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CHAPTER 3

ALTERNATIVES TO THE PROPOSED ACTION

CRANDON PROJECT

ENVIRONMENTAL IMPACT REPORT

REVISED
NOVEMBER 1985

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CHAPTER 3

ALTERNATIVES TO THE PROPOSED ACTION

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3.0 INTRODUCTION

The purpose of this chapter is to describe reasonable alternatives to the proposed Project, including those which might not be considered desirable by the Applicant. As described by the DNR, a reasonable alternative is one which is feasible or practical from a technical and economic standpoint (Druckenmiller, 1981).

Discussion in this chapter is limited to description and comparative characteristics of the alternatives. Environmental impacts and mitigative measures associated with the alternatives are discussed in Chapter 4.

Sections 3.1 through 3.3 describe three broad alternative types: no action; project expansion; and project reduction. All siting alternatives are included in Section 3.4. Structural and operational alternatives are described in Section 3.5, concentrate transport alternatives in Section 3.6, and final use alternatives in Section 3.7. References cited are presented in Section 3.8.

3.1 NO ACTION

The "no action" alternative would be to not construct and operate the proposed Crandon Project and to allow the area to continue its present day socioeconomic and environmental trends. Summarized below are the general forecasts related to continuance of the present day trends. More specific information is presented in Chapter 4 and the material referenced within it.

If the Crandon Project were not developed, little change would be expected to occur in the current socioeconomic trends of the area. At this time, there appears to be no other impetus for a change in trends in the area. The local area historically is characterized by high unemployment and low income relative to the rest of the State. None of the economic sectors which form the base of the area's economy appear to have the potential of creating a substantial number of new jobs. With the exception of the Crandon Project, there are no published plans for new industrial development and, therefore, the area would probably experience relatively slow growth for the foreseeable future. These economic conditions could cause out-migration from the area of young persons unable to find work. The result would be a relatively stable, more elderly population base, with little change to the area's housing, public facilities and services, fiscal, and sociocultural conditions. These trends are discussed further in subsection 4.2.10.

The "no action" alternative would not significantly affect either employment or income for the local study area as a whole. The jobs and payroll due to the permitting effort are not significant factors in the local economy.

At the national level, one important effect of abandoning Project plans is that a valuable domestic mineral resource would be unused. As discussed in subsection 1.1.3.1, development of the Crandon deposit has the potential for benefiting the national economy by reducing the country's dependence on foreign suppliers of mineral resources, and thereby improving the balance of payments. Without additional domestic production of these mineral resources (such as the Crandon Project), an increase in demand could result in increased dependence on foreign sources and/or accelerated depletion of existing domestic reserves.

Environmental trends, such as land use, fish and wildlife management, demand for recreational opportunities, use of ground and surface water, and agricultural activities, would also continue in their existing state in the site area and in the region. Forest production and recreation would continue as the two main forms of land use. Management programs for fish, wildlife and forest resources would continue to follow recommendations of state and federal resource agencies based upon projected use and need. Use and management of recreational resources would follow historical trends based upon projected demand. Use of the site area for agricultural purposes would remain at the current low levels because of climatic limitations and the greater importance of other land uses. Based on projected population levels, use of surface water and ground water probably would not be greatly altered. No major industrial or agricultural developments have been announced that would require considerable quantities of these resources.

The land controlled by Exxon is described in subsection 1.1.2. If permits acceptable to Exxon are not received, then the Company will evaluate the situation and decide what to do with the land. The results of that evaluation for all parcels of land can not be reliably predicted.

3.2 EXPAND THE PROPOSED PROJECT

The Crandon Project as proposed is based on an average ore production rate of approximately 7,500 tons per day for a planned production operating life of about 29 years. The operating life is based on a conservative definition of ore reserves which is subject to confirmation as mining progresses.

There is little likelihood of finding profitable ore reserves significantly exceeding the current estimated reserve of 67.4 million tons. Drilling from the surface has defined the extent of the orebody along the east/west strike and perpendicular across the deposit into the hanging wall and footwall.

The Crandon deposit has not been completely defined at depth. However, the deep orebody drilling indicates that the deposit thins rapidly below 2,330 feet. The current mine plan assumes the recovery of ore down to the 1,935 feet.

The decision by Exxon to recover additional reserves, should they be found or market conditions warrant, would be based on a detailed study that would consider the technical, environmental, and economic parameters at the time of mining.

The ramifications of the unlikely event of finding significantly more profitable ore and recovering these reserves would probably result in an extended mine life beyond the present forecast of 29 years of production. The current facilities design and the constraints of underground mining limit the daily production from Crandon to a normalized rate of about 7,500 tons per day. With the exception of the MWDF, the extended operation would have the same impact as the normal operations. The additional tailings that would be generated would fill the contingent capacity provided in the current MWDF design, or if additional capacity were required, permit applications would be filed prior to the time of such need.

The economical production rates and planned operating lives of mining projects are based on estimates of the average grade (metal content) of mined ore, the economic cutoff grade between ore and waste, and the total deposit mining reserve tonnage.

The cutoff grade may vary somewhat during project operation according to metal prices or mining costs. The initial planning grade is more of an economic expectation than a determinable operational rule.

Once a design ore production rate is selected and the facility is constructed, the maximum production rate is basically fixed for the project. Some flexibility exists to exceed design production capacity for relatively short periods by slightly increasing the mine productivity or changing mine operations to favor one ore type or another. This flexibility is, however, relatively short-term and represents the operator's choices in responding to the dynamic and uncertain conditions in ever-changing world metal markets.

If the ore reserves are greater than currently estimated, they can be recovered by extending mine operating life or by increasing the production rate. The mine/mill facilities, as currently designed, are capable of extended operation by proper maintenance practices which are built into the operating plan. To increase the design production rate at this time above the current plan would result in building a facility larger than required for economic recovery of the reserve and thereby creating an economic penalty because of the underutilization of invested capital.

Reserve estimates often increase or decrease somewhat as operations develop and new data are collected. Such may be the case for the Crandon Project as well, but typical mine design practice dictates that such uncertainties be accommodated by allowing for an extension of project life rather than speculative overbuilding.

The potential use of Crandon facilities for milling of the ores of other owners is discussed in subsection 3.7.1. Extended use of the Crandon concentrator and related facilities would require that ores from other properties be compatible with the Crandon processes. Exxon is in no position to judge whether or not any future ore deposits of others might be economic to mine or process.

Historically, large concentrator plants to service a single mine like Crandon do not mix their ores with those of other independent shippers because of the difficulty in storing, processing, and accounting for ores and concentrates on behalf of a non-affiliated shipper. Accordingly, it is not probable that the processing of such ores would be of interest or advantageous to Exxon during the mining and processing of the Crandon ore deposit.

3.3 DECREASE THE PROPOSED PROJECT

An alternative to the proposed action would be to decrease the production rate or reduce the ore reserve used as a design basis.

To design for a lower production rate is technically feasible but would not represent prudent planning based on the economic evaluations completed to date. The planned production rate for the Project was established on these economic evaluations and the design capacity provided to accomplish this objective. Designs based on lower production rates would not meet the objectives for a project investment. Further, expansion of an undersized mine is an expensive proposition which the planning process is developed to prevent.

In some years, average production rates could be lower than the design base. Such an event might reflect extensive underground development work or might be a response to market conditions. Operating flexibility can more readily be achieved by lowering production rates than by undersizing facilities.

An alternative development approach to full capacity might be indicated by adverse market conditions, poor metal prices, lack of investment capital, or other considerations. Under these conditions a more cautious development approach might be warranted. Typically, this might include a test mine and/or staged mine development to the full production capacity of approximately 7,500 tons per day.

Another means of reducing the size of the Project would occur if the estimated ore reserves are less than the level which is considered economically recoverable. Once a mine is built, all the ore that is economically recoverable will be mined.

3.4 SITING

This section briefly describes siting criteria and alternatives which were considered for the major Project on-site and ancillary facilities. Where appropriate, a brief description of the function of the facility is included for clarity. Some information on potential impacts (e.g., area of wetland disturbance) is also included where a comparative analysis of several alternatives is provided.

Subsection 3.4.1 describes the potential siting alternatives for the mine/mill facilities. The siting process and alternatives evaluated for the mine waste disposal facility and related tailings and reclaim water pipeline corridor are discussed in subsection 3.4.2. Ancillary facilities siting descriptions, including the railroad spur, access road, power corridor, and surface and ground water discharge locations, are contained in subsection 3.4.3.

3.4.1 Mine/Mill Facilities Siting

The Project area was studied for potential mine/mill surface facilities sites (Dames & Moore, 1977; Exxon Minerals Company, 1978-1979). The major criteria used to screen potential sites were:

1) Within a 2-mile radius of the orebody;
2) Surface facilities as close as practical to the orebody without being directly over it;
3) Greater than 1,000 feet from a lake;
4) Greater than 1,000 feet from residences;
5) Greater than 0.5 mile from endangered species nests;

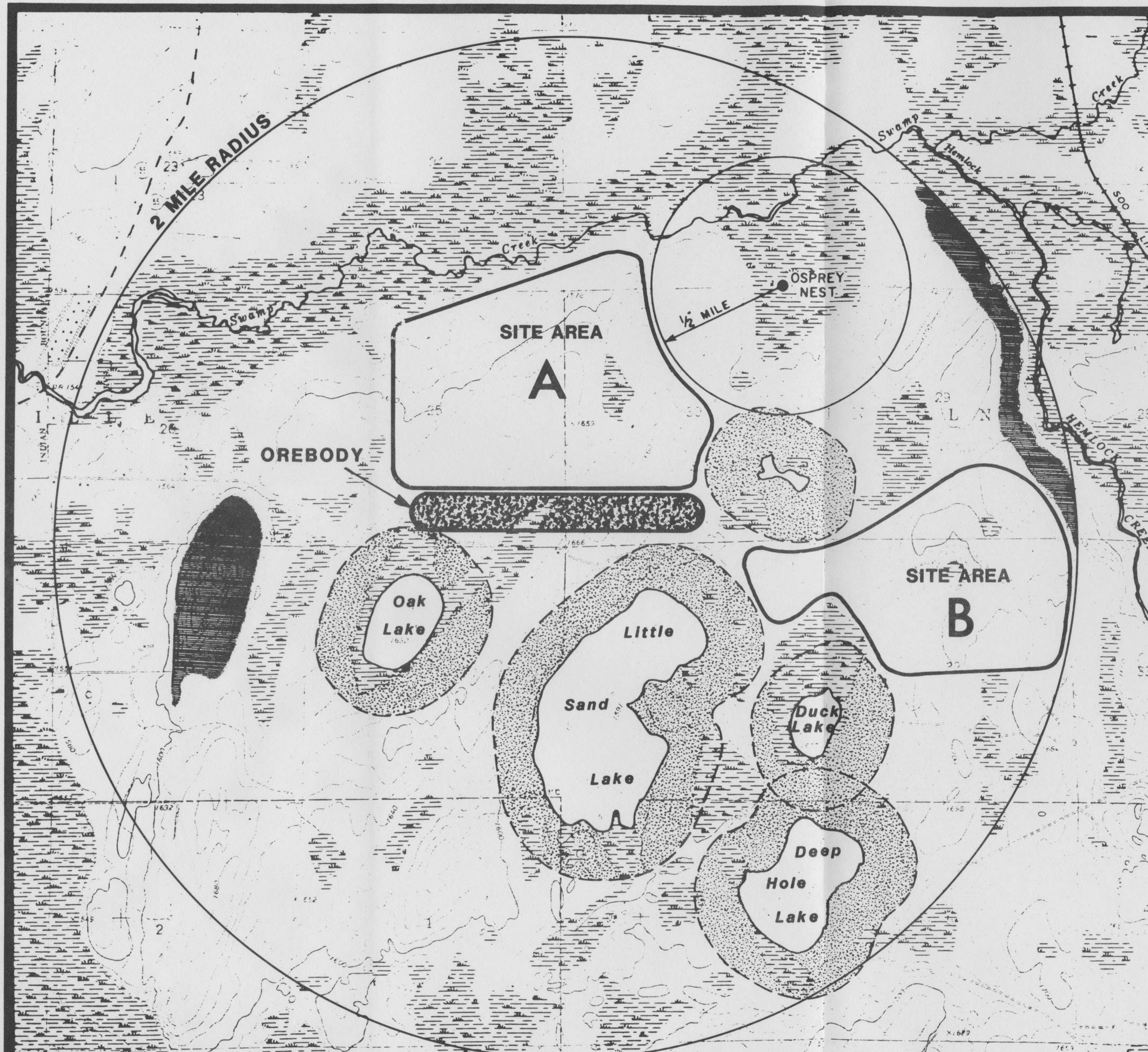
6) Avoid wetland areas, stream channels, and steeply sloping terrain; and

7) At least 100 acres in surface area.

Two site areas, A and B, were identified for surface facilities siting (Figure 3.4-1). Site Area A is located about 2,000 feet north of Oak Lake and Little Sand Lake and encompasses about 600 acres. Site Area B is located approximately 0.25 to 1.5 miles east-northeast of the northern end of Little Sand Lake, northeast and north of Duck Lake, and west of Hemlock Creek.

Site Areas A and B have similar geohydrologic, soil and environmental conditions and both contain sites suitable for surface facilities. Because of the proximity to the orebody and the relatively large siting area available, Area A was selected as the more suitable and a plot plan was designed for the southeast portion of the site which will accommodate both the mine surface and mill facilities (Chapter 1, subsections 1.2.1 and 1.2.2).

Site Area B contains some moderately sloping terrain that could be utilized in the design of a gravity-flow process in the mill (as is planned for the proposed design for Site Area A). Because of its distance from the orebody, Site Area B would only be suitable for the mill facilities. Mine surface facilities would have to be located adjacent to the orebody and a conveyor about 1 mile long would be required to transport ore to the mill. This split-site design would spread the environmental effects over a larger area and necessitate duplication of some facilities (e.g., water, storage, and power).



KEY:

- LOWLANDS
- STEEP TOPOGRAPHY
- 1000 FOOT LAKE BUFFER ZONE

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 FEET

BASE MAP REFERENCE:

PORTION OF U.S.G.S. 7.5 MINUTE SERIES TOPOGRAPHIC QUADRANGLES: CRANDON, WISCONSIN, 1965 AND MOLE LAKE, WISCONSIN, 1973.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE

SITE SELECTION LOCATIONS, PROPOSED SURFACE FACILITIES

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY R.C. DIETZ	DATE 11/82	CHECKED BY		DATE 12/8/82
APPROVED BY	DATE	APPROVED BY C. C. Schoder		DATE 11/85
APPROVED BY	DATE	EXXON		DATE
DRAWING NO. FIGURE 3.4-1		SHEET ___ OF ___		REVISION NO. 0

3.4.2 Waste Disposal

3.4.2.1 Mine Waste Disposal Facility

Site selection for the MWDF occurred over a 4-year period and included environmental and engineering analyses. Primary screening criteria for site selection were:

1) Estimated total facilities capacity of 21,150 acre-feet of tailings;
2) Single pond minimum capacity of 6,350 acre-feet;
3) NR 132 (wetlands criteria) and NR 182 (location criteria); and
4) Areas within 0.5 mile of cities or Indian communities were eliminated from consideration.

Siting studies were conducted in a phased manner and included independent third party review.

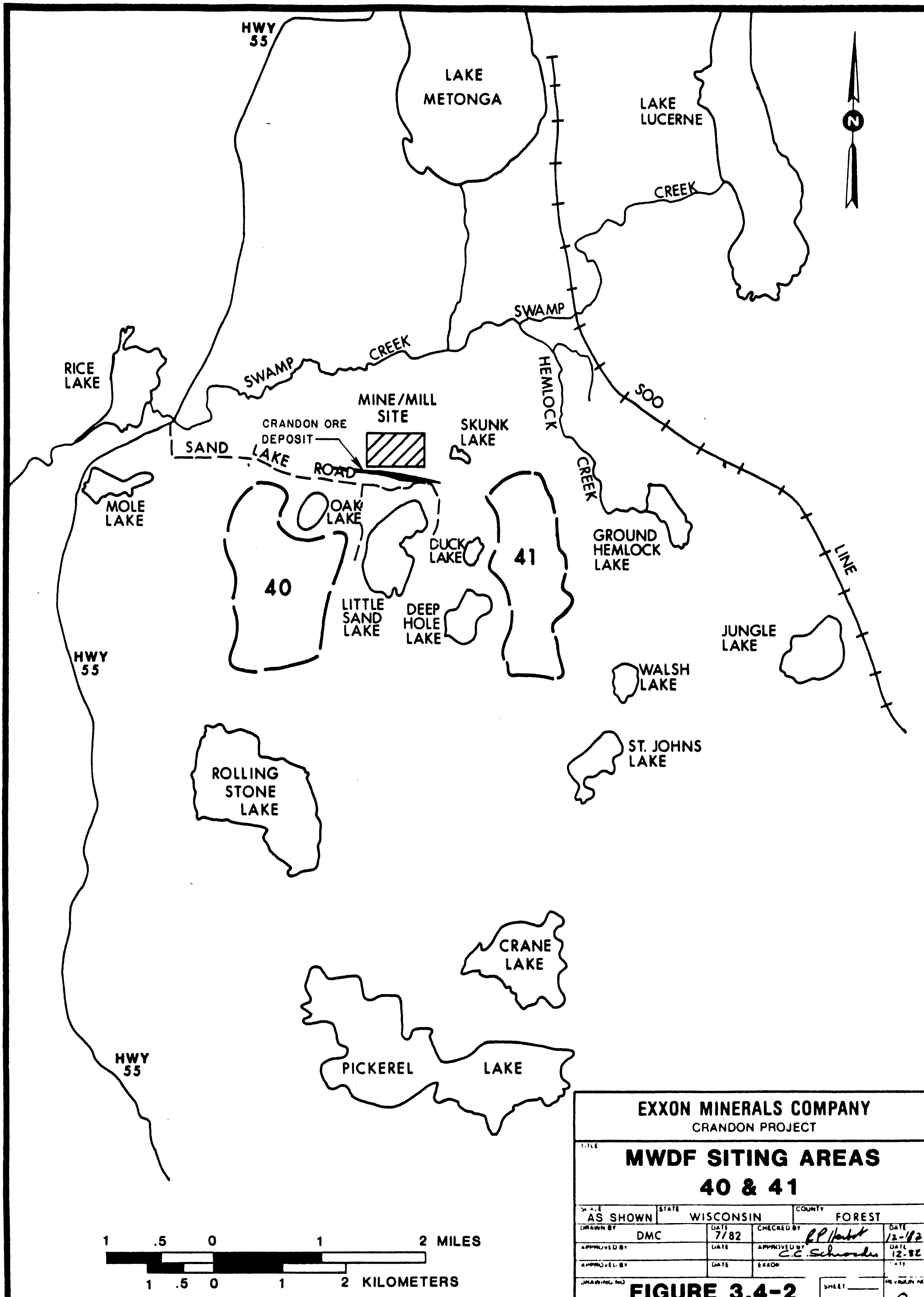
Phase I involved identification of potential mine waste disposal areas within 12 miles of the orebody. A radius of about 25 miles was also examined but proved to have no areas which offered any advantages over those within the 12-mile radius originally studied. The number of areas initially identified (35) was reduced to 20 for further study by application of the above mentioned criteria (Dames & Moore, 1979). Site-specific data were collected for these 20 areas which included both lowland and upland areas. Ecological, land use, and geohydrological criteria were applied to further reduce the candidate areas to eight (Dames & Moore, 1979).

These eight areas were studied using technical and economic analyses based on engineering considerations, including all the technical factors associated with the construction, operation, and reclamation of the MWDF (Exxon Minerals Company, 1982a).

In Phase II, additional studies were performed on the eight areas identified as promising in Phase I. These studies included preliminary engineering and design for the tailings disposal facility (Golder Associates, 1979). Initially, both lowland and upland areas were considered. The DNR, in a May 22, 1979 letter, advised Exxon to avoid locating the MWDF in lowland areas (areas below 1,600 feet elevation). As a result, these areas were excluded from further consideration. Additional criteria included political boundaries, containment volume requirements, distance from the orebody, and earthwork requirements for the construction of embankments (Golder Associates, 1979).

