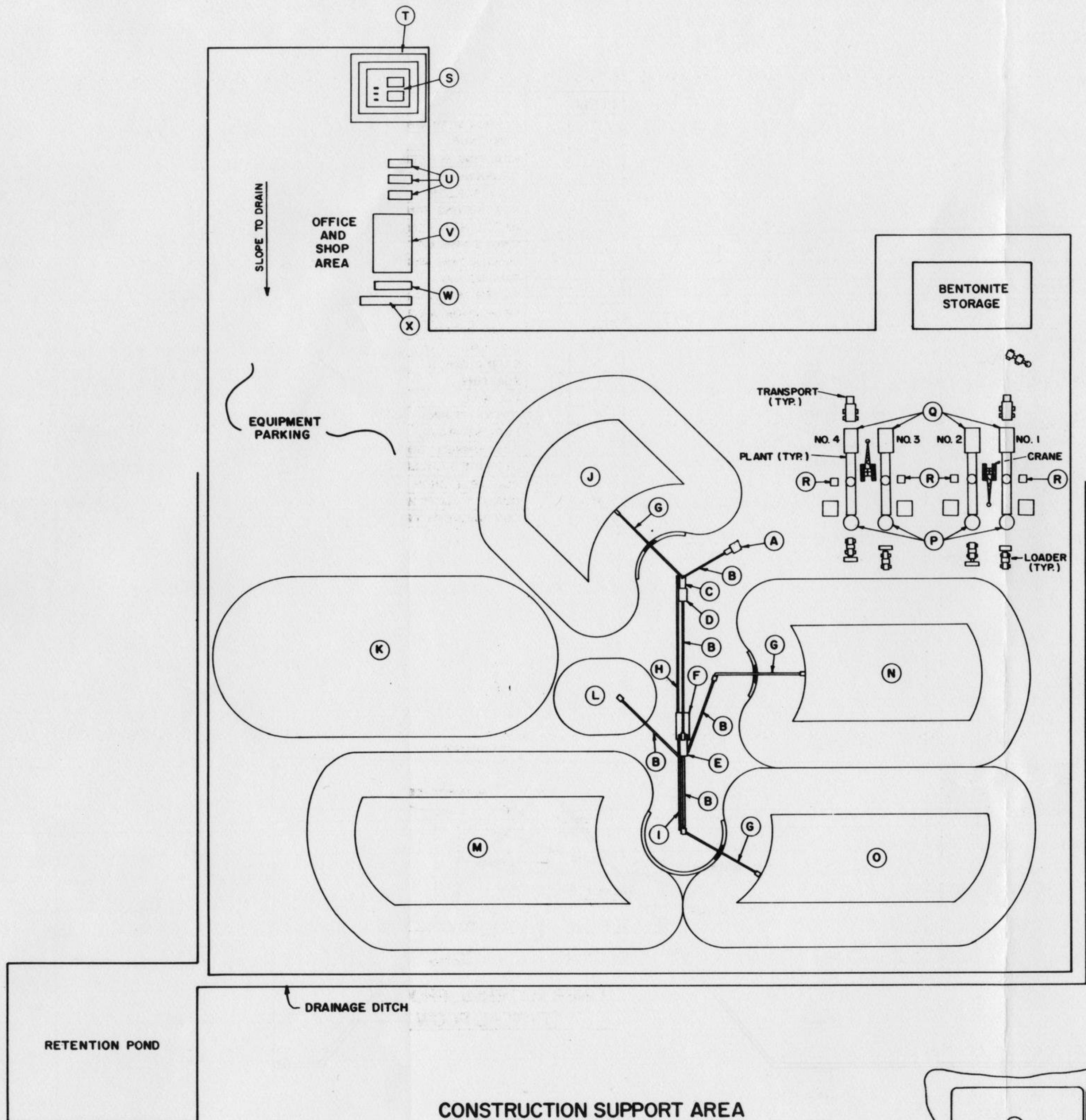
PLAN SHEET 35

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MONITORING DETAILS

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY JMM & ACD	DATE	E. Schroeder	12/10/85
APPROVED BY	DATE	A. Wallen	12/4/85
APPROVED BY	DATE	EXXON D.E. Moe	12/9/85
DRAWING NO		SHEET 35 OF 36	REVISION NO 0

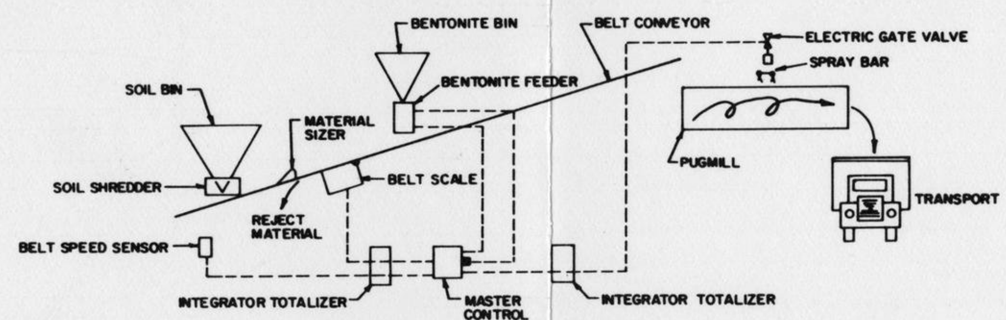
DESIGN PRODUCTS CO —



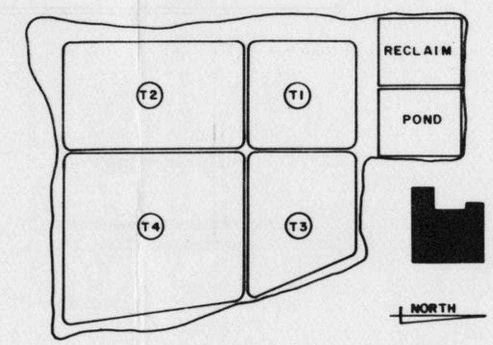
CONSTRUCTION SUPPORT AREA

30 0 30
SCALE IN METERS

ITEM		DESCRIPTION
A		HOPPER WITH VIBRATING FEEDER
B		CONVEYOR
C		SCALPING SCREEN
D		CRUSHING PLANT
E		DECK SCREEN
F		CLASSIFYING TANK
G		RADIAL STACKER
H		SINGLE FINE MATERIAL SCREW
I		DOUBLE FINE MATERIAL SCREW
J		SAND CUSHION
K		FILTER MATERIAL
L		TRANSITION MATERIAL
M		DRAIN MATERIAL
N		LINER MATERIAL
O		SAND CUSHION
P		SOIL BINS
Q		PUG MILL
R		BENTONITE BINS
S		FUEL STORAGE
T		CONTAINMENT DIKE
U		STORAGE TRAILERS
V		PORTABLE SHOP
W		QUALITY CONTROL TRAILER
X		CONTRACTOR'S TRAILER



LINER MATERIAL PROCESSING PLANT (TYPICAL FLOW DIAGRAM)



PROJECT LOCATION

PLAN SHEET 36

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: CONSTRUCTION SUPPORT AREA PLAN & ELEVATION

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-31-85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXEC.	DATE
DRAWING NO		SHEET 36 OF 36	REVISION NO

DESIGN PRODUCTS CO.—