As a result of Phase II, Areas 40 and 41 were indicated as the most promising from the ecological, technical, and engineering aspects (Figure 3.4-2). Overall, Area 41 (Figure 3.4-3) was considered the most viable for the construction, operation, and reclamation of a mine waste disposal facility for the Crandon Project (Exxon Minerals Company, 1982a; Golder Associates, 1982a). Additional discussion of the MWDF siting evaluation of Areas 40 and 41 is presented in the MWDF Feasibility Report.

Within Area 41, several tailings and waste rock disposal sites were evaluated. Layout 41-114B (Figure 3.4-4) was initially proposed for the Project. Alternative disposal sites within Area 41 included 41-103 and 41-121 as shown on Figures 3.4-5 and 3.4-6, respectively.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MWDF SITING AREAS 40 & 41

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		DATE	
DRAWING NO	**FIGURE 3.4-2**	SHEET ___ OF ___		REVISION NO 0	

LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
AREA-41
31
32
36
NOTE: SHADED AREAS DESIGNATE WETLANDS
SCALE IN FEET
0 500 1000 1500
SCALE IN METERS
0 100 200 300 400 500
EXXON MINERALS COMPANY
CRANDON PROJECT
SITE AREA 41
AS SHOWN
WISCONSIN
FOREST
DR SPRINGBORN
11/82
FIGURE 3.4-3


MINE/MILL SITE
WATER RECLAIM PONDS
R1
R2
WASTE DISPOSAL PONDS
T1
T2
T3
T4
OAK LAKE
LITTLE SAND LAKE
SKUNK LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-114B
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY R.C. DIETZ
DATE 11/82
CHECKED BY
APPROVED BY
DATE
EXXON
DRAWING NO
FIGURE 3.4-4
SHEET 1 OF 1
REVISION NO 1


MINE/MILL SITE
WATER
RECLAIM POND
TAILS POND
TAILS POND
TAILS POND
OAK LAKE
SKUNK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-103
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY C.A. HACKER
DATE 11/82
CHECKED BY
APPROVED BY
DATE
EXXON
DRAWING NO
FIGURE 3.4-5
SHEET 1 OF 1
REVISION NO 1

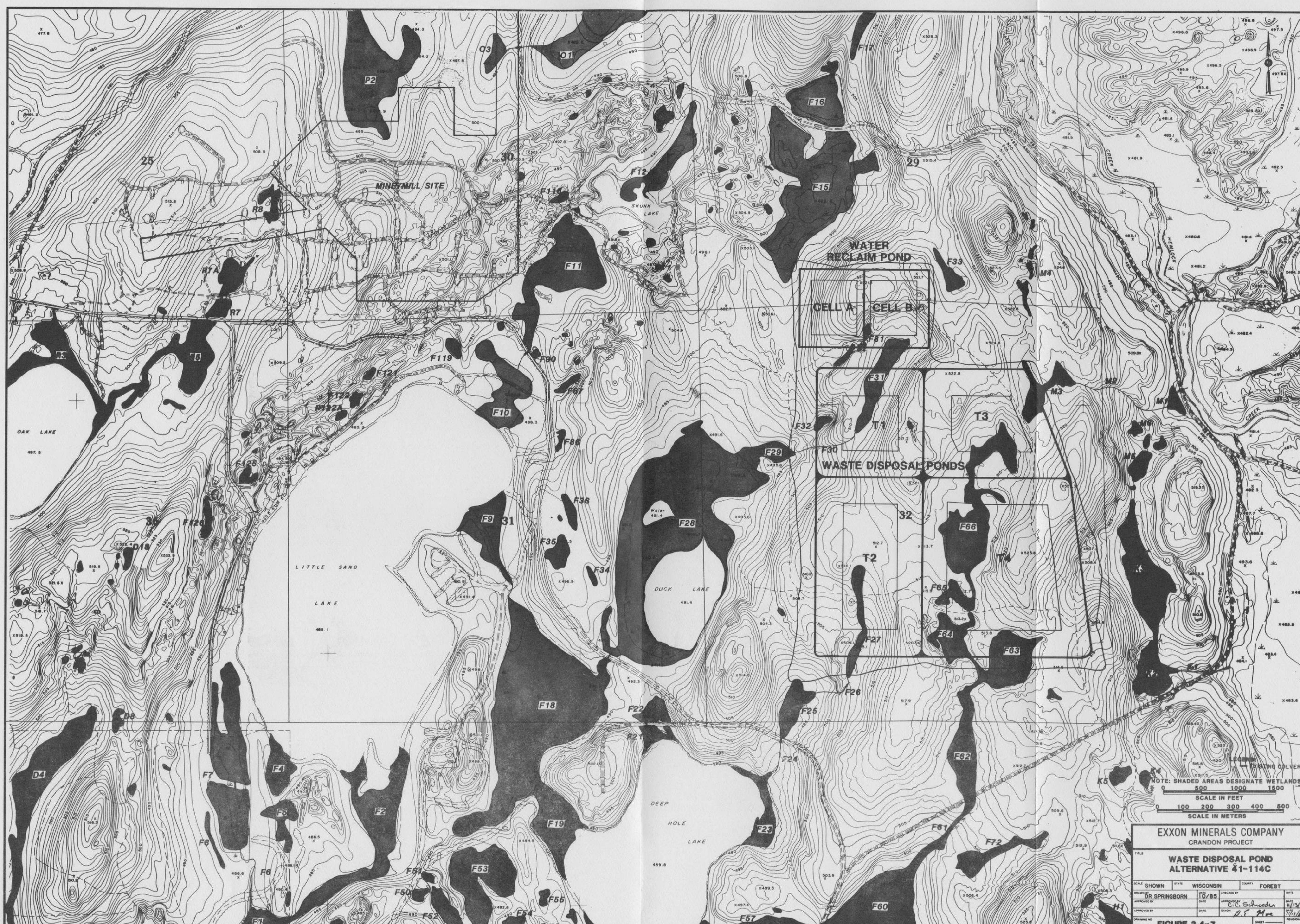

WATER RECLAIM POND
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
TAILS POND
TAILS POND
TAILS POND
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-121
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY C.A. HACKER
DATE 11/82
DATE 11/13/85
DATE 11/85
DRAWING NO
FIGURE 3.4-6
SHEET 1 OF 1
REVISION NO 1

Subsequent to the selection of layout 41-114B, changes in the Project plan allowed a reduction in size of the MWDF. The revised facility is designated site 41-114C and is described in Chapter 1 and shown on Figure 3.4-7.

Prior to development of site 41-114C, comparisons were made of numerous siting features for disposal sites 41-103, 41-114B, and 41-121 (Table 3.4-1). While sites 41-103 and 41-121 would affect less wetland area than 41-114B, the lowest pond bottom for these sites would be closer to the ground water table than in site 41-114B. This is because the topography is low on the east side of the hill just north of Deep Hole Lake. Both sites 41-103 and 41-121 would require less total area than site 41-114B; however, both of these sites would 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 tailing ponds in siting these facilities. Various MWDF and reclaim pond layouts were reviewed, including some layouts with separated ponds. As a result of the studies, it was generally concluded that separate locations for these facilities would spread the land disturbance over a greater area and complicate the transfer of water from the tailing ponds to the reclaim ponds.

As part of the study and development of site 41-114C, the aspect of siting was again considered. In the final analysis, since site 41-114C is smaller and primarily fits within the footprint of site


MINE/MILL SITE
WATER RECLAIM POND
CELL A
CELL B
T1
T2
T3
T4
WASTE DISPOSAL PONDS
OAK LAKE
LITTLE SAND LAKE
SKUNK LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-114C
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 10/85
CHECKED BY
APPROVED BY C.C. Schroeder
DATE 11/13/85
EXXON D.E. Moe
DATE 11/13/85
DRAWING NO
FIGURE 3.4-7
SHEET
OF
REVISION NO

41-114B, it was concluded that the previous siting evaluation and results leading to the selection of site 41-114B were also applicable to site 41-114C.

For the smaller 41-114C facility, some minor grade elevations have been incorporated to achieve a balanced earthwork condition, which results in substantially less overall earthwork than for site 41-114B. Other data for site 41-114C are presented in Table 3.4-1.

A more complete review of the MWDF siting studies, which included the water reclaim ponds, is presented in the June 1982 siting report "Review of Potential Alternative Mine Waste Disposal Areas" (Exxon Minerals Company, 1982a). When site 41-114B was the preferred site, the water reclaim ponds were located north of Duck Lake in a relatively flat area that was judged most favorable from a topographic standpoint. Other factors that were considered in the siting included the function of the reclaim ponds as water holding and transfer ponds between the mine/mill site and the MWDF. A location between the two facilities would minimize the water handling systems. In that regard, because the majority of the water circulated in the reclaim ponds comes directly from the thickeners at the mine/mill site, location of the reclaim ponds close to the mine/mill site is preferred.

With the reduced land area requirements for the proposed MWDF layout, in comparison to the other site alternatives (Table 3.4-1), it was possible to locate the reclaim pond within the old 41-114B footprint. This eliminated any modifications in the surface water drainage system immediately north of Duck Lake.

TABLE 3.4-1

SUMMARY OF COMPARATIVE FEATURES
OF WASTE DISPOSAL FACILITY LAYOUTS

Comparative Feature	System Designation 41-114C	41-114B	41-103	41-121
Number of tailing ponds	4	4	3	2
Distance from nearest lake (feet)	1,050	1,050	170	200
Wetlands covered (acres)	46	55	34	43
Total land area (acres)	390	577	505	485
Area inside crests (acres)	307	449	405	406
Height above ground water* (feet)	39-43	48-54	30-69	30-55
Height crest elevation (feet)	1,732	1,737	1,735	1,723
Max. pond depth (feet)	98	102	90	98
Max. exterior fill height (feet)	102	107	123	98

*Heights given are from tailing pond bottoms only. Reclaim pond bottoms for all four cases range from 35 to 45 feet above ground water.

Source: Golder Associates (1982a) and Exxon Minerals Company.

Additional information related to siting of the MWDF is presented in Appendix 3.4A.

3.4.2.2. Tailings and Reclaim Water Pipelines and MWDF Access Road Corridor

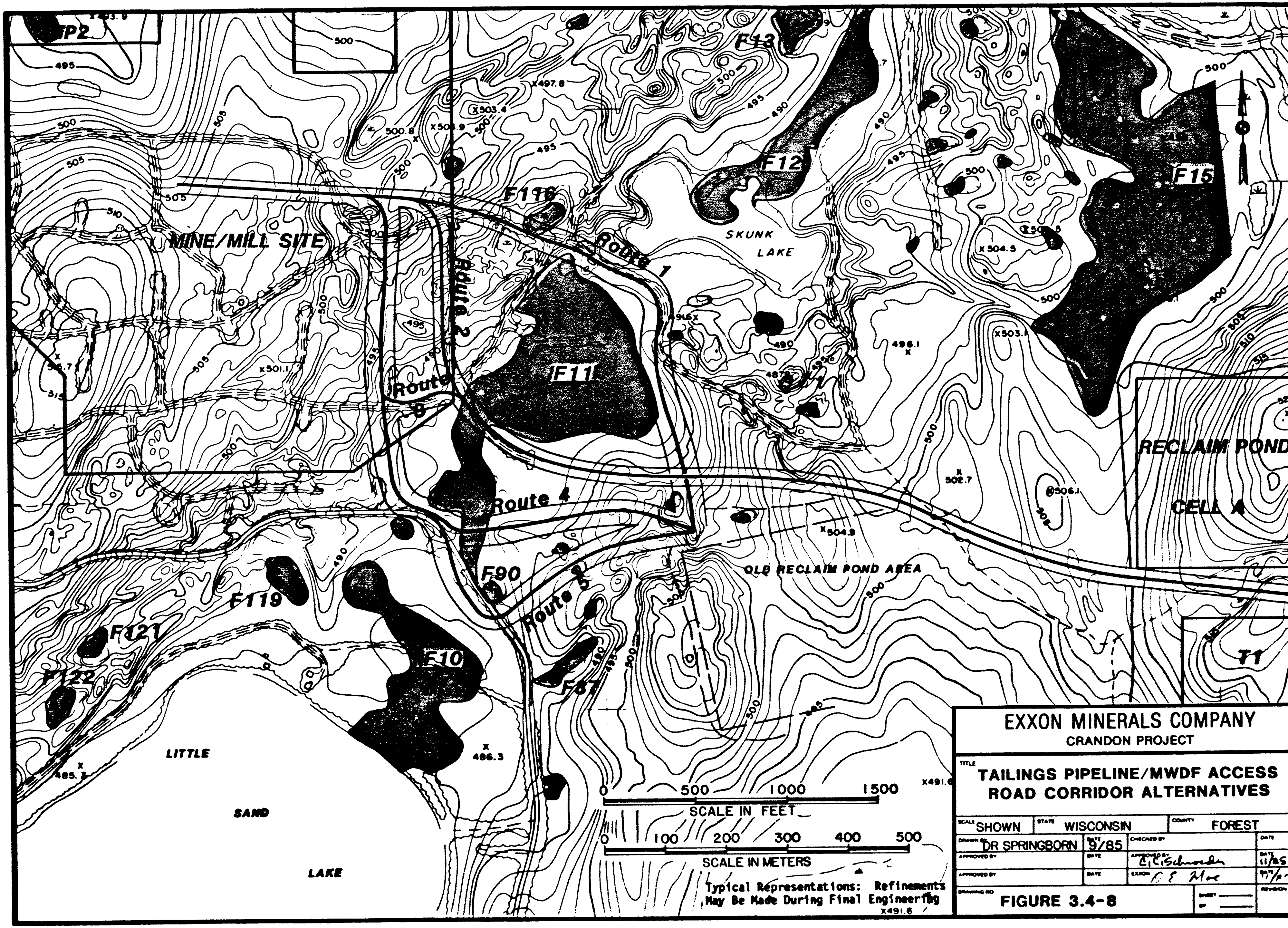
Five potential routes were evaluated for the tailings and reclaim water pipelines and MWDF access road corridor from the mine/mill site to the mine waste disposal area (Figure 3.4-8). Criteria that were evaluated in the siting process included length of the route, topography, and potential disturbance to wetlands. For purposes of estimating the area of wetland disturbance, a corridor width of 130 feet was assumed. Route 2, the proposed route, is described in Chapter 1. Routes 1, 3, 4 and 5 are all viable alternatives. Comparative data for each route from the mine/mill site to the previously proposed reclaim pond area are presented below:

Tailings and Reclaim Water Pipelines
And MWDF Access Road Corridor Data*

Route	Mine/Mill Site Route Length (feet)	Overland Route Length (feet)	Total Length (feet)	Area of Wetlands Affected (acres)
1	1,560	2,590	4,150	0.5
2	2,440	1,640	4,080	0.5
3	2,650	1,620	4,270	0.5
4	2,580	2,030	4,610	0.4
5	2,580	2,480	5,060	-

*Length measurements rounded to nearest 10 feet.

The topographic features of each route are about the same and the total length of each route from the mine/mill site to the previously proposed reclaim pond area ranges from 4,080 feet for Route 2 to 5,060 feet for Route 5. The length of Routes 2 through 5 would be longer than



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: TAILINGS PIPELINE/MWDF ACCESS ROAD CORRIDOR ALTERNATIVES

SCALE: SHOWN	STATE: WISCONSIN	COUNTY: FOREST
DRAWN BY: DR SPRINGBORN	DATE: 9/85	

FIGURE 3.4-8

Route 1 in the mine/mill site before going to the disposal facility. Route 3 has two additional turns and Route 4 runs adjacent to Sand Lake Road at one point, which made them less attractive. A portion of Sand Lake Road would have to be relocated if Route 5 was utilized. Route 2 was selected over Route 1 because there would be less potential for environmental impacts to Skunk Lake. Route 2 will extend an additional 2,460 feet from the previously proposed reclaim pond area to the southwest corner of the current reclaim pond location (Figure 3.4-8).

The wetland area that could be disturbed in the tailings and reclaim water pipeline and haul road corridor is approximately the same for the proposed route and Routes 1, 3 and 4. The maximum wetland area that would be affected is 0.5 acre. No wetland area would be disturbed by Route 5.

Route 5 is the only feasible alternative for avoiding all wetlands (Figure 3.4-8). This "no wetland impact" route would require relocation of a segment of Sand Lake Road approximately 980-1,150 feet in length, which would require approval from the Town of Nashville. The existing road corridor would have to be widened to accommodate the Project facilities and a new area cleared for Sand Lake Road. The new route would follow Sand Lake Road south for a distance of about 650 feet beyond the point where the corridor for Route 4 currently leaves the road. From this point, the route would traverse in an easterly direction to the northwest corner of tailing pond T1. This route would be approximately 5,060 feet in total length and would disturb no wetland areas larger than 0.25 acre in size. Because this route would be longer than the proposed and other alternative routes and would require greater overall land disturbance due to the relocation of Sand Lake Road, it is judged to be less viable than Routes 1, 2, 3 and 4.

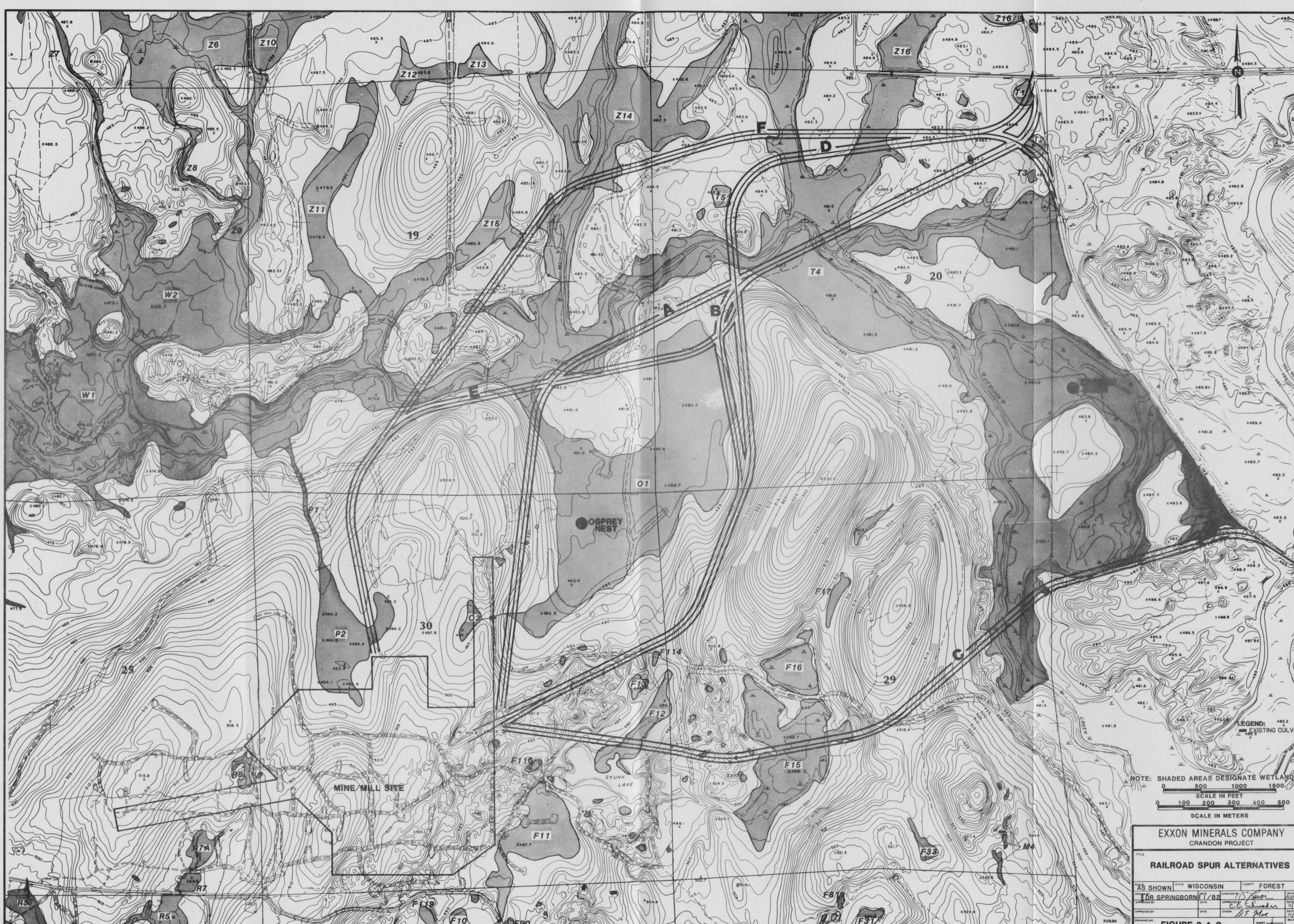
3.4.3 Ancillary Facilities

3.4.3.1 Railroad Spur

Railroad access will be required to facilitate the movement of concentrate to and receipt of bulk supplies from the Soo Line Railroad located approximately 2.7 miles northeast of the mine/mill site.

Both the Chicago & Northwestern Railroad and the Soo Line Railroad were contacted to discuss service to the site. The Chicago & Northwestern Railroad was not interested due to the 12-mile distance to the site and potential abandonment of their nearest trunk line.

Six routes were identified and reviewed from an engineering standpoint and to determine environmental characteristics associated with each route (Figure 3.4-9). Topographic maps, aerial photos, and on-site inspections were used by Soo Line engineers to evaluate the area under consideration and three possible routes (A, B, and C) were plotted based solely on alignment and grade considerations. Environmental characteristics of these potential routes were then reviewed by Dames & Moore. Principal siting criteria that were evaluated included number of stream crossing, area of wetlands affected, and proximity to eagle and osprey nests. Based on this review, a fourth alternative, Route D, was selected as the proposed route. Two additional routes (E and F) were studied in 1980 by Exxon Minerals Company. These routes were aligned to prevent having to cross land owned by Forest County in Sections 29 and 30, T35N, R13E.


EXXON MINERALS COMPANY
CRANDON PROJECT
RAILROAD SPUR ALTERNATIVES
AS SHOWN
WISCONSIN
FOREST
FIGURE 3.4-9
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
LEGEND:
EXISTING CULVERT
OSPREY NEST
MINE/MILL SITE
SKUNK LAKE
A
B
C
D
E
F
19
20
25
29
30
W1
W2
Z6
Z7
Z8
Z9
Z10
Z11
Z12
Z13
Z14
Z15
Z16
T1
T2
T3
T4
O1
O3
P1
P2
F11
F12
F13
F15
F16
F17
F31
F33
F90
F114
F116
F119
R5
R7
R7A
M4

Route D, with the east-west oriented siding north of Swamp Creek, is the proposed route and is described in Chapter 1. Each of the other routes is discussed below with data for all routes summarized in Table 3.4-2.

Route A would encroach on Swamp Creek and associated wetlands and would require three Swamp Creek crossings. About 7.0 acres of roadbed for this route would be located in wetlands which are part of the Swamp Creek deeryard.

Route B would require about 5.7 acres of roadbed in the Swamp Creek wetlands and would also traverse the Swamp Creek deeryard. Both Routes A and B would pass within 0.5 mile of an osprey nest; Route A would be closest, passing within 0.13 mile of the nest.

Route C avoids the Swamp Creek wetlands but would cross several perched wetlands. This wetland area includes a marsh surrounded by bur oak. Route C would be located within 730 feet of Skunk Lake and requires crossing Hemlock Creek and cutting through a high ridge. This route would pass along the south edge of the wetland-spring pond complex located west of the intersection with the Soo Line Railroad. Although the wetlands in this area were not mapped in detail, this alternative route would follow the higher ground south of the wetland and would result in infringement on the wetland-spring pond complex.

Route E and F share a common corridor between the Soo Line Railroad mainline and a point approximately 330 feet south of the Swamp Creek crossing (Figure 3.4-9). Route E would parallel Swamp Creek for approximately 1 mile from the interface point with Route D to the

Table 3.4-2

RAILROAD ALTERNATIVES ROUTING DATA

Route Characteristic	Railroad Route A	B	C	D	E	F
Overall Track Length[a] (feet)	12,680	12,900	11,520	14,420	15,560	15,160
Siding Length (feet)	-[b]	-	-	9,840	-	-
Number of Stream Crossings (Stream Crossed)	3 (Swamp Creek)	1 (Swamp Creek)	1 (Hemlock Creek)	1 (Swamp Creek)	1 (Swamp Creek)	2 (Outlet and Swamp Creeks)
Area of Wetlands Affected[c] (acres)	7	6	6	3	7	6
Closest Eagle or Osprey Nest (mile)	0.13	0.33	0.40	0.33	0.35	0.45

[a]Overall route length measured from the Soo Line Railroad mainline to the mine/mill site perimeter and is rounded to nearest 10 feet.

[b]No siding alternatives developed for these routes. Would be about the same length as for Route D.

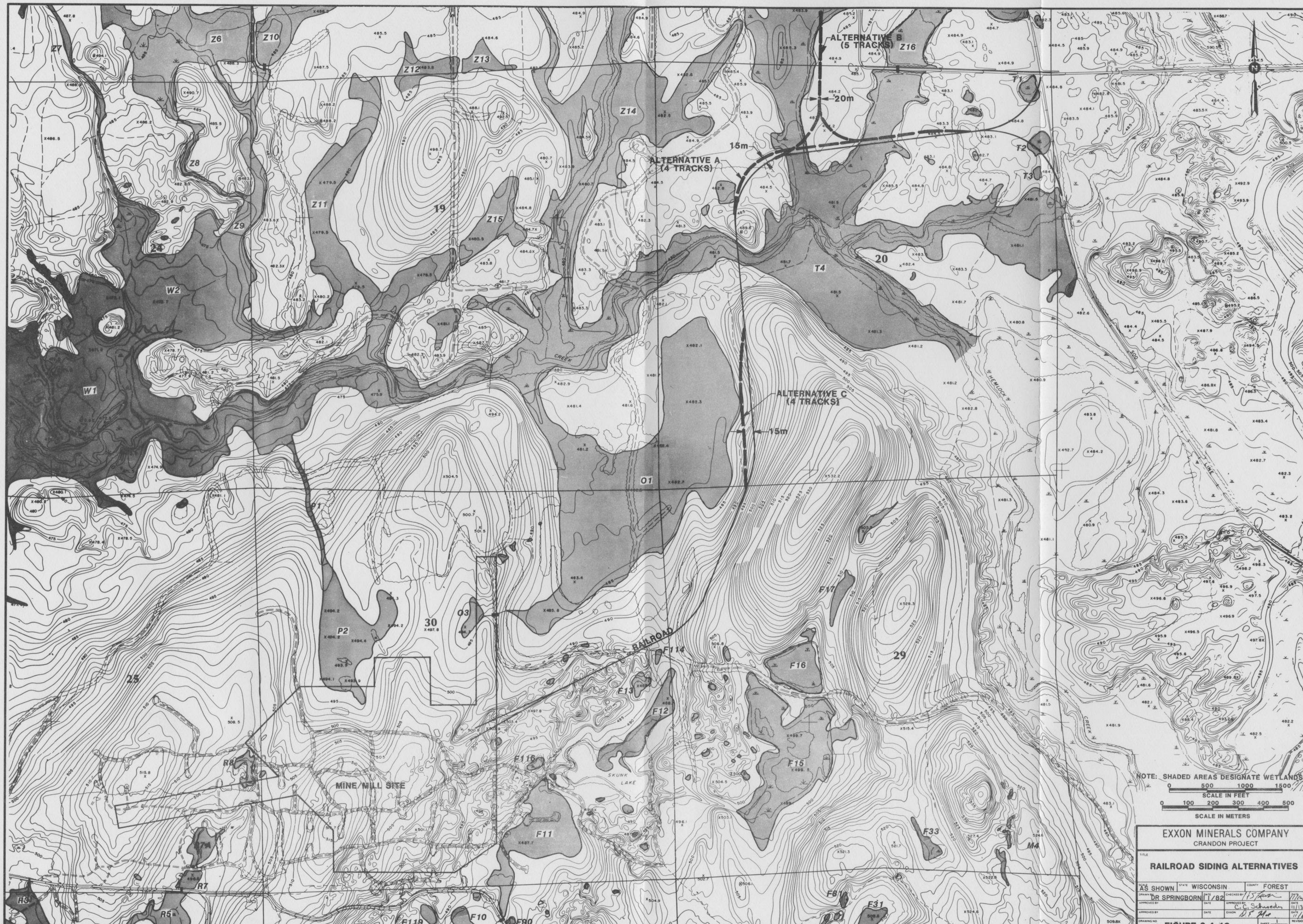
[c]The area of wetland disturbance is based on a corridor width of 100 feet, and area disturbance is rounded to nearest 1 acre.

southwest portion of Section 19 prior to changing alignment in a southerly direction to the mine/mill site. Route E would have a greater effect on the Swamp Creek deeryard and wetlands than all other alternatives except Route A (Table 3.4-2). This route would also pass within 0.35 mile of an osprey nest.

Route F would connect to the Soo Line Railroad mainline at the same point as Route D and was routed west approximately 6,000 feet before turning south toward the mine/mill site. Route F would be approximately 740 feet longer than the proposed route and would cross both Outlet and Swamp creeks.

In addition to route alternatives, alternative siding locations were examined for Route D (Figure 3.4-10). These were: (1) the area immediately west of the takeoff point from the Soo Line Railroad with one siding oriented east-west (the proposed siding) and one oriented north-south (Alternatives A and B, respectively) and (2) along the hillside south of Swamp Creek (Alternative C). The major environmental siting criteria used to evaluate alternative siding locations included land use, area of wetlands affected, and location of residences.

One rail siding, Alternative B, has a north-south orientation in two fields north of Swamp Creek. With the necessary access trackage for curves to the siding, the total wetland area disturbed by this siding (1.7 acres) would be approximately twice that for the proposed siding location (0.8 acres). The position of the paved town road effectively limits the length of the tracks, thereby requiring more tracks of shorter length. Additionally, this land is now used for agricultural purposes and the siding would be located immediately in front of an existing residence.


ALTERNATIVE A (4 TRACKS)
ALTERNATIVE B (5 TRACKS)
ALTERNATIVE C (4 TRACKS)
20m
15m
15m
RAILROAD
CREEK
HEMLOCK
LINE
SKUNK LAKE
MINE/MILL SITE
Z6
Z7
Z8
Z9
Z10
Z11
Z12
Z13
Z14
Z15
Z16
W1
W2
T1
T2
T3
T4
O1
O3
P1
P2
F10
F11
F12
F13
F15
F16
F17
F31
F33
F90
F114
F116
F119
R5
R6
R7
R7A
R8
M4
19
20
25
29
30
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
RAILROAD SIDING ALTERNATIVES
AS SHOWN
WISCONSIN
FOREST
DR SPRINGBORN 11/82
FIGURE 3.4-10
0

The feasibility of locating the siding south of Swamp Creek along the hillside parallel to the north-south elongated high ground, Alternative C, was also examined. The required grade through much of this section is 1 percent, which violates the design constraint of 0.5 percent maximum grade on sidings to minimize the danger of movement of parked rolling stock. The total width of the construction zone would have to be increased considerably to accommodate more sidehill cut and fill. Furthermore, three grade crossings would be required in this section of track under the terms of a railroad easement signed with American Can Company. The coniferous swamp west of siding Alternative C would receive limited, if any, physical disturbance during construction and operation of this alternative. The erosion control plan would reduce siltation caused by erosion through the use of surface diversions in conjunction with straw bales and berms.

A siding location immediately north of the mine/mill complex was discussed and considered but not pursued. The deadend location of the siding in that area along with the additional congestion from having all car handling activities centralized was not viewed favorably. Also, Exxon's objective is to minimize reliance on the Soo Line Railroad by keeping their car handling operations and travel on the spur line to a minimum.

The estimated additional wetland area removed for the three siding tracks in their proposed location is approximately 0.8 acre. The area immediately north of the mine/mill site is being proposed for the location of preproduction ore storage. Assuming a siding in the mine/mill area is located north of the preproduction ore storage area, it would pass through wetland P2, affecting approximately 1.2 acres of wetland vegetation. A siding location in this area versus the proposed location would affect a larger wetland area.

In addition to alternative railroad routes, an aerial tramway system and a belt conveyor system were examined. These two systems are concentrate handling systems only and would, therefore, provide only one-way transportation. The movement of bulk supplies such as steel, lime, reagents, and cement would still require rail facilities or increased truck traffic and off-site handling/storage facilities. The tramway and belt conveyor systems were consequently eliminated from further consideration.

3.4.3.2 Access Road

The Project will require an access road for employees, visitors, and truck traffic. Three general directions were studied for the access corridor: north-south from the town road near the Crandon Airport to the Project site, southeasterly beginning at various points off State Highway 55, and easterly utilizing the existing Sand Lake Road. Numerous routes were investigated during the route selection process. The major criteria used to screen the potential routes were:

1) Area of wetlands affected;
2) Stream crossings (where necessary);
3) Total route length;
4) Amount of earthwork required;
5) Effect on developed areas of increased traffic volume; and
6) Availability of the necessary right-of-way.

More detailed discussion of the access road siting process and alternatives is presented in Exxon Minerals Company (1980, 1982b) and Inman-Foltz & Associates, Inc. (1979).

Route B-1 (described in Chapter 1) was selected as the proposed route. Two alternative routes (A-1 and E) and Route B-1 are shown on Figure 3.4-11. Environmental data for the three routes are presented in Table 3.4-3.

Route A-1 reflects alignment adjustments made to earlier, similar routings to: (1) minimize wetlands disturbance, and (2) consider the Town of Nashville's request to move the route north of the existing town road. While this route is shorter than the proposed route, it would affect more wetland area and traverse two unnamed creeks which provide suitable spawning habitat for trout.

Route E, which uses the existing Sand Lake Road, is located south of Swamp Creek and would not materially affect any wetlands beyond those already affected by Sand Lake Road. Approximately 0.6 acre of wetland vegetation could be affected if this route is utilized. A portion of this route does, however, pass through the Mole Lake Indian Reservation. Additional width on the right-of- way would be required, which could potentially disturb residences. This route requires all traffic to and from the mine/mill site to pass through the established Sokaogon-Chippewa Community. Route E was relegated to a lesser ranking to reduce traffic impacts to a residential community (Exxon Minerals Company, 1982c).

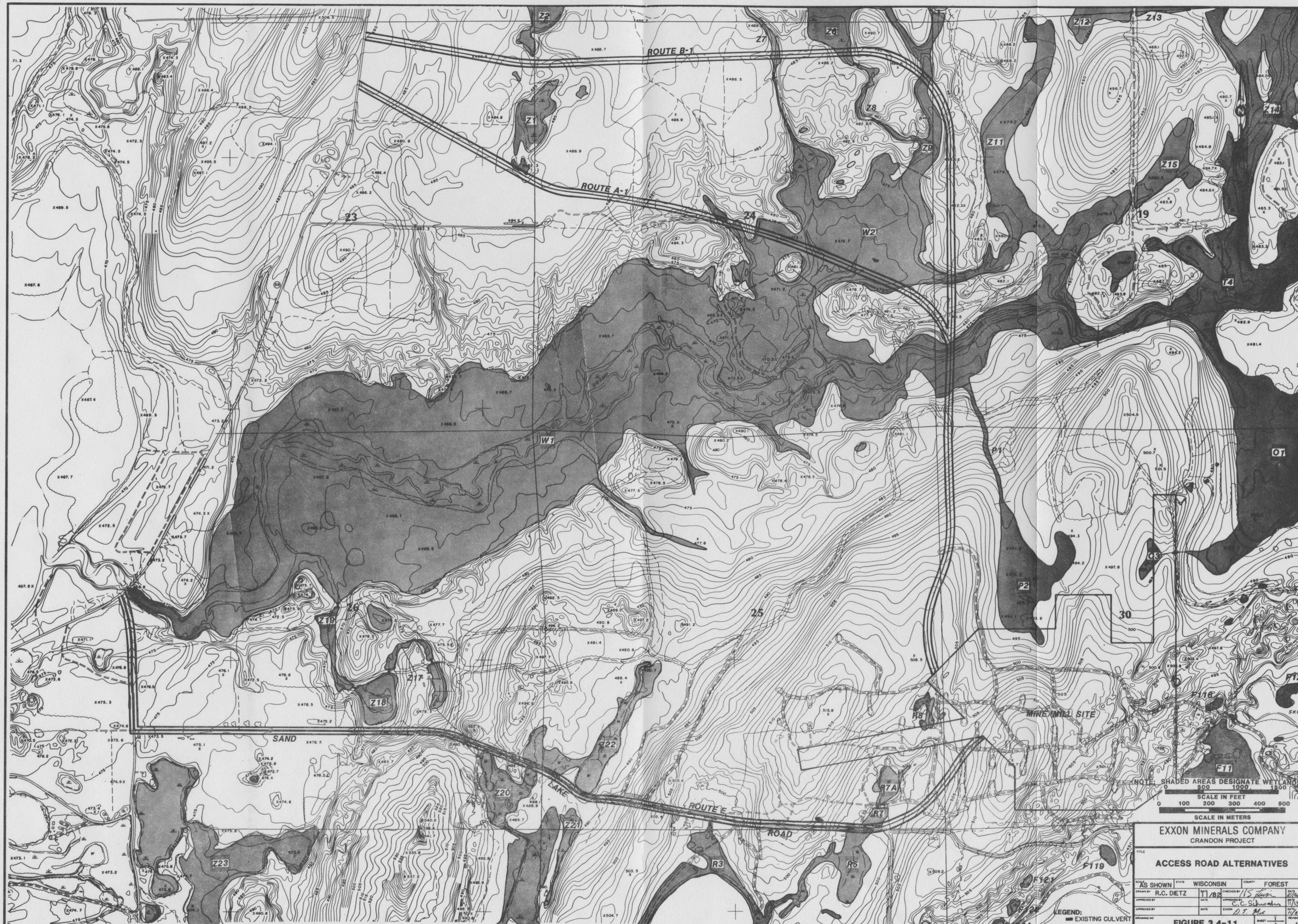

ROUTE B-1
ROUTE A-1
ROUTE E
SAND LAKE ROAD
MINE/MILL SITE
W1
W2
P1
P2
O1
O3
Z1
Z2
Z6
Z7
Z8
Z9
Z11
Z12
Z13
Z14
Z15
Z17
Z18
Z19
Z20
Z21
Z22
Z23
R3
R5
R7
R7A
R8
F11
F12
F116
F119
T4
19
23
24
25
26
30
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
LEGEND:
EXISTING CULVERT
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
ACCESS ROAD ALTERNATIVES
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY R.C. DIETZ
DATE 11/82
CHECKED BY
APPROVED BY
DATE
APPROVED BY
DATE 11/13/85
APPROVED BY
DATE
EXXON
DATE 11/85
DRAWING NO
FIGURE 3.4-11
SHEET 1 OF 1
REVISION NO 1

TABLE 3.4-3

ACCESS ROAD ALTERNATIVES ROUTING DATA

Route Criteria	Access Road Route A-1	B-1	E
Overall Length[a] (feet)	12,780	15,360	13,520
New Stream Crossing Structures	1	1	0
Area of Wetland Affected[b] (acres)	7	3	1
Closest Home (feet)	120	500	--[c]
Homes Within 0.1 mile	3	1	19
Closest Eagle or Osprey Nest (mile)	0.8	0.8	1.0

[a]Overall route length measured from State Highway 55 to the mine/mill site perimeter and is rounded to nearest 10 feet.

[b]The area of wetland disturbance was based on a corridor width of 100 feet and area disturbance is rounded to the nearest 1 acre. For Route E, only the incremental additional wetland disturbance is identified.

[c]One residence is located within the 100-foot wide corridor.

3.4.3.3 Power Corridor

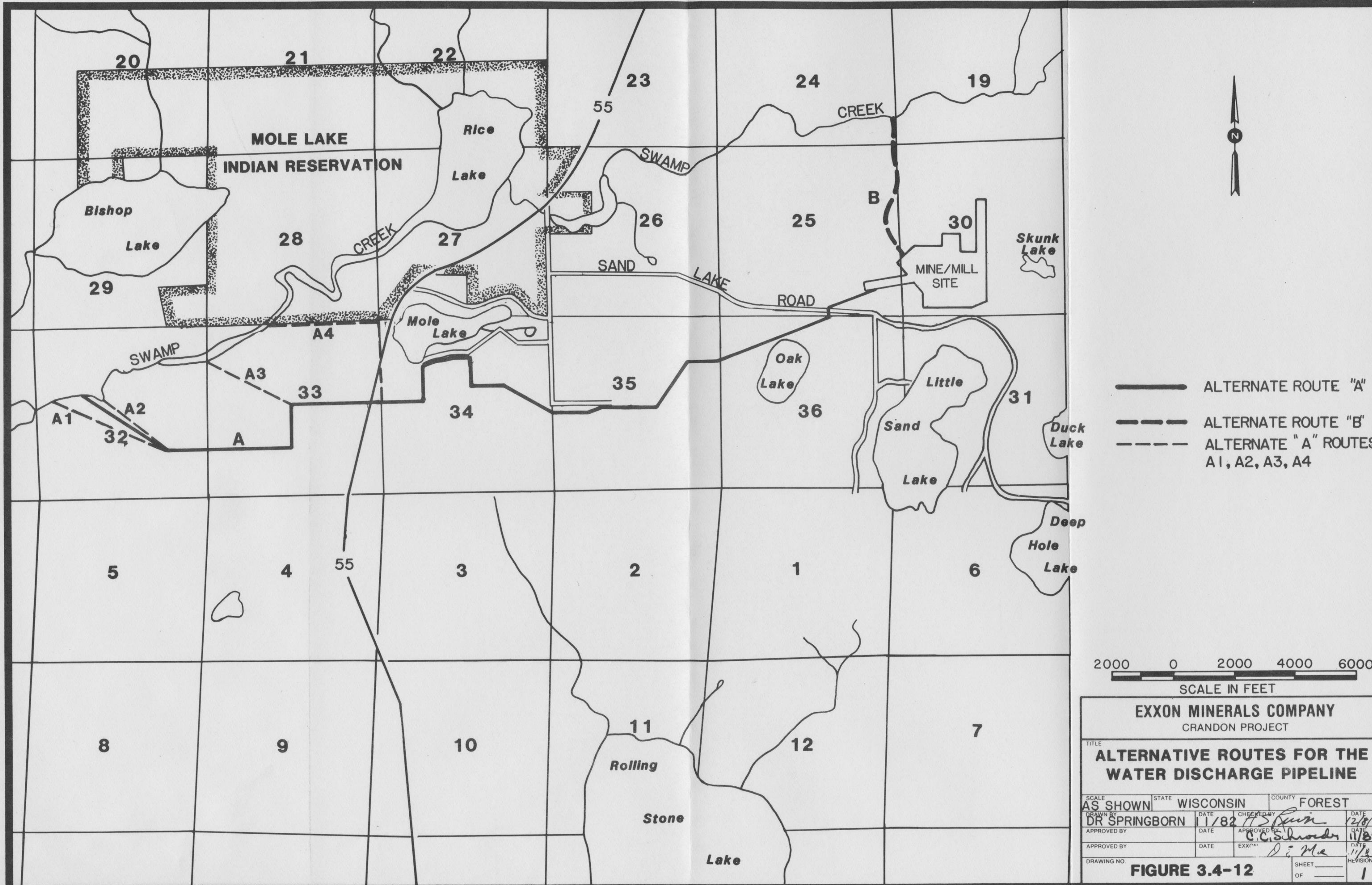
The Crandon Project will require a 115 kV electric transmission line to be constructed from the Wisconsin Public Service Corporation (WPSC) Venus substation near Monico, Wisconsin to the mine/mill site. Several routes have been proposed and studied by WPSC. The details concerning these potential routes are included in the Environmental Screening Worksheet which is part of WPSC's application to the Public Service Commission of Wisconsin for a Certificate of Public Convenience and Necessity.

3.4.3.4 Surface Water Discharge

The siting of water discharge pipeline routes on land not under Exxon's control is subject to considerable uncertainty. Exxon does not have the right of condemnation. Without the right of condemnation, the routes cannot be publicly disclosed prior to the acquisition of right-of-way along the entire length of each route.

Two alternative pipeline routes have been secured (Figure 3.4-12) for the Crandon Project. Both alternative routes terminate with a discharge into Swamp Creek. For environmental reasons, Route A is the proposed route. Several alternative Swamp Creek discharge routes (A1 through A4) below Rice Lake were considered and negotiations for land along the routes were initiated. However, because of various landowner concerns, land negotiations were successful only on Route A.

Several environmental factors were used in selecting the proposed alternative over Route B. Route B discharges into Swamp Creek in a stream section designated by the DNR as a Class II trout stream.



EXXON MINERALS COMPANY					
CRANDON PROJECT					
TITLE: ALTERNATIVE ROUTES FOR THE WATER DISCHARGE PIPELINE					
SCALE: AS SHOWN	STATE: WISCONSIN		COUNTY: FOREST		
DRAWN BY: DR SPRINGBORN	DATE: 11/82	CHECKED BY: H S Ervin	DATE: 12/8/82		
APPROVED BY	DATE	APPROVED BY: C. C. Schroeder	DATE: 11/85		
APPROVED BY	DATE	EXXON: D. E. Ma	DATE: 11/85		
DRAWING NO. FIGURE 3.4-12			SHEET ___ OF ___	REVISION NO. 1	

The fish community in this cold water section of Swamp Creek would be more sensitive to moderate variations in water quality resulting from the proposed discharge than would the warm water populations downstream of Rice Lake.

Also Route B discharges upstream of Rice Lake which is part of an extensive wetland system producing wild rice which is commercially and culturally important to the Mole Lake Sokaogon-Chippewa Community. This lake also has abundant phytoplankton and invertebrate populations which serve as food sources for downstream fish populations. The potential impacts to this aquatic system from discharge of excess water were considered to be greater than those associated with Route A. Although Route B does present some advantages over Route A, as discussed in subsection 4.4.1.6, the overall potential for environmental impacts appears greater with Route B.

Several generic discharge structures were considered for use. One type discharges from the stream bank (the proposed plan), whereas the other would be placed in the stream channel. While structures placed in the stream channel would have less aesthetic impact and allow increased mixing, they would cause greater disturbance to the existing aquatic environment (e.g., displacement of habitat area and food organisms), possibly impact navigation, and increase the potential for substrate erosion during operation. For these reasons a stream bank discharge method was chosen.

A temporary construction access road will be required while the discharge pipeline is being laid. After construction, only periodic access for sampling and inspection normally would be required. As part of the access easement with the landowner, a new road will be constructed to the discharge site area from Shallock Lane located directly north of the proposed discharge. The easement for the one-lane gravel road is 25 feet wide and approximately 2,000 feet long and the road would terminate near the stream bank opposite the discharge structure. The temporary construction area for the pipeline and discharge structure would be allowed to revegetate and no all weather (hard surface or gravel) access road is required. If some maintenance for the discharge structure or pipeline is required (i.e., replacement of rip-rap), a construction access road along the pipeline route would again be utilized.

3.4.3.5 Ground Water Discharge

The ground water system was considered as a potential receptor for excess treated water from mine/mill operations. Discharge would be via a seepage lagoon. The following specific criteria were used in the selection of potential ground water recharge sites:

1) Located within the northern half of the Pickerel Creek drainage basin (to avoid effects on Rice Lake or Swamp Creek near the Mole Lake Indian Reservation);

2) Not directly cover any wetlands;

3) Maintain a sufficient distance from ground water discharge areas to lengthen the time before discharged to surface water; and

4) Presence of a thick layer of stratified drift (aquifer) relatively close to the ground surface.

Based on these criteria, four potential excess water disposal areas were identified (Golder Associates, 1981a). These areas are shown on Figure 3.4-13.

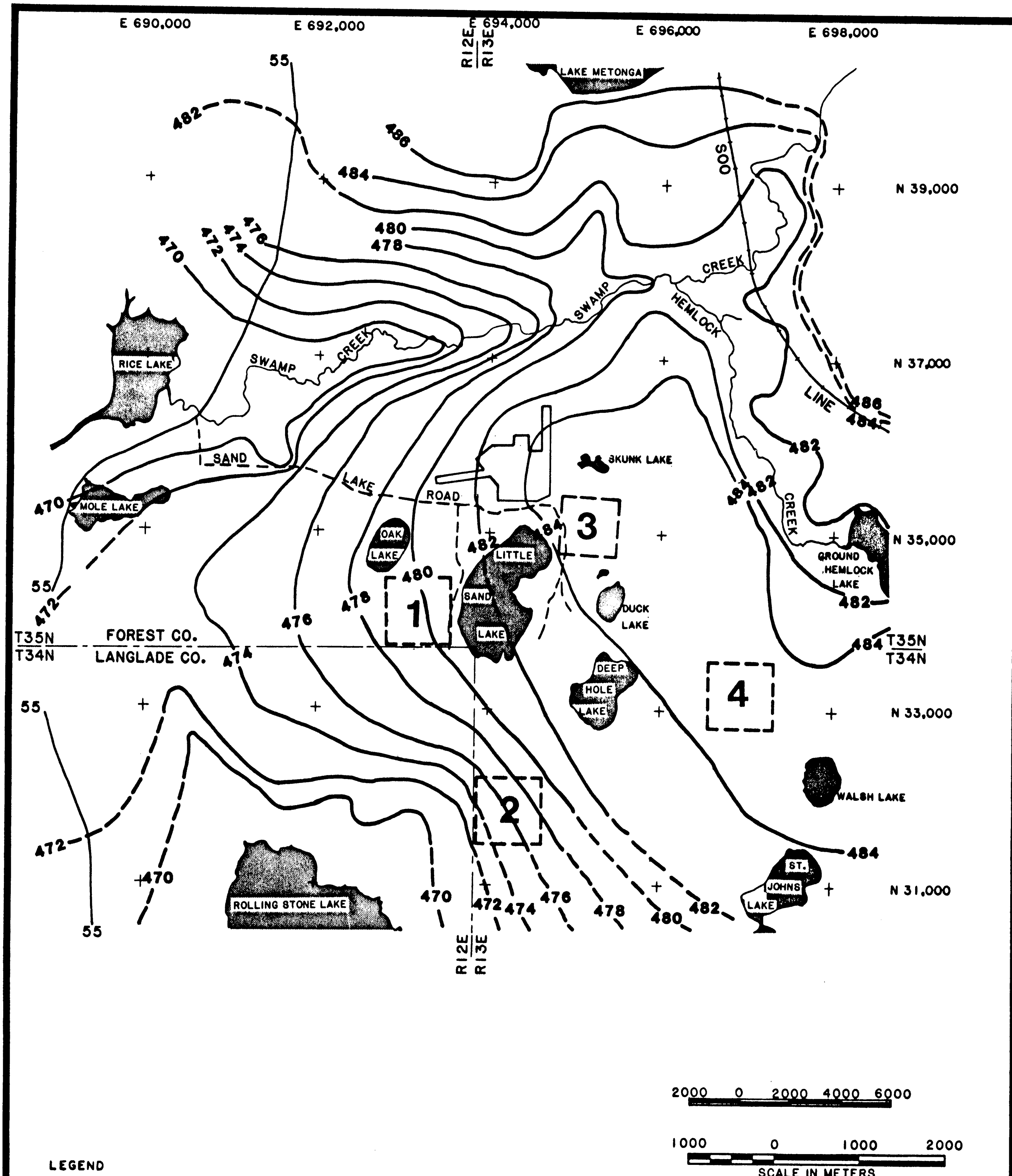
Area 1 is located west of Little Sand Lake. Based on available data, the surficial soils at this site consist of till, ranging in thickness from 50 to 82 feet. The till is underlain by the regional ground water aquifer (stratified drift) which varies from 100 to 130 feet thick.

Area 2 is located northeast of Rolling Stone Lake. Borings near this area indicated a thin cover of till (± 15 feet), capping 100 to 130 feet of stratified drift.

Area 3 is located on the northeast side of Little Sand Lake. Three borings and three test pits, all shallow, were completed in this area. The estimated thickness of the stratified drift in this area ranges from 100 to 180 feet.

Area 4 is located east of Deep Hole Lake. Four borings were completed within this area; three extend to bedrock. The surficial deposits in this area range in thickness from about 0 to 65 feet of till, underlain by approximately 130 to 200 feet of stratified drift.

Additional hydrogeological data and site conditions for these alternative disposal areas are described in the December 1981 report, entitled "Excess Water Discharge, Crandon Project" by Golder Associates (1981a) and the report by STS Consultants Ltd. (1984), entitled "Hydrologic Study Update for the Crandon Project."



LEGEND

- GROUND WATER ISOPLETHS (contours) IN METERS ABOVE MSL
- GROUND WATER ISOPLETHS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA
- GROUND WATER ISOPLETH 486 METERS ABOVE MSL AS ESTIMATED EXCLUDING EFFECTS OF JUNE-JULY 1980 PUMP TEST
- GROUND WATER RECHARGE AREAS

NOTE

GROUND WATER CONTOURS INTERPRETED BY GOLDER ASSOCIATES AND DAMES & MOORE BASED ON THE FOLLOWING DATA:

a. GOLDER ASSOCIATES AND DAMES & MOORE OBSERVATION WELL MEASUREMENTS ON SEPT. 10 AND 11, 1980
b. WATER CHEMISTRY DATA FROM D&M AND DNR
c. SURFACE TOPOGRAPHY
d. USGS WELL DATA AND GOLDER WELL DATA FROM DIFFERENT TIME PERIODS

EXXON MINERALS COMPANY CRANDON PROJECT					
TITLE: GROUND WATER RECHARGE AREAS					
SCALE: SHOWN	STATE: WISCONSIN		COUNTY: FOREST		
DRAWN BY: C.A. HACKER	DATE: 8/82	CHECKED BY: [signature]		DATE: 12/8/82	
APPROVED BY	DATE	APPROVED BY: C.C. Schroeder		DATE: 11/85	
APPROVED BY	DATE	EXXON: D. E. Moe		DATE: 11/85	
DRAWING NO: FIGURE 3.4-13		SHEET OF		REVISION NO: 1	

3.5 STRUCTURAL/OPERATIONAL ALTERNATIVES

This section provides a description of major structural and operational alternatives in contrast to those proposed for the Project in Chapter 1. Alternative mining, mine water control, mine backfill and ore processing methods are described in subsections 3.5.1 and 3.5.2. Subsection 3.5.3 contains a discussion of waste rock transport alternatives and alternatives for storage of preproduction ore and concentrate are discussed in subsection 3.5.4. Alternative tailings transport systems are described in subsection 3.5.5. Subsection 3.5.6 contains tailings disposal alternatives, including tailings deposition methods, alternate types of seepage control, and tailing pond facility reclamation methods. Water treatment systems, water storage and discharge, water treatment waste disposal, solid waste disposal methods, sanitary waste treatment, and mine air heating and energy conservation are described in subsection 3.5.7. Energy source alternatives are presented in subsection 3.5.8.

3.5.1 Mining Methods

The primary criteria for selection of a mining method are the size, shape, grade (contained value), rock strengths, and location of the deposit. On this basis, the Crandon deposit can be characterized as a large tabular orebody of average grade, vertically oriented in a host of predominantly competent volcanic rocks, overlain by a thick mantle of partially saturated glacial overburden, and situated in an environmentally sensitive lake, wetland and forest natural resource area.

Mining method alternatives considered included open pit, underground, and combination mine plans. It was concluded at an early phase of Project evaluation that open pit mining at the Crandon site would be impractical and environmentally unacceptable. Extensive site dewatering would be required for pit development. Large volumes of overburden and waste rock would be generated for surface disposal. Nearby surface waters and wetland resources would limit pit expanse and thus depth and resource recovery. Finally, pit and waste stockpile reclamation approaching pre-mining site conditions would be extremely difficult.

The mining method selected for primary recovery of the Crandon orebody is mechanized sublevel blasthole open stoping with delayed backfill. It is a highly efficient method for mining vertical deposits in competent ground with techniques for drilling, blasting, and haulage similar to those of surface mines. A cost effective method like this is required for economic viability since the deposit is of only average grade. No alternative mining method is applicable on a broad scale. The only planned method variation is reduction of stope dimensions for recovery of weakened but enriched weathered zones beneath the orebody crown pillar. In these areas shrinkage blasthole stoping and horizontal cut and fill methods will be practiced where these less efficient methods can remain profitable.

3.5.1.1 Mine Water Control

Hydrologic studies for mine design have indicated that ground water from the glacial overburden aquifer will seep into the mine at an average rate of 1,270 gallons per minute. For facility design purposes the mine inflow quantity has been conservatively assumed to be 2,000 gallons per minute. Because of technical and economic constraints, no surface control of mine water inflow is currently planned. Instead, the proposed plan is to intercept as much ground water inflow as possible high in the mine prior to any contamination. The normal mine process drainage and the intercepted ground water inflow will be separately collected, pumped to surface, treated as required, and discharged or reused (see subsection 1.2.1.2.16). Alternatives to the proposed action include reduction of inflow by pumping down the glacial aquifer above the mine, aquifer flow restriction methods such as selective placement of bentonite grout, slurry trenching and vertical grout curtains, and natural uncontrolled ground water inflow throughout the mine.

Potential mine inflow control techniques have been investigated by Klohn Leonoff (1982). This study includes a review of all technically applicable ground water control methods and a comparison of their site specific feasibility, including relative effectiveness and cost. The discussion of mine inflow control techniques presented below is based on the results presented in Klohn Leonoff's 1982 report.

Surface pumping of the glacial aquifer would reduce the water in the overburden aquifer available for influx into the mine. This technique has the advantage that ground water is intercepted prior to any potential contamination in the mine and is, thus, suitable for reinjection or surface discharge with minimal treatment. With this technique, however, larger volumes of water would be discharged than in the proposed method. For example, pumping at a rate of 1,500 to 2,000 gallons per minute would be only partially effective and probably would not reduce mine inflow by more than 500 to 1,000 gallons per minute.

The results of Klohn Leonoff's investigation indicated that overburden pumping atopthe orebody might moderately reduce inflow. Generally, more than twice as much ground water would have to be evacuated from the mine area to produce a drawdown cone with small residual heads over potential mine inflow locations. However, on a very localized basis involving only a few wells, overburden aquifer pumping may be applicable if a small and particularly active subcrop water course is identified. In such a case, ground water could be pumped to provide local aquifer desaturation. Well field discharge could be directed to surface waters or reinjected by drain field or wells to the ground water system exterior to the locally pumped cone of depression. Ground water displaced by a segregated program of this type should maintain its existing quality. Potential environmental ramifications of utilizing this alternative include recharge of aquifers, maintenance of water supply wells, preservation of wetland hydrology, and protection of major surface water drainage patterns.

General aquifer flow restriction methods would be impractical at the Crandon site because of the extensive overburden depth; however, underground rock grouting may be used to reduce and redirect localized water inflows.

Another alternative is to capture all of the natural inflow to the mine in the contaminated water sump system and pump it to the surface water treatment plant for subsequent discharge or reuse. The uncontrolled inflow of up to the design maximum of 2,000 gallons per minute would not greatly affect mining methods or general mine conditions. Furthermore, the ability to intercept ambient ground water is related to the rate of natural inflow. As lower inflow rates are experienced, it will become increasingly difficult and less practical to attempt segregation, collection and pumping of uncontaminated ground water. At steady state inflow rates less than about half the 2,000 gallons per minute design maximum, it may be prudent to allow all ground water seepage to flow to the normal mine drainage sumps.

3.5.1.2 Mine Backfill

The proposed mine backfill will consist primarily of the deslimed or coarse fraction of the mill tailings. Coarse tailings will be recovered by cyclones at a size fraction exhibiting "free drainage" characteristics when placed uncemented in depleted mine stopes. Cement will be added to about one-third to one-half of the total backfill placed in the mine to add stability so that the column of fill will stand unsupported. Since the available coarse tailings will be less than the total backfill demand, it will be supplemented with coarse and crushed waste rock, and possibly make-up glacial sand.

An alternative backfill preparation concept is to leave all or most of the fines in the backfill slurry and reduce its water content. Such a fill would be paste-like in consistency and would be pumped or "extruded" into the stopes. When placed at a 75 to 85 percent solids density (as opposed to 65-70 percent for conventional backfill), this material would require a minimum of water drainage by percolation and/or decantation. Claimed advantages of high density backfilling are:

1) Increase in backfill strength, both uncemented and especially cemented;

2) Increase in the quantity of available fill; and

3) Decrease in surface waste storage requirements.

All three of these effects would benefit Project operations.

The obstacle to implementation of the high density backfill alternative is the lack of industry experience in an operational situation. The high density backfill method is currently in the developmental stage and has not been tested over a long-term period at an operating facility. This technology could be incorporated into the Project after proper testing. Implementing this change would likely require only a relatively minor retrofit of equipment in the backfill preparation plant. The progress of high density backfill research and development will be monitored with ultimate utilization depending on engineering, economic, and environmental considerations at the time that this technology is proven for commercial application.

If make-up glacial sand is needed to supplement backfill, one of the Marconaflo systems used for repulping backfill may be installed below grade. This would allow sand to be dumped directly from haulage trucks into this storage facility.

3.5.2 Process Alternatives

The proposed process for treating both types of Crandon ore is similar to processes which are commercially proven and accepted in industry. The proposed process will include grinding and flotation circuits and was developed by extensive bench scale and pilot plant testing. A semi-autogenous grinding and ball mill grinding circuit will be used to liberate valuable mineral particles from the gangue minerals; flotation circuits will separate and concentrate the zinc, copper, and lead minerals into three concentrate products. Once the basic process was developed for treating the massive and stringer ore types, further testing and pilot scale studies led to process simplification and a reduction in the number of reagents required for the flotation process.

The alternative of an additional process step, pyrite flotation, is discussed in subsection 3.5.2.1. Other process alternatives are discussed in subsection 3.5.2.2.

3.5.2.1 Pyrite Flotation

Pyrite (FeS_2) flotation was developed as an additional step to the proposed concentration process and not as a replacement alternative. It was evaluated from a technical and economic standpoint prior to designing the proposed flotation process. In this step, the final zinc flotation tailings would be subjected to flotation to produce a pyrite concentrate and non-pyrite tailings. These products would be treated in the backfill preparation plant separately to recover the coarse fraction from each to be used as mine backfill.

The pyrite concentrate would be stored as a separate waste product, marketed, or processed further to recover sulfur, iron, and minor nonferrous metals if economical. To determine the viability of marketing and/or further processing, a study was done to determine if pyrite could be marketed in its basic form and, if not, whether marketable products could be made using proven technology (Davy-McKee, 1981). Capital and operating cost estimates were developed to determine whether the processing of pyrite was economically viable.

As a result of these study efforts, the following conclusions were reached:

Pyrite Concentrates - Two potential customers were identified for marketing the pyrite. These were Copper Range at White Pine, Michigan, and Cities Service Company at Copperhill, Tennessee. Copper Range could only consume 10 percent of the potential Crandon production. Cities Service Company examined the feasibility of purchasing Crandon pyrite and subsequently notified Exxon that they would not be able to use the product because of its extreme fineness and the high transportation costs.

It was concluded that no market exists for Crandon pyrite concentrates. Pyrite is not in demand for the following reasons:

1) Pyrite has potential commercial value only because of its sulfur content; the main use of sulfur is in the manufacture of sulfuric acid.

2) The Frasch process for mining elemental sulfur and the availability of by-product sulfur from metal smelters and oil refineries have eliminated pyrite as a major source of sulfur in North America.

3) The pyrite roasting industry in North America has disappeared because of:

-- competition from less expensive sulfur sources;
-- shortage of existing roasting facilities;
-- high cost of pyrite roasting; and
-- future adequacy in North America of other by-product sulfur/sulfuric acid from coal burning power plants and metal smelters.

4) Only one company in the U.S. today processes the pyrite it mines. This is Cities Service Company at Copperhill, Tennessee. They produce only sulfuric acid from the pyrite; the iron pellet circuit was closed because of technical and economic considerations.

<u>Pyrite Products</u> - Since no pyrite concentrate market was identified, it became necessary to examine the feasibility of producing other products from pyrite. Although technically feasible, Davy-McKee found that no product could be economically produced.

The following is a list of products studied:

1) Sulfuric acid with disposal of iron oxide waste;

2) Sulfuric acid, iron pellets, nonferrous metals and precious metals recovery;

3) Diammonium phosphate fertilizers from sulfuric acid, iron pellets, nonferrous metals and precious metals recovery; and

4) Elemental sulfur, iron pellets, nonferrous metals and precious metals recovery.

Other products considered but eliminated from consideration were as follows:

1) Liquid SO_2 - consumption in the potential market areas was only about 220,000 tons per year and not large enough to warrant investigation;

2) By-product Gypsum - this product would contain impurities which must be removed and the processes are prohibitively expensive; and

3) Miscellaneous Iron Products - products, such as pigments and powder, were eliminated due to lack of markets or production consideration.

The recommendation in the report by Davy-McKee (1981) was that the coarse fraction of the plant tailings be used as mine backfill with the fine fraction placed in the tailings disposal pond leaving the possibility of later reclamation of pyrite if economics were to prove favorable. However, it was concluded in the CRU marketing study (contained in Davy-McKee [1981]) that there is little chance of a reversal in the downward trend in pyrite roasting, because of the relatively high cost and future adequacy in North America of by-product sulfur and sulfuric acid from coal burning power plants and metal smelters. Furthermore, the results were not optimistic about the demand for iron pellets. There is considerable unused capacity to produce pyrite. Consequently, the demand for pyrite is not expected to increase in the next 10 to 20 years.

The Davy-McKee report included a discussion of the possibilities of producing fertilizer by the Pircon-Peck process and contained the following conclusions:

1) The required defluorinated phosphate rock is expensive;

2) There is no current interest or demand; and

3) Commercial success in the near term is not likely.

Production of elemental sulfur from pyrite roasting with high oxygen in the gas is energy and capital intensive and should not be considered an economic source of elemental sulfur.

The pyrite in the Crandon tailings will not be lost as a resource if the tailings are disposed as planned and could be reclaimed if a suitable market is found.

Exxon Minerals Company considered the possibility that there might be some potential advantages to pyrite separation of the zinc flotation tailings. However, no advantages were identified. Pyrite separation has the following disadvantages in the design and operation of the Crandon Project:

1) Pyrite flotation requires an acidic condition. This means that sulfuric acid use would be greatly increased and the water treatment facility would be required to remove more sulfate. The acidic condition also results in reduction of the natural pH buffering capacity of the rock;

2) Capital and operating costs would increase to separate pyrite, and water treatment capital and operating costs would also increase. A pyrite flotation circuit would have to be added to the concentrator requiring additional capital, reagents, manpower, electricity, and mill space. Furthermore, two separate backfill sand production circuits would be needed which will require more cyclones and pumps and more mill area;

3) A larger disposal area would be needed since there would be two separate ponds operating at the same time. The proposed MWDF includes development of four ponds, used sequentially, and reclaimed during the mine life. It follows that more land area would be required to construct and operate two ponds simultaneously with provisions for a tailings line and access road to each pond;

4) Both pyrite and non-pyrite tailings are potentially acid generating. The non-pyritic tailings have a sulfur content of 1.86 percent compared with 22 percent for

pyrite tailings (CSMRI, 1982) and would have the potential to produce sulfuric acid. Two separate lined tailings disposal areas would be required. The two tailings disposal areas would operate simultaneously and require two separate tailings thickeners, two tailings transport lines and pumps, and additional capital, manpower, and space;

5) Since operation of two tailings ponds would be required at all times instead of one, and would require more disposal area, more precipitation would be collected which would cause water treatment costs to increase;

6) Since disposal areas for both types of tailings would require liners, there is no incentive to produce a low-sulfur tailing which, conceivably, could go to an unlined pond area;

7) The annual consumption of sulfuric acid by the Crandon concentrator would be about 2,000 tons. This compares to a potential production of one-half million tons of acid from Crandon pyrite concentrates. The cost of building an acid plant to produce 2,000 tons of sulfuric acid per year could not be justified nor would it help with disposal of pyrite because the consumption is negligible in comparison to the available pyrite; and

8) More water treatment creates more water treatment waste for disposal.

Since the tailings disposal facilities will be lined and will be built with a seepage collection system (underdrain), there are no environmental advantages to pyrite separation as it relates to mine waste disposal. After considerable study, pyrite flotation was not found to be a viable method of disposing of pyrite, nor was pyrite found to be a valuable resource of iron and sulfur.

3.5.2.2 Other Process Alternatives

Use of Sodium Cyanide - In the recovery of copper minerals from massive ore, sodium cyanide in combination with zinc sulfate and lime is used to control and prevent the activation and premature flotation of zinc minerals which would otherwise be a contaminant in the copper-lead bulk product. It also serves to depress the flotation of pyrite. The sodium cyanide is added to the process as a zinc cyanide complex ($Zn[CN]_4^{=}$) which is formed in a mixture of sodium cyanide, zinc sulfate and lime. Hydrogen cyanide is not involved in the process. Cyanide is not required in the treatment of the stringer ore.

Researchers have been attempting to develop alternatives to sodium cyanide as a depressant or as a component of a depressant scheme. However, no reagent has been identified as a replacement for sodium cyanide. During the development of the process for treating the Crandon massive ore, many alternatives to sodium cyanide were investigated, none of which were sufficiently effective.

Sodium sulfite (Na_2SO_3) and sodium sulfide (Na_2S) were investigated as replacements for the sodium cyanide-zinc sulfate mixture. The combination of sodium cyanide-zinc sulfate allows for higher recovery of copper and lead while keeping the amounts of pyrite and sphalerite in the copper-lead rougher scavenger concentrate at a minimum.

The proposed concentrating process will utilize the lowest practical amounts of cyanide.

Heap Leaching of Tailings - Heap leaching of finely ground tailings from massive sulfide flotation is not practiced at any mining operation. Heap leaching of Crandon tailings is impractical for the following reasons:

1) Low residual metal value and complex mineralogy (i.e., locked sulfides of zinc in pyrite and non-pyritic matrices);

2) Insoluble nature of the copper, lead, and zinc remaining in the tailings; a strongly oxidizing leaching solution would be required;

3) Low permeability of the tailings which would allow for only very slow percolation rate of the leaching solution; and

4) Any solution resulting from the oxidative leaching of the tailing would be high in iron content but low in copper and zinc content; recovery of copper and zinc from this solution would be impractical.

Heap leaching is generally done on low-grade overburden removed during the open-pit mining of porphyry copper ores in the west and southwest regions of the U.S. Some of these overburden materials contain recoverable amounts of copper as mixed oxides and sulfides and, in some cases, gold. Since the overburden material consists of blasted rock (i.e., not ground to a fine size like flotation tailings), it has a permeability suitable for leaching. The Crandon Project is an entirely different situation and heap leaching to tailings is not planned.

3.5.3 Waste Rock Transport

The proposed waste rock transport system will use trucks to move mine development waste rock about 0.5 mile from the mine shaft to the preproduction ore storage area on the north side of the mine/mill site.

A conveyor system was considered as an alternative to the proposed truck transport system. Factors which were considered in the evaluation of a conveyor system for waste rock transport included: (1) waste rock volume; (2) waste rock size; (3) maintenance requirements; (4) need for a service roadway; (5) loading and handling; and (6) economic sensitivity.

Waste rock will be produced in high volumes during the initial years of mine development, ranging up to about 3,000 tons per day, but will more typically be only several hundred tons per day over most of the operating mine life. Most of the waste rock will be crushed and returned underground as mine backfill. Trucks can more readily accommodate this range; a conveyor would need to be sized for the higher volumes and then would be significantly oversized for most of the mine life.

The waste rock produced during the first 3 years of development will be about minus 24 inches in size. The remainder, over the life of the mine, will be about minus 8 inches in size. Trucks can easily handle this change in material size; conveyors would need to be designed for the larger size material.

At the preproduction ore storage pad, truck dumping will allow flexibility. Conveyors would have to be moved periodically or another means of handling the rock included.

In addition to the above disadvantages, using a conveyor for transport of waste rock from the main shaft to the preproduction ore storage pad is not operationally or economically desirable for the following reasons:

1) Use of a conveyor system may require crushing of material prior to belt loading, thus presenting schedule problems and increased front end capital;

2) All trucks and loaders would not be eliminated as some equipment would have to be purchased and used for placement of conveyed material;

3) A conveyor would still require construction of a roadway for installation and maintenance of the system; and

4) Any emission reductions realized by use of a covered conveyor system as opposed to truck haulage would be offset by increased emissions from double handling at the preproduction ore storage pad.

Emissions estimates for transport of waste rock by trucks are presented in the Air Permit Application subsection 2.2.3, Mine Waste Disposal Facility Construction and Operation. A conveyor alternative would have a total emission rate approximately equal to the total for truck haulage.

3.5.4 Storage of Preproduction Ore and Concentrate

3.5.4.1 Preproduction Ore Storage

The proposed preproduction ore storage pad will have the capacity to accommodate in excess of 800,000 tons of rock. As proposed in subsection 1.2.4.15, this storage pad will be located immediately north of the plant site (see Figure 1.2-50). The pad will be 8.0 acres in area. There will be a central ridge dividing the pad on a north-south axis and a grade of 2 percent will be maintained on the slopes away from this ridge. The pad will be bounded on the east, west and south sides by berms and drainage ditches directing runoff to surface drainage basin No. 3.

The pad and drainage basin will be lined with a bentonite-soil admixture and the drainage basin will be equipped with a sump pump to allow the water to be pumped to the tailings thickener overflow and then to the reclaim pond. This will assure that water runoff from the pad will be treated in the water treatment plant. The storage pad and drainage basin are shown on Figure 1.2-50.

The ore and waste rock will be hauled to the pad in trucks and will be reclaimed using a front-end loader. The total haul distance from the discharge near the headframe to the storage pad is approximately 0.5 mile.

Use of the northern portion of the MWDF area is an alternative for the temporary storage of preproduction ore. However, the haul distance to this area (approximately 1.5 miles) is longer than to the proposed storage area and its use for storage of preproduction ore would interfere with the development of the MWDF site. The longer haul would also contribute to increased noise and air emissions at the MWDF.

3.5.4.2 Concentrate Storage

Under normal operating procedures direct loadout of concentrates is proposed to railcars located on parallel tracks immediately north of the mill building (subsection 1.2.2.9). The anticipated availability of railcars is such that only limited storage space for concentrates has been provided. Should normal operation of the railroad be interrupted, approximately 2 days' production of zinc concentrate, 5 days' production of copper concentrate, and 19 days' production of lead concentrate can be accommodated in concrete bunkers directly below the filters.

If an extended suspension of rail service should occur, plant operations would have to be discontinued or an alternative location would be required for the storage of additional concentrates.

An alternate contingency storage location would be to use the preproduction ore storage pad. Concentrates would be placed in three individual stockpiles separated sufficiently to avoid intercontamination. Assuming a 65-foot wide roadway is maintained between the stockpiles and an angle of repose of 30°, three concentrate stockpiles, each approximately 66,000 tons, could be placed in the preproduction ore storage area. This would accommodate in excess of 75 days of mill concentrate production.

As with any contingency measure, the duration of possible concentrate storage on the preproduction ore storage pad cannot be accurately predicted. However, assuming concentrate shipments had to be curtailed and concentrates temporarily stored at this site, the length of storage time would be kept to a minimum. Stored quantities of concentrates would be shipped in approximately 2 to 3 months after normal shipping operations resumed. The concentrate would be reclaimed from temporary storage with front-end loaders and possibly trucks and loaded into railcars.

While stored on the pad, measures would be taken to prevent wind or water erosion of the concentrates. The piles would be stabilized by covering with synthetic materials or chemical sprays that would form a crust on the surface of the pile. The method of stabilization would be dependent on the size of the concentrate pile, expected duration of storage, and the availability of cover material.

As described in subsection 1.2.4.15, proposed water control facilities associated with the preproduction ore storage pad will capture any runoff and direct it into surface drainage basin No. 3. The permanent pump that is installed at this location will then transfer any collected water to the water treatment plant.

3.5.4.3 Other Uses

Because the preproduction ore storage pad will be a relatively secure site designed to minimize impacts to the environment, it will be maintained by grading the compacted surface. Additional potential uses for this pad could include equipment staging or other temporary uses.

3.5.5 Tailings Transport System

The proposed tailings transport system, as described in Chapter 1, consists of three high density polyethylene (HDPE) pipelines buried below the land surface. Alternatives consist of installing the pipelines on the land surface and installation of a second tailings transport pipeline as a backup system. A surface pipeline system could be installed on the same route as the proposed system (see subsection 3.4.2.2). The pipelines would have to be separated from the haul road by a guard rail or earthen berm to protect the lines from accidental damage from moving vehicles.

The proposed system is designed so that it can be shutdown and restarted without draining the system. Installing the pipelines below the frostline prevents freezing and plugging of the lines during shutdowns in the winter. Installation of the pipelines on the surface may require dump stations at the low spots in the pipeline route to handle emergency shutdowns. These dump stations would consist of a valve in the pipeline, controls to operate the valve, and a receptacle such as a tank or lined pond to contain the water and tailings as they drain by gravity out of the pipelines. An additional pump would be required to reintroduce the tailings and water back into the pipeline when the line is restarted and normal operation is reinstituted.

The surface installation of the pipelines has the advantage that if leaks were to develop in the lines they would be more readily apparent. The proposed system relies on pressure and flow monitoring instrumentation, as well as inspection, to indicate leakage. Buried pipelines are less subject to the effects of weather and vandalism. The land disturbance with the surface lines could be greater due to the probable requirement for dump stations.

Solid and water flow rate gage monitoring equipment would be utilized to immediately warn the plant operator of pipeline problems. These types of monitoring systems are amenable to use with surface and buried pipelines. Early leak detection capabilities would allow an orderly stoppage of tailings transport so that minimal solid quantities are in the pipeline.

For a worst-case slurry pipeline break with minimal warning, the tailings transport would be stopped and would drain to its lowest point(s). The contents of a 5,900-foot length of line could leak from the pipeline. This is equal to approximately 10,200 gallons of slurry. Because of the low elevation, the rate of leakage would be slow. Because the pipeline is buried, little solid material would escape.

Clean-up would involve excavation around the area of leakage and disposal of water and tailings solids to the MWDF. With the exception of the excavation area, there would be no other environmental effects of consequence.

The anticipated repair and/or replacement frequency has been assessed largely from manufacturers' literature and experience. In water transport service, a 50-year pipeline life might be achieved. This is well within the proposed Project life for active pipeline use of less than 30 years.

HDPE was provisionally selected as the proposed pipeline material because it has the following advantages over alternative materials, such as steel pipe, rubber-lined steel pipe or cement-lined pipe:

Resistance to Corrosion - Corrosion tests performed by PSI, Inc. (1982) indicated that corrosion rates for steel in contact with tailings slurry would be high. In contrast, HDPE is inert to a wide variety of chemicals as evidenced by corrosion tests performed by a leading manufacturer of HDPE materials. In addition, HDPE does not rot, pit, corrode, or lose wall thickness by reaction with the surrounding soil. It is unaffected by algae, bacteria, or fungi.

Abrasion Resistance - The abrasivity of the tailings slurry is low as evidenced by Miller number determinations performed by PSI, Inc. In addition, test work performed for a leading manufacturer by Williams Brothers Engineering, Tulsa, Oklahoma, compared a proprietary brand of HDPE pipe to steel in controlled pipe loop pumping tests. HDPE out performed steel by a factor of four to one.

Friction Factor - Friction pressure loss in HDPE pipe is less than pressure loss in steel or cement lined pipe. Typical "C" valves used in the "Hazen and Williams" formula for calculating pressure loss are:

HDPE Pipe	155
New Steel Pipe	140
Cast Iron Pipe	130
Concrete Pipe	120

The favorable friction factor for HDPE pipe results in lower pumping energy consumption and reduced pipeline pressure.

Fusion Welding - HDPE pipe can be installed in a continuous fusion welded line. Lined steel pipes are joined by flanged connections. A pipeline with many flanged connections is more prone to leakage than a welded line. On this basis, the unflanged fusion welded HDPE pipeline would be superior to flanged pipeline. Therefore, this review indicated that the superior corrosion and abrasion resistance exhibited by HDPE pipe and the life and reliability of HDPE pipelines can be expected to be superior to the life of pipelines fabricated from competing materials, including steel.

In addition, several recent applications of slurry pipeline transport have selected HDPE over other materials. Examples of the use of HDPE in mining industry slurry service are:

1) Pinto Valley (Miami, Arizona);
2) Lornex (Highland Valley, British Columbia);
3) Phelps Dodge (Morenci, Arizona); and
4) Inspiration Consolidated Copper Company (Miami, Arizona).

During preliminary engineering studies for the tailings transport system, a backup tailings pipeline was considered. However, based on continuing study and planning of the system a single pipeline was selected. The design and construction procedures proposed for the tailings transport system reduce the risk of an unplanned shutdown to such a low level that the additional cost of a backup system is not justified. The design and installation procedures are more comparable to an underground water transmission line installation rather than a conventional tailings transport line laid above ground. These procedures reduce the susceptibility of the tailings transport line to damage or failure. If a failure would occur, operations would be interrupted for the repair period. Repair materials will be stockpiled and procedures established prior to operations to ensure repairs are made as expeditiously as possible to minimize environmental impacts.

3.5.6 Tailings Disposal

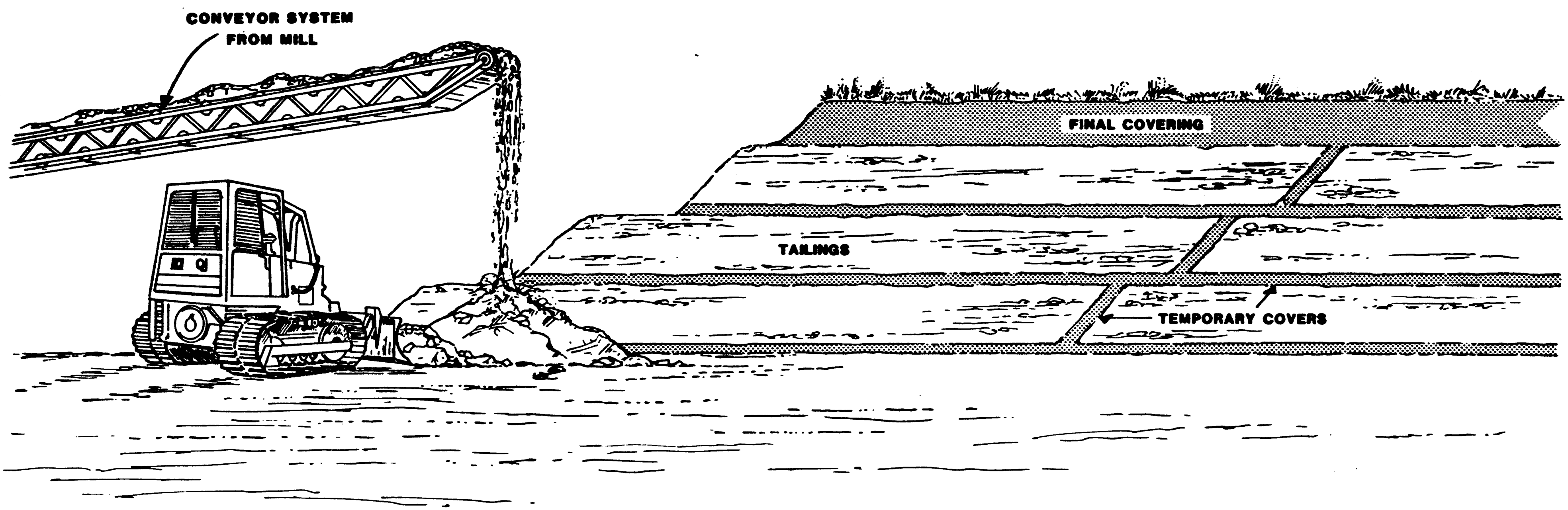
3.5.6.1 Tailings Disposal Methods

Three basic tailings disposal methods were studied for the Project: subaqueous, "dry," and subaerial. A modified subaqueous disposal (described in Chapter 1) is the proposed method for tailings deposition.

One alternative is "dry" disposal which involves dewatering the tailings to the point that they can be handled as a solid (about 15-18 percent moisture content). The main components of a "dry" disposal system include mechanical equipment to dewater the tailings and a conveyor or other transport system to move the tailings from the mine/mill area to the waste disposal facility. With a "dry" system, the disposal facility could be a landfill operation in which the tailings are stacked above ground and periodically covered with soil excavated and placed by a dragline or other equipment. Another method would be a cut-and-cover operation whereby trenches are excavated in step with tailings production and the tailings deposited and covered continuously. Operational concepts and representative layouts for both the landfill and cut-and-cover alternatives are presented on Figures 3.5-1 and 3.5-2.

There are some unknowns associated with both tailings dewatering and susceptibility of the tailings to consolidation and resaturation. The staging concepts for pond development employed in the proposed system would not eliminate the possibility of later use of "dry" disposal. Extensive field testing would be necessary to verify the applicability of a "dry" system to the Project.

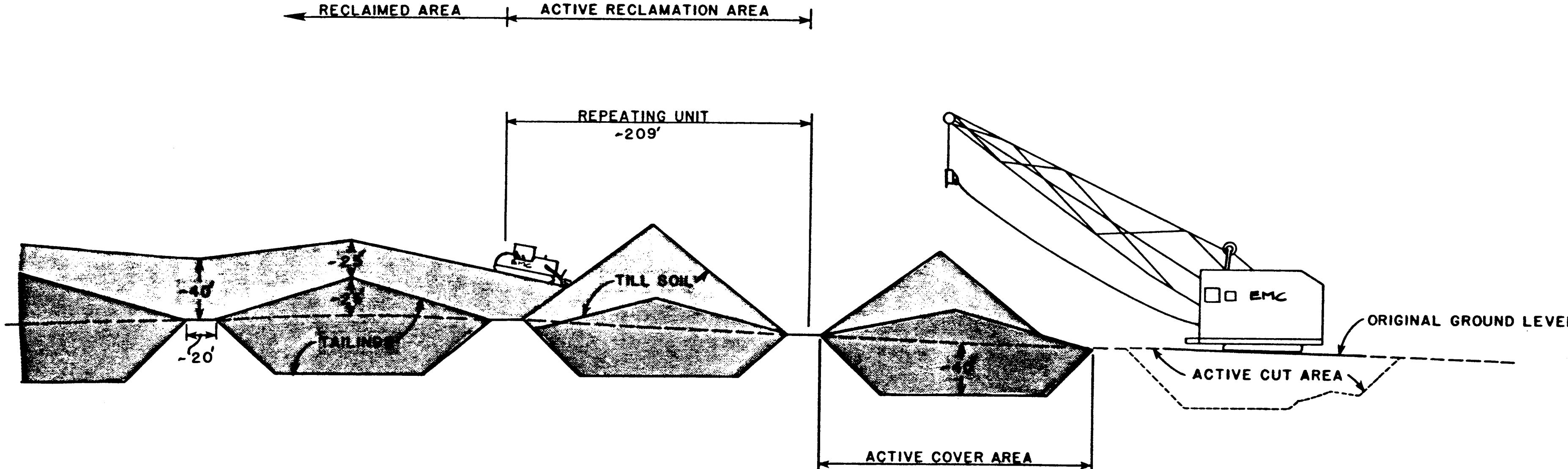
A second alternative is subaerial tailings disposal. This method should achieve greater in-place tailings densities than conventional pond disposal with possible resultant strength increases and permeability reductions through more intensive management of the tailings deposition process. The subaerial method allows tailings to dry through thin layer deposition and evaporation which enhances consolidation resulting in increased densities of about 15-20 percent. Because of the increased density of the deposited tailings, the overall size of the disposal facility would be smaller than for a conventional tailings pond. Another potential advantage to a subaerial system would be the enhanced material strengths achieved through the deposition



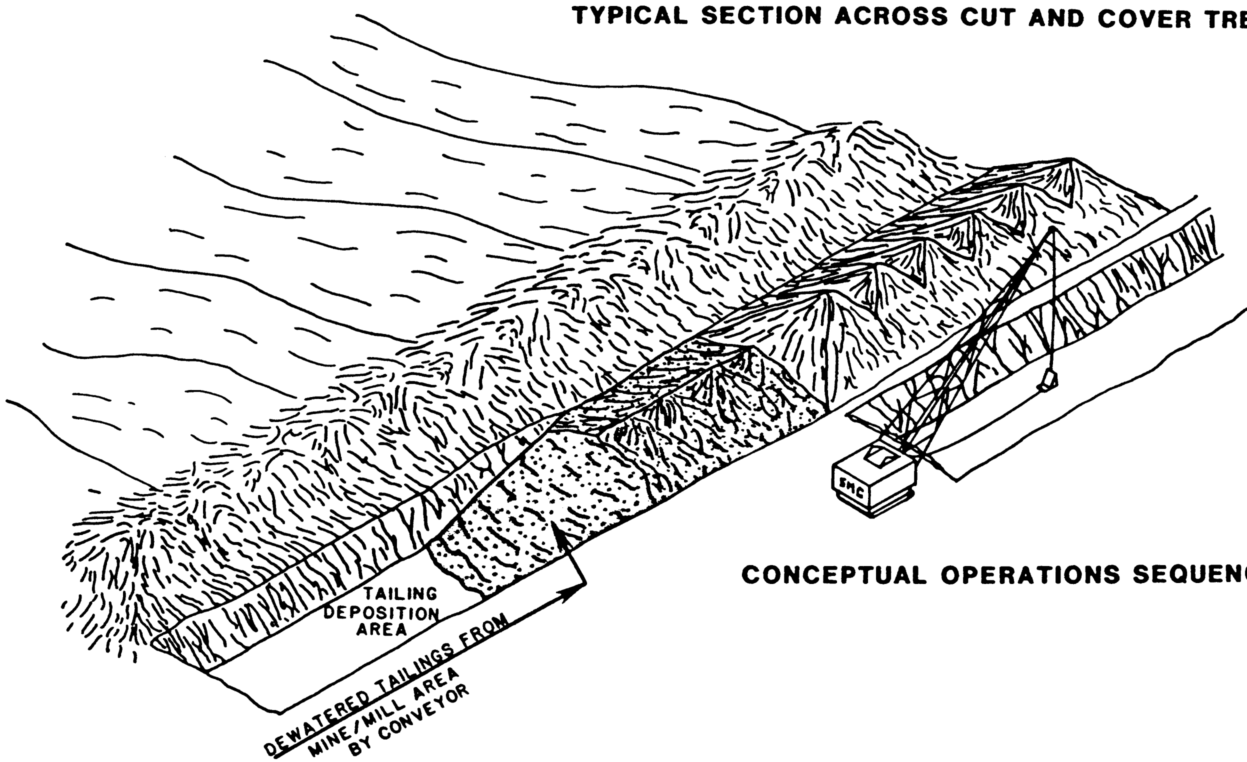
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
SOLID WASTE DISPOSAL SYSTEM
LANDFILL TYPE OPERATION

SCALE NTS	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY R. C. Dietz	DATE 8/13/82	CHECKED BY H.S. [signature]		DATE [illegible]	
APPROVED BY	DATE	APPROVED BY C.C. Schwede		DATE 11/83	
APPROVED BY	DATE	EXXON D.E. [signature]		DATE [illegible]	
DRAWING NO FIGURE 3.5-1			SHEET 1 OF 1	REVISION NO 0	



TYPICAL SECTION ACROSS CUT AND COVER TRENCHES

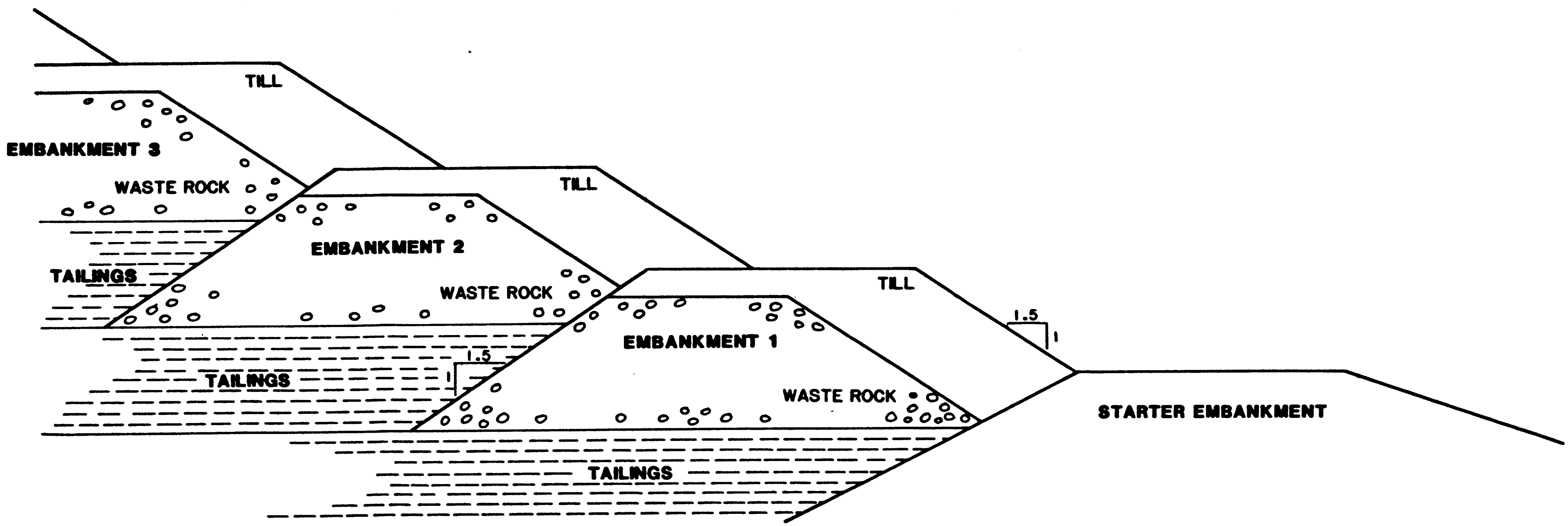


CONCEPTUAL OPERATIONS SEQUENCE

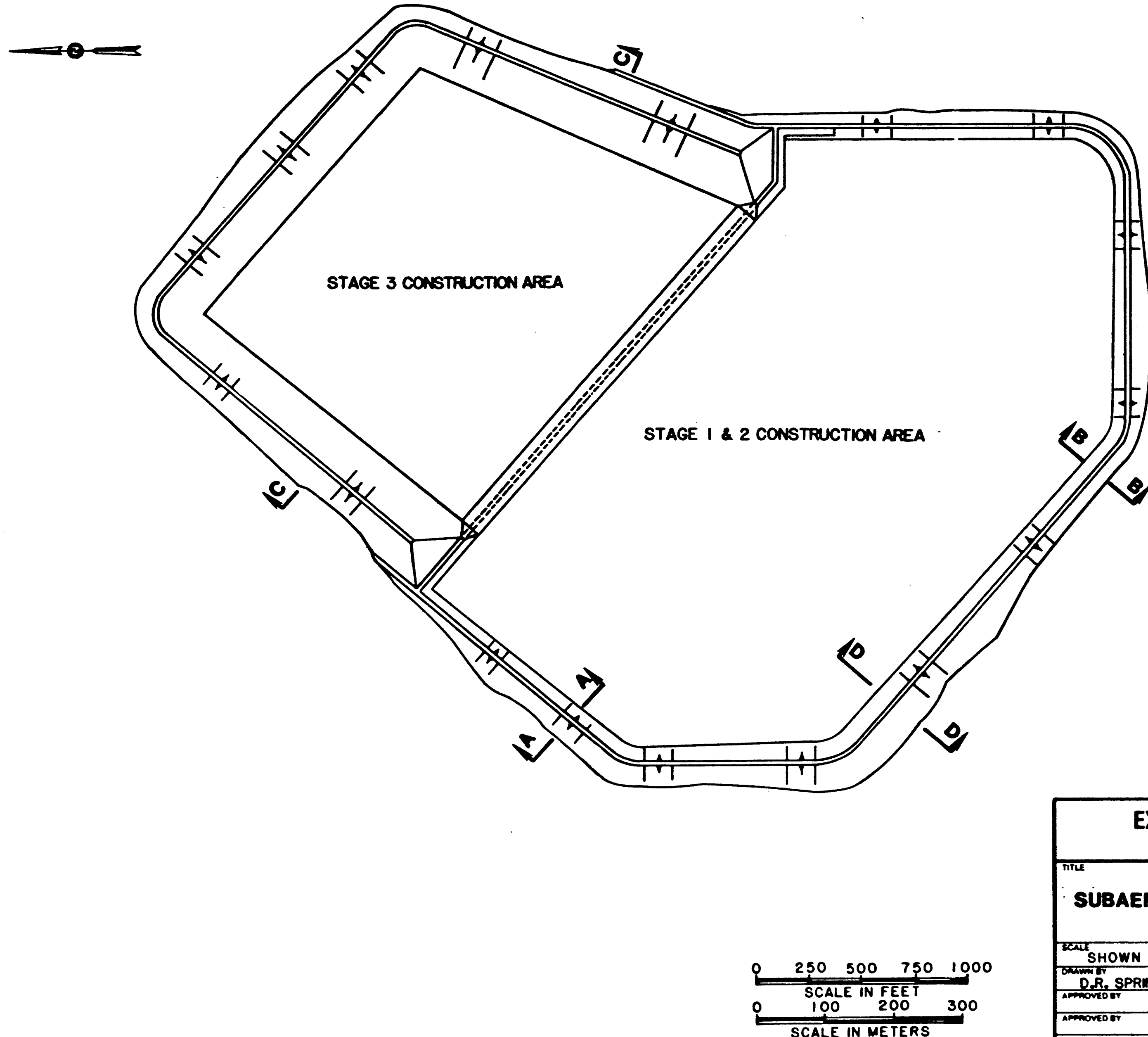
EXXON MINERALS COMPANY CRANDON PROJECT			
TITLE SOLID WASTE DISPOSAL SYSTEM CONCEPTUAL CUT AND COVER			
SCALE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY D.R.SPRINGBORN	DATE 8/82	CHECKED BY [signature]	DATE 12/8/82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/86
APPROVED BY	DATE	EXXON [signature]	DATE 11/85
DRAWING NO FIGURE 3.5-2		SHEET ___ OF ___	REVISION NO. 0

method. This allows upstream construction for a portion of the embankments (Figure 3.5-3) and, if feasible for Crandon, could reduce the earthwork volumes in those embankments. With tailings an integral part of the embankment, the overall size of the facility may be further reduced. Conceptual layout and typical embankment sections for a subaerial type system are shown on Figures 3.5-4 and 3.5-5. With a subaerial method, however, the entire subaerial facility would have to be operated for most of the mine life. A layer of tailings, about 4 inches thick, would be deposited in one area of the pond and the operation then moved to another area, while drying and consolidation began on the first area. Based on climatic conditions and the rate of tailings production, the number of areas within the facility would be planned so that upon completion of a cycle, the first area would be ready for another layer of tailings. The system would also include a seepage control system similar to that planned for the proposed system. For the subaerial system, a higher portion of water would be handled through the surface water decant system.

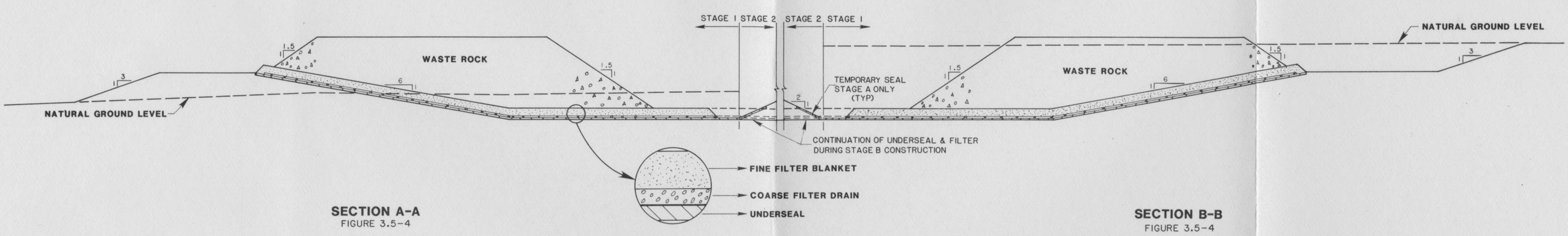
The results of preliminary design work and lab testing of subaerial tailings disposal appear encouraging (Knight and Piesold, Ltd., 1982). However, no operating experience currently exists for subaerial facilities with climatic conditions similar to northern Wisconsin. Facilities now under construction in Canada may provide the necessary operating data over the next several years to evaluate the desirability of revising the Project's waste management facility to use a subaerial system.



EXXON MINERALS COMPANY CRANDON PROJECT				
TITLE **SUBAERIAL WASTE DISPOSAL CONFINING BUNDS FOR MAIN EMBANKMENT RAISING**				
SCALE NONE	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY D.R.SPRINGBORN	DATE 8/82	CHECKED BY	DATE	
APPROVED BY	DATE	APPROVED BY C.C.Schroeder	DATE 11/86	
APPROVED BY	DATE	EXXON	DATE	
DRAWING NO **FIGURE 3.5-3**		SHEET ___ OF ___	REVISION NO 0	

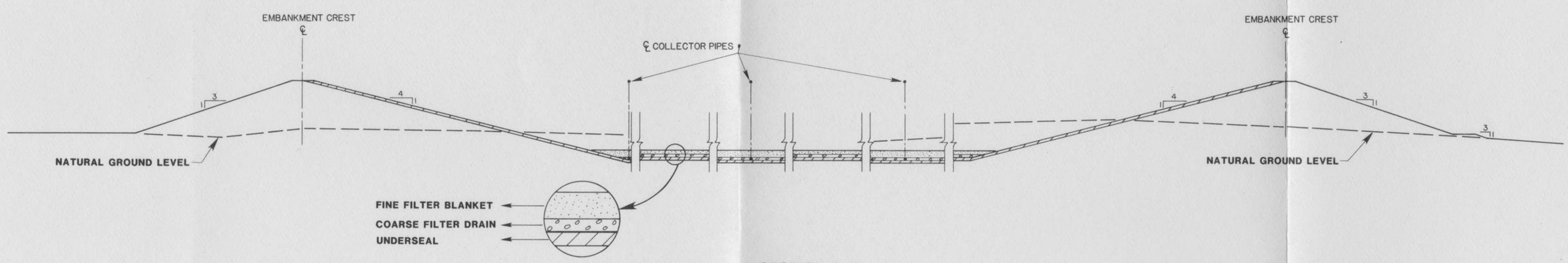


EXXON MINERALS COMPANY CRANDON PROJECT				
TITLE **SUBAERIAL WASTE DISPOSAL FACILITY PLAN VIEW**				
SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY D.R. SPRINGBORN	DATE 8/82	CHECKED BY H.S. [illegible]		DATE 12/8/82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11/85
APPROVED BY	DATE	EXXON D.E. [illegible]		DATE [illegible]
DRAWING NO **FIGURE 3.5-4**			SHEET ___ OF ___	REVISION NO. 0

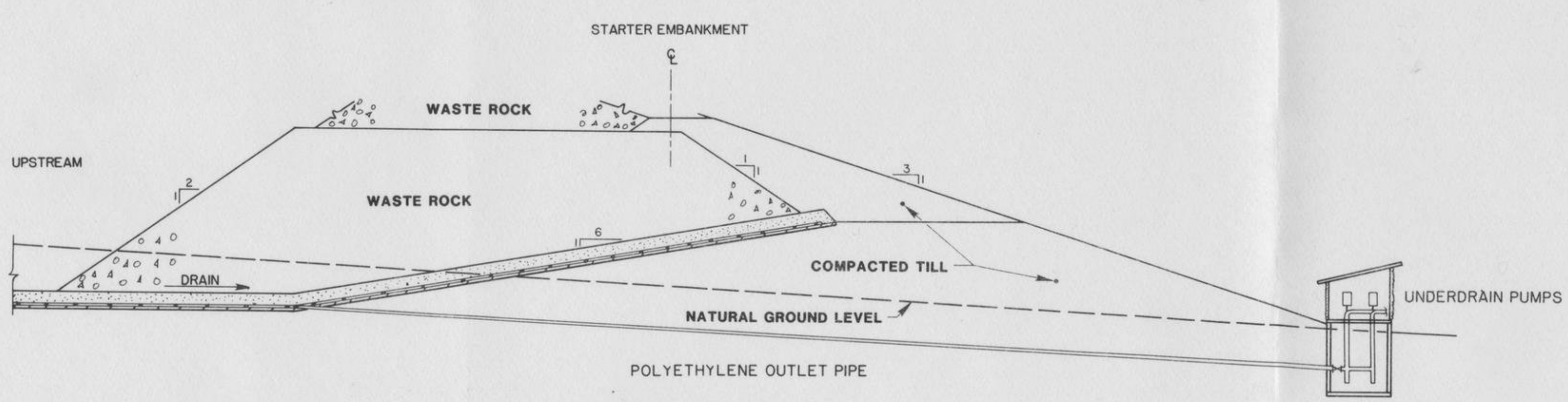


SECTION A-A
FIGURE 3.5-4

SECTION B-B
FIGURE 3.5-4



SECTION C-C
FIGURE 3.5-4



SECTION D-D
FIGURE 3.5-4

TYPICAL DETAIL OF STARTER EMBANKMENT

REVISED	DATE	BY	DESCRIPTION

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
SUBAERIAL WASTE DISPOSAL FACILITY CROSS SECTIONS

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY C.A. HACKER	DATE 12/82	CHECKED BY C. C. Schroeder	DATE 12-82		
APPROVED BY	DATE	APPROVED BY	DATE		
APPROVED BY	DATE	EXXON C. E. Fowler	DATE 8 Dec 82		
DRAWING NO	**FIGURE 3.5-5**	SHEET 1 OF 1	REVISION NO 0		

GBB 5/1981

3.5.6.2. Tailing Pond Seepage Control

3.5.6.2.1 Liner Materials

The evaluation of seepage control from the tailing ponds primarily involved the study of liner materials, including their compatibility with the waste, reliability and failure risk, permeability, cost, and installation methods; and the effectiveness of a tailings underdrain placed over the liner in reducing seepage through the liner. Studies by Golder Associates were designed to evaluate and select the most efficient and effective method of seepage control.

Four general classes of liner types were studied:

1) Native soil materials (clays or silty-clays available locally for use directly as a liner);
2) Polymeric materials (synthetic membranes);
3) Surface sealants (sprayed or paved liners such as epoxies, asphalts, or concrete); and
4) Soil additives (materials incorporated into the soil base such as cement or bentonite clay).

The results presented in the following Golder Associates' reports supported the selection process: (1) "Parametric Seepage Rate Estimates" (1982b), (2) "Underdrain Review" (1982c), (3) "Laboratory Testing Programs" (1982d), (4) "General Properties of Common Liners" (1981b), and (5) "Evaluation of Prospective Common Liners" (1981c).

The proposed seepage control system (described in Chapter 1) will consist of a bentonite modified soil liner. This system was developed based on an evaluation of the results of Golder Associates' studies and review, revision and improvement of alternatives or components of the alternatives.

The proposed underdrain system reduces the head on the liner to such a small depth that the hydraulic gradient across the liner approaches unity, and flow across the liner is then dependent upon the permeability of the liner, not thickness of the liner, and its area, as shown below:

$$Q = K\,i\,A$$

where Q = flow across the liner
K = coefficient of permeability for the liner
i = hydraulic gradient (approximately 1)
A = area of the liner.

Native clays having a permeability of 1×10^{-9} m/s are generally recommended as liner materials for solid waste disposal facilities in Wisconsin. The proposed bentonite modified soil admixture liner will be constructed to an in-place permeability of 5×10^{-10} m/s 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, is expected to be twice that across the proposed system.

In addition, native soil materials, meeting the material guidelines for liners, have not been found in required quantities within an economical haul range of the MWDF. The closest potential known sources are in the area of Goodman in Marinette County, about a 40-mile one-way haul, and Fence in Florence County. Hauling costs alone would exceed $30 million for clay material required to construct a traditional thickness lining of 5 feet. This total cost is many times that of the proposed liner material. When comparing on only a volumetric basis, the difference in cost between materials is small (less than 25 percent in favor of hauled native soil materials); therefore, native clay material offers no major benefits over the proposed system and requires borrowing and hauling large volumes of material.

Another 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 (1×10^{-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 natural clay liner, either by using the -200 sieve fraction or the material in whole, unless materials can be found with uniform permeabilities of less than 5×10^{-10} m/s.

Polymeric materials, in general, have low permeabilities and, therefore, usually make good liners. In general terms, however, pond seepage depends on liner integrity, which in turn is dependent primarily upon fabrication techniques, area required to be lined, and accidental damage. These liners typically have a manufacturer's guaranteed life in excess of 30 years, making them suitable for a reclaim pond application.

High density polyethylene and other geomembranes were reviewed by Golder Associates. It, along with Hypalon, is one of the suggested membranes for the reclaim water pond's lining system. However, for permanent disposal of wastes, the life time of polymeric materials is not adequately documented to make them suitable for liner applications.

3.5.6.2.2 Liner Performance

A discussion of alternative liner performance is provided in subsection 11.2.2.5, Seepage Rate Comparisons in the MWDF Feasibility Report. Potential underdrain failures and their effects, as well as contingency measures, are discussed in the report, entitled "Operating Aspects and Contingency Plans" by Exxon Minerals Company (1983a).

Both Golder Associates and Knight and Piesold, Ltd. utilized the concept of a drain layer over a liner as the most effective means of reducing liner seepage. The differences between the two designs (i.e., drain material soil particle sizes, incorporation of interior herringbone network of collector pipes) were not considered significant and would be subject to some minor design refinements during Plan of Operations work or during subsequent stages of pond development.

3.5.6.2.3 Liner Thickness

Thicknesses considered for the native clay soil liners have ranged up to 5 feet in general accordance with previously accepted practices for sanitary landfills in Wisconsin. However, as indicated in subsection 3.5.6.2.1, bentonite amended soil liners have more advantages than the native clay soil liner alternatives. For the bentonite amended soil liners, the thicknesses evaluated have ranged from 4 to 8 inches. As described above, with the combination underdrain and liner system, the liner thickness is not a 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 is being achieved.

A liner thickness of 6 inches was initially proposed in the EIR submitted in 1982. The final selected thickness of a minimum 8 inches has been determined through discussion and review of the initial design with the DNR. The new increased thickness liner has been selected to provide an additional measure of security and redundancy above that afforded by the initial proposal.

3.5.6.2.4 Construction Aspects

A uniform thickness of the bentonite modified soil seal can be maintained during construction of the pond liners and reclamation cap. Construction studies by INDECO (1982a), Exxon Minerals Company (1983b), Black and Veatch (1984), and Knight and Piesold, Ltd. (1984) provide general details of the necessary tolerance control in layer placement. These studies also contain a summary of details and information for similar liner and seepage control systems in other facilities. Additional details of the placement techniques to ensure attainment of the required minimum liner thickness are presented in the MWDF Feasibility Report. Complete construction specifications, inspection procedures, and total quality control/assurance plans will be a part of the Plan of Operations.

Most alternative construction techniques have centered around preparation and placement of the bentonite amended soil liner. The alternative of a mix in place liner has been 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.

The placement alternatives for the central mix prepared liner have included (1) simple hauling, dumping, and spreading and (2) hauling and placing with a paving machine. The hauling, dumping, and spreading alternative initially proposed required greater subgrade and final surface control than the final selected paving method alternative. Placement with a paver provides greater assurance of thickness control with less subgrade control. Also, with the paved 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.

The construction method for the liner/drain system includes placement of drain and filter materials atop the liner to protect it from frost, rainstorms, and equipment traffic. Daily placement of overlying drain and filter materials will also protect the liner from dessication.

A common aspect associated with both geomembrane and soil bentonite liner systems is the earth work construction control. In both systems this applies to shaping and compacting the supporting subgrade. Control of thickness and compaction is required for cushion layers which are usually constructed on top and bottom of the geomembrane liners. Similar construction control is required to develop the design thickness for a soil-bentonite liner with special attention given to material composition (percent bentonite) and compaction moisture content.

Quality assurance and control aspects of construction would have some similarities for both systems including proper thickness control and verification, minimum compaction standards, and proper material gradations. Quality control testing for liner seaming and placement, such as vacuum testing, would be unique to polymeric liner systems. Specific quality control requirements for the soil-bentonite system would include moisture-control documentation and field and laboratory verification of the design permeability. Depending on the method of construction (in-situ or batch), additional quality control procedures addressing liner composition would be performed.

3.5.6.2.5 Cost Comparisons

Cost comparisons for the seepage control alternatives were generated as components of the system were evaluated and developed. Costs of alternative liners alone have been evaluated in the previously cited Golder Associates' reports, and bentonite modified soil liner costs have been compared to native clay liner costs in a report by Exxon Minerals Company (1983c). Also, underdrain costs were developed by INDECO (1982b) when they estimated costs for the entire MWDF. For relative cost comparison of a synthetic membrane liner versus bentonite modified soil liners, cost estimates are included below. Approximate costs, as estimated by Exxon Minerals Company in the report noted above, for a 5-foot thick native clay liner are also included. 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 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:

1) Bentonite Modified Soil Seepage Control System

a. 8-inch (2 - 4-inch lifts) thick bentonite modified till liner	-	$0.55/ft^2$
b. 8-inch (average) thick underdrain layer of processed till	-	$0.22/ft^2$
c. 12-inch thick filter layer of unprocessed till	-	$0.14/ft^2$
Total cost		$0.91/ft^2$

2) Membrane Liner and Underdrain Seepage Control System

a. synthetic liner plus subgrade preparation - 40 mil polyethylene	-	$0.66/ft^2$
b. 8-inch (average) thick underdrain layer of processed till	-	$0.22/ft^2$
c. 12-inch thick filter layer of unprocessed till	-	$0.14/ft^2$
Total cost		$1.02/ft^2$

3) Native Clay Liner and Underdrain Seepage Control System

a.	5-foot thick native clay liner hauled from Fence area in Florence County	-	$4.10/ft^2$
b.	8-inch (average) thick underdrain layer of processed till	-	$0.22/ft^2$
c.	12-inch thick filter layer of unprocessed till	-	$0.14/ft^2$
	Total cost		$4.46/ft^2$

In these alternative seepage control systems the important component is the underdrain. When the underdrain performs its function of reducing the pressure head (i.e., by collection and removal of water) acting to cause seepage through the liner, then the primary factor causing seepage has been eliminated and minimal seepage will be achieved.

3.5.6.3 Mine Waste Disposal Facility Reclamation Cap

3.5.6.3.1 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).

Each alternative is described below:

Alternative 1: 36 inches glacial till underlain by a 6-inch bentonite modified soil seal layer.

Alternative 2: 36 inches glacial till underlain by an 8-inch coarse drain, in turn, underlain by a 6-inch bentonite modified soil seal layer.

Alternative 3:	28 inches glacial till underlain by an 8-inch coarse drain, in turn, underlain by a 6-inch bentonite modified soil seal layer.
Alternative 4:	5 feet glacial till underlain by an 8-inch coarse sand drain, in turn underlain by a 40 mil polyethylene membrane in turn underlain by an 8-inch (2 - 4 inch lifts) bentonite modified soil seal layer.

Alternative 4 was selected as the proposed cap design and is discussed in greater detail in the Reclamation Plan and in Ayres Associates (1984, 1985).

Geomembranes offer very low permeabilities and will reduce seepage through the cap and hence long-term MWDF steady state seepage. The membrane in conjunction with the increased thickness of the bentonite modified seal (8 inches) and the increased protective cover layer thickness (5 feet) adds significantly to the redundancy and security of the overall reclamation cap in offering maximum long-term seepage control.

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 system presented in Section 1.5 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.

For all the alternatives three climatic conditions, based on precipitation data obtained over a 42-year period at the NOAA weather station at Nicolet College, Rhinelander, Wisconsin, were used in the analysis. Average annual precipitation for the 42-year period, 30 inches, was used to represent the first climatic condition. During the period of record, precipitation totaled 18 inches in the driest year, whereas the wettest years (39.9 inches) were used to represent the second and third climatic conditions, respectively.

The water balance modeling and analysis used monthly data for each of the following parameters: potential evapotranspiration, precipitation in an average, dry and wet year, and surface runoff. Moisture available for infiltration, initial soil moisture, total available soil moisture, actual evapotranspiration, remaining available moisture and percolation were determined through the model.

For Alternative 1 as a tailings cap design, the water balance model predicted wide fluctuations in surface runoff, available soil water and percolation. For the wettest year, the 3-foot glacial till overburden would be completely saturated for a 4-month period beginning in August. The degree of overburden saturation would result in a greatly increased level of surface runoff as well as the creation of a soil environment detrimental to vegetative growth. In a year of average precipitation, an excessively dry overburden (available soil moisture below the plant wilt point) would occur during August. During the dry year, an excessively dry overburden would occur for 5 months, June to October. Total percolation through the cap to the underlying tailings was predicted at 1.6 inches in the dry and average year, and 4.5 inches in the wettest year (Table 3.5-1). The percolation in each case would normally occur in the March-May period when infiltration from snowmelt and rainfall would exceed the level of evapotranspiration occurring at that time.

Cap designs for Alternatives 2 and 3 differed from that used in Alternative 1 by the inclusion of an 8-inch thick coarse drain layer between the overburden 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 1, is similar to Alternatives 2 and 3 but improves on their performance. The increased protective layer thickness reduces surface runoff and also allows more overall soil moisture storage thereby lessening possibilities of soil drying. The synthetic membrane addition reduces a very minimal final seepage rate to a negligible amount.

TABLE 3.5-1

WATER BALANCE SUMMARY
FOR FOUR ALTERNATIVE MINE WASTE DISPOSAL FACILITY CAP CONSTRUCTION SYSTEMS

Seasonal Variation	Precipitation (inches)	Runoff (inches)	Evapotranspiration[a] (inches)	Vertical Percolation (inches)	Horizontal Percolation (inches)
Alternative 1					
Normal Year	30.0	5.0	23.4	1.6	
Dry Year	17.6	4.6	14.2	1.6	
Wet Year	40.0	12.1	22.1	4.4	
Alternative 2					
Normal Year	30.0	5.1	22.2	0.6	2.1
Dry Year	17.6	4.6	12.7	0.6	2.4
Wet Year	40.0	4.7	22.1	0.7	12.4
Alternative 3					
Normal Year	30.0	5.1	21.6	0.6	2.7
Dry Year	17.6	4.6	12.0	0.6	2.4
Wet Year	40.0	4.7	22.1	0.7	12.4
Alternative 4[b]					
Normal Year	30.0	3.0	22.1	0.7	4.3
Dry Year	17.6	2.3	13.0	0.6	4.1
Wet Year	40.0	5.9	22.1	0.7	11.3

[a]Evapotranspiration includes plant interception estimated as 20 to 30 percent of total precipitation.

[b]Values are based on a worst-case analysis assuming no seepage control from the synthetic membrane. Analysis including the synthetic membrane reduces vertical percolation to approximately zero.

Source: Owen Ayres and Associates, Inc. (1982); Ayres Associates (1984).

Data from the water balance model are presented for each of the alternative design systems and for the three climatic periods in Table 3.5-1. Alternative 1 provides greater evapotranspiration than Alternative 2. The difference in evapotranspiration between the two systems is caused by the lesser soil water storage capacity of the shallower overburden layer in Alternative 2, and hence, a lower amount of water is available for evapotranspiration. Alternative 4 with its increased overburden thickness provides additional soil moisture storage capacity and reduces surface runoff.

A comparison of percolation in Alternative 1 with the vertical percolation in Alternatives 2, 3, and 4 demonstrates the efficiency of the drainage layer in the latter system in reducing percolation to the tailings.

For the preferred alternative the reclamation cap water balance for a normal year indicates that approximately 4.3 inches of precipitation per year will move laterally through the drain layer (Ayres Associates, 1984). The purpose of the drain is to reduce infiltration through the seal and to transport water to the perimeter and cross member embankments of the MWDF. Grading of the reclamation cap (and drain layer) has been planned to distribute this water uniformly to the embankments for infiltration throughout the MWDF. For the normal year, the 4.3 inches of infiltrating precipitation being carried in the drain layer will be distributed uniformly throughout the infiltration zones constructed atop of the embankment crests. The infiltrating water will then begin to percolate through the embankment soils as it leaves the underdrain and recharge to ground water.

The coarse drain layer and membrane above and the till grading layer below the bentonite modified soil seal prevent the development of capillary pore pressures which might draw water from the bentonite modified soil seal. The water balance analysis by Ayres Associates indicated that sufficient moisture would be retained in the 5.0 feet of till cover to support the vegetation. The bentonite modified soil is similar to the glacial till soils except for permeability reduction. The soil structure mix is less susceptible to shrinkage and swelling than a high clay content soil.

An additional analysis of the reclamation cap water balance was performed by Ayres Associates (1985) to determine the effect of downsizing the MWDF area, reclamation cap regrading, and slope length changes. The results of this analysis indicated minor changes in the water balance summary presented in Table 3.5-1. The water balance results presented in Ayres Associates (1985) represent the most typical slope condition for the downsized MWDF; however, the data in Table 3.5-1 are still representative of some slope conditions that have not changed from the previous design.

3.5.6.3.2 Revegetation of the Reclamation Cap

Following final grading of the reclamation cap of each tailing pond, herbaceous vegetation, consisting of introduced and indigenous species, 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 woody plant species on reclaimed tailing pond T1, strip or block plantings of indigenous tree species are proposed over a portion of the pond. This will allow monitoring and the evaluation of performance of a relatively mature forested community on the cap before the end of the 30-year long-term care period. Tree species also will be established on subsequent tailing ponds but at lower densities and over less area than on pond T1.

The proposed reclamation cap design (Alternative 4) includes 5 feet of glacial till 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 become established on 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 would be greater for Alternatives 1, 2 and 3 than for the proposed design.

Based on the water balance analysis of the reclamation cap (Owen Ayres and Associates Inc., 1982; Ayres Associates, 1984), the alternative cap design without a drain layer (Alternative 1) would result in periods of saturated soil conditions during wet years and periods of minimal soil moisture during dry years. This fluctuation in soil moisture condition would limit species selection for revegetation to those that could withstand such fluctuations.

Alternatives 2 and 3, three layered cover systems with 36-inch and 28-inch upper till layers, respectively, would eliminate the saturated soil condition (because of the drain layer) which occurs during wet years. However, these alternatives would provide less storage of soil moisture and were considered less suitable for long-term plant species development than the proposed design. Also, the proposed alternative was judged to offer a significantly higher measure of overall reclamation cap security and safety due primarily to increased protective cover thickness.

3.5.7 Ancillary Facilities

3.5.7.1 Water Treatment Systems

Screening Process - The water treatment alternatives were developed through a series of screening steps. These provided a basis for comparing various treatment technologies and systems against the established criteria listed below:

1) Meet effluent limitations and/or standards;
2) Remove scale forming compounds;
3) Provide cost-effective treatment;
4) Use proven technology;
5) Be flexible with respect to influent water quality;
6) Remove thiosalts;
7) Remove metals;
8) Produce environmentally acceptable sludges; and
9) Produce marketable by-product, if possible.

The effluent from the water treatment system had to be of a quality that could be discharged to the environment and/or reused in the ore treatment process.

A list of 38 water treatment unit process technologies was developed from available literature for consideration. A list of these technologies is shown in Table 3.5-2. These unit processes were evaluated by comparing their performance, applicability, reliability, and cost against the criteria established for the Project as prescribed above. Based on the results of this screening evaluation, the list was

TABLE 3.5-2

ASSESSMENT OF WATER TREATMENT METHODS AND TECHNOLOGIES

PROCESS TYPE AND DESCRIPTION	STATE OF DEVELOPMENT	CAPITAL COST	O&M COST	REMOVAL EFFICIENCY: TSS	ORGANICS	METALS	CYANIDE	SULFATE	THIO SALTS	NITRATE	PHOSPHATE	OVERALL EFFLUENT QUALITY	COMMENTS
PHYSICAL/CHEMICAL SEPARATION													
FILTRATION	COMMERCIAL INSTALLATIONS	MODERATE	LOW	VERY HIGH	NIL	LOW (TSS REMOVAL)	NIL	NIL	NIL	NIL	NIL	VERY LOW TSS	SUSPENDED SOLIDS REMOVAL POLISHER
TAILING PONDS	IN GENERAL USAGE	HIGH	VERY LOW	HIGH	LOW	LOW	NIL	NEGATIVE	LOW	NIL	NIL	UNSUITABLE FOR DISCHARGE	LARGE AREA REQUIREMENTS
LIME PRECIPITATION	IN GENERAL USAGE	MODERATE	MODERATE	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	MOST COMMONLY USED METHOD FOR HEAVY METAL REMOVAL
ELECTRO-FLOTATION	COMMERCIAL INSTALLATIONS	HIGH	HIGH	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	SIMILAR TO LIME PRECIPITATION	3% SOLIDS IN FLOAT
SULFIDE PRECIPITATION													
SODIUM	COMMERCIAL INSTALLATIONS (NO MINE-MILLING)	MODERATE	MODERATE	LOW	NIL	VERY HIGH	NIL	NIL	NIL	NIL	NIL	BETTER THAN LIME PRECIPITATION	POTENTIAL H_2S
IRON	COMMERCIAL INSTALLATIONS (NO MINE-MILLING)	MODERATE	MODERATE	LOW	NIL	VERY HIGH	NIL	NIL	NIL	NIL	NIL	BETTER THAN LIME PRECIPITATION	SULFEX PROCESS
BARIUM	BENCH SCALE	MODERATE	MODERATE	LOW	NIL	VERY HIGH	NIL	NIL	NIL	NIL	NIL	BETTER THAN LIME PRECIPITATION	BARIUM SULFIDE NOT READILY AVAILABLE
CARBONATE PRECIPITATION	IN GENERAL USAGE	MODERATE	MODERATE	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	SIMILAR TO LIME PRECIPITATION
IONIC FLOTATION	BENCH SCALE	UNKNOWN	UNKNOWN	NIL	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	TIED-UP METALS ARE FLOATED
NAGAHM	COMMERCIAL FLOTATION PROCESS	UNKNOWN	UNKNOWN	HIGH	MODERATE	HIGH	NEGATIVE	UNKNOWN	UNKNOWN	NIL	NIL	HIGH CN	NOT SUITABLE FOR WASTEWATER TREATMENT
COPRECIPITATION WITH TAILINGS	IN GENERAL USAGE	MODERATE	MODERATE	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	THICKENER DESIGN WILL HAVE TO BE REVIEWED
SOLVENT EXTRACTION	THEORETICAL	UNKNOWN	UNKNOWN	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW	POOR, FURTHER TREATMENT REQUIRED	PROBABLY BETTER SUITED TO MINERAL PROCESSING THAN WASTE TREATMENT
DISSOLVED AIR FLOTATION	COMMERCIAL INSTALLATIONS	MODERATE	HIGH	VERY HIGH	UNKNOWN	LOW	NIL	NIL	NIL	NIL	NIL	FAIR	NO INSTALLATIONS FOR FROTHER REMOVAL
FERRO CYANIDE PRECIPITATION		MODERATE	MODERATE	HIGH	NIL	NIL	HIGH	NIL	NIL	NIL	NIL	PRIMARILY FOR CYANIDE REMOVAL	
ADSORPTION													
CARBON (GRANULAR)	COMMERCIAL INSTALLATIONS	VERY HIGH	HIGH	HIGH	HIGH	HIGH	NIL	NIL	NIL	NIL	NIL	HIGH (IF PROPERLY PRETREATED)	CARBON REGENERATION FACILITY REQUIRED
POWDERED ACTIVATED CARBON	COMMERCIAL INSTALLATIONS	VARIES	HIGH/VERY HIGH	HIGH	HIGH	HIGH	NIL	NIL	NIL	NIL	NIL	HIGH	APPLICABILITY QUESTIONABLE
PEAT MOSS	VERY LIMITED	HIGH	HIGH	LOW	HIGH	HIGH	UNKNOWN	NIL	UNKNOWN	NIL	NIL	LOW IN HEAVY METALS	PEAT MOSS DISPOSAL SITE REQUIRED
STARCH XANTHATE	BENCH SCALE	MODERATE	MODERATE	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	POTENTIAL BIOLOGICAL GROWTH
XANTHATED SAWDUST	BENCH SCALE	UNKNOWN	UNKNOWN	LOW	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN HEAVY METALS	POTENTIAL BIOLOGICAL GROWTH
CHEMICAL OXIDATION/REDUCTION													
CHEMICAL OXIDATION	COMMERCIAL INSTALLATIONS	MODERATE	VERY HIGH	NIL	HIGH	LOW	HIGH	NEGATIVE	HIGH	NIL	NIL	LOW C.O.D.	ONLY PRACTICAL FOR POLISHING
ALKALINE CHLORINATION	COMMERCIAL INSTALLATIONS	MODERATE	HIGH	LOW	HIGH	HIGH	VERY HIGH	NEGATIVE	HIGH	NIL	NIL	NO CN; HIGH pH	MOST COMMONLY USED METHOD FOR CYANIDE DESTRUCTION
OZONATION	COMMERCIAL INSTALLATIONS (NO MINE-MILLING)	VERY HIGH	VERY HIGH	LOW	VERY HIGH	MODERATE	VERY HIGH	NEGATIVE	HIGH	NIL	NIL	LOW C.O.D.	ONLY PRACTICAL FOR POLISHING
CARO'S ACID	THEORETICAL	MODERATE	VERY HIGH	MODERATE	VERY HIGH	LOW	UNKNOWN	NEGATIVE	HIGH	NIL	NIL	LOW C.O.D.	PERSULFURIC ACID (H_2SO_3)
H_2S REDOX	COMMERCIAL INSTALLATIONS (NO MINE-MILLING)	MODERATE	MODERATE	NIL	NIL	NIL	NIL	UNKNOWN	HIGH	NIL	NIL	LOW IN THIO SALTS	PRODUCES ELEMENTAL SULFUR
HYDROGEN PEROXIDE	COMMERCIAL INSTALLATIONS (NO MINE-MILLING)	VERY LOW	VERY HIGH	LOW	VERY HIGH	LOW	HIGH	NEGATIVE	HIGH	NIL	NIL	LOW C.O.D.	FACILITY EASILY ENLARGED
BIOLOGICAL TREATMENT													
OXIDATION PROCESSES	IN GENERAL USAGE	VARIES	HIGH	LOW	HIGH	LOW	NIL	NEGATIVE	HIGH	NIL	NIL	LOW OXYGEN DEMAND	ACTIVATED SLUDGE
RECLAIM POND	IN GENERAL USAGE	HIGH	VERY LOW	MODERATE	MODERATE	NIL	NIL	NEGATIVE	HIGH	NIL	NIL	UNSUITABLE FOR DISCHARGE	SENSITIVE TO SEASONAL CHANGES
SULFATE REDUCTION	PILOT PLANT	UNKNOWN	UNKNOWN	NIL	MODERATE	NIL	NIL	HIGH	UNKNOWN	NIL	NIL	REDUCED SO_4 LEVEL	ANAEROBIC PROCESS
AIR OXIDATION													
MECHANICAL AERATION (NO BIO ACTIVITY)	BENCH SCALE	MODERATE	LOW	NIL	NIL	NIL	NIL	NIL	LOW	NIL	NIL	VIRTUALLY UNCHANGED	INEFFECTIVE FOR MINE/MILL WASTEWATER
WET AIR OXIDATION	COMMERCIAL INSTALLATIONS	VERY HIGH	VERY HIGH	HIGH	VERY HIGH	UNKNOWN	HIGH	NEGATIVE	VERY HIGH	NIL	NIL	LOW ORGANICS/THIO SALTS	HIGH HEATING COSTS
VERTICAL TUBE REACTOR	PILOT PLANT	HIGH	HIGH	HIGH	VERY HIGH	UNKNOWN	HIGH	NEGATIVE	VERY HIGH	NIL	NIL	LOW ORGANICS/THIO SALTS	EXPERIMENTAL PROCESS
DESALINIZATION/SULFATE REMOVAL													
ION EXCHANGE (DESAL)	COMMERCIAL INSTALLATIONS	VERY HIGH	VERY HIGH	HIGH	NIL	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH TDS	LARGE VOLUMES OF SPENT REGENERANT
REVERSE OSMOSIS	COMMERCIAL INSTALLATIONS	VERY HIGH	HIGH	VERY HIGH	VERY HIGH	HIGH	HIGH	VERY HIGH	HIGH	MODERATE	VERY HIGH	VERY LOW TDS	POTENTIAL GYPSUM FOULING
ELECTRODIALYSIS	PILOT PLANT	VERY HIGH	HIGH	NIL	HIGH	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	VERY LOW TDS	POTENTIAL GYPSUM FOULING
VAPOR COMPRESSION EVAPORATION	COMMERCIAL INSTALLATIONS	HIGH	HIGH	VERY HIGH	LOW	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH QUALITY	HIGH TDS BRINE PRODUCED
SODIUM ALUMINATE	BENCH SCALE	HIGH	HIGH	LOW	NIL	HIGH	NIL	HIGH	UNKNOWN	NIL	NIL	HIGH TDS	PRESENCE OF Fe DEPRESSES SO_4 REMOVAL
FLYASH TREATMENT	THEORETICAL	MODERATE	MODERATE	LOW	NIL	HIGH	NIL	UNKNOWN	NIL	NIL	NIL	LOW IN HEAVY METALS	UNTESTED, UNPROVEN
ION EXCHANGE (CATION/Ca REMOVAL)	COMMERCIAL INSTALLATIONS	VERY HIGH	VERY HIGH	HIGH	NIL	HIGH	NIL	NIL	NIL	NIL	NIL	LOW IN ALL CATIONS	LARGE VOLUMES OF SPENT REGENERANT

SOURCE: BASED ON CH2M HILL 1982

reduced to 19 available unit process technologies for further consideration in development of a water treatment system. The screening evaluation resulted in 12 of these unit processes being incorporated directly into water treatment systems, three were used elsewhere in the overall water management scheme, and four were unsuitable. A detailed discussion of the original screening evaluation and characteristics of each unit process is presented in CH2M Hill (1982).

Subsequent to that screening study, other processes were evaluated in an effort to provide cost-effective treatment systems that would meet the selection criteria.

An extensive literature review was conducted to document the performance capabilities of each of the selected water treatment technologies. This information was used to develop effect matrices for the water use computer model. The effect matrices are mathematical models which describe the performance capability of each water treatment technology. Further discussion of the preparation of these effect matrices is presented in CH2M Hill (1982).

Thirteen water treatment systems were ultimately selected and evaluated for potential use in the Crandon Project. These systems used various combinations of the unit processes found acceptable in the screening evaluations; for example, water treatment Alternative No. 1 consists of lime precipitation, filtration and pH adjustment.

Computer model runs were completed on 10 of the systems to determine their overall effectiveness and efficiency. Additional water treatment testing was undertaken in 1984 after discussions with the DNR. Three other treatment systems (sodium sulfide, starch xanthate and ion exchange) were identified as part of this work for a total of 13 systems that were evaluated. The performance capabilities, coupled with effluent qualities and cost, and the results of the water treatment testing programs provided the basis for selecting the proposed water treatment systems discussed in Chapter 1. Simplified block flow diagrams for these 13 systems are shown on Figure 3.5-6.

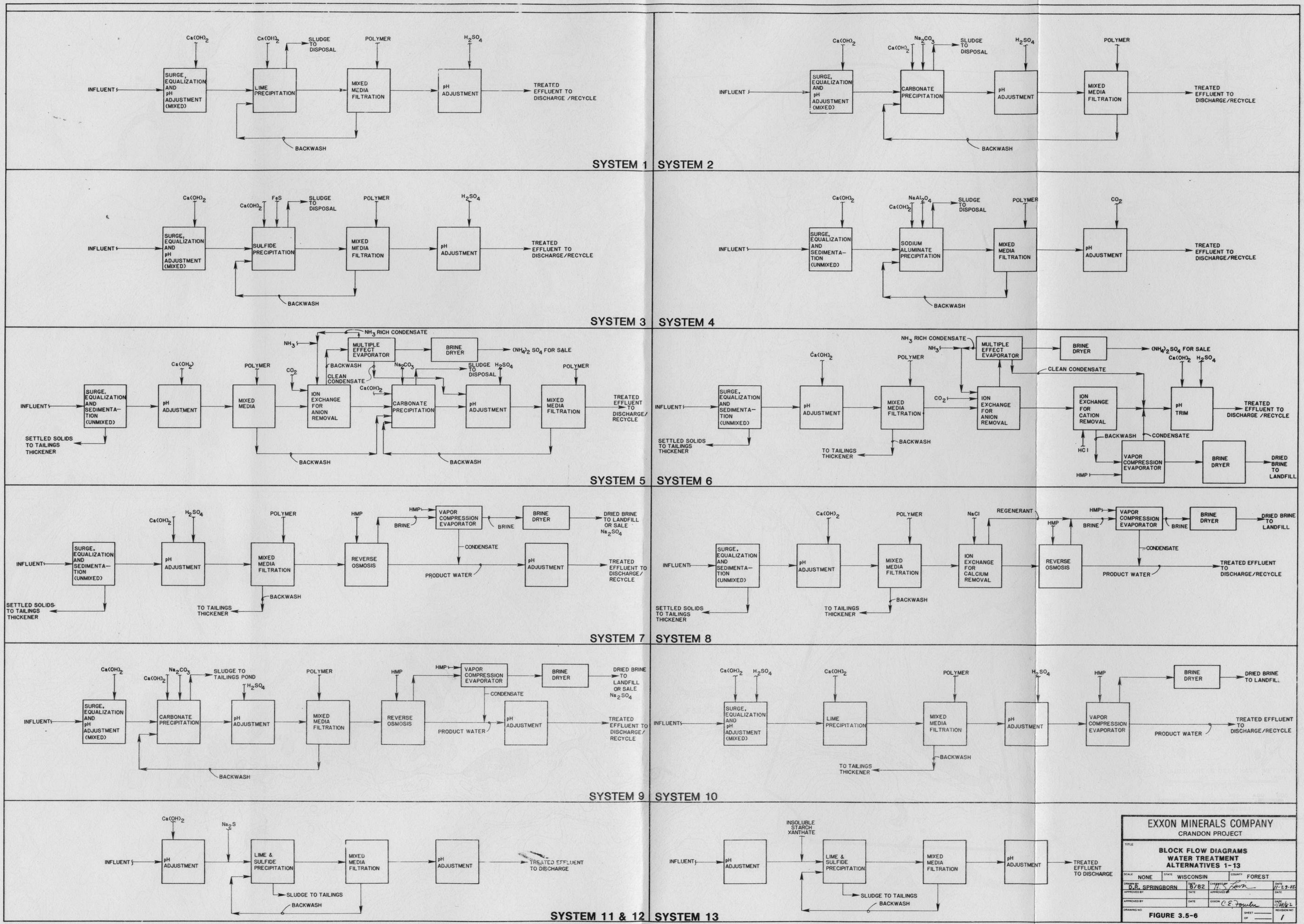
A constraint on the water treatment system selection and development was the lack of definitive effluent limits for water discharge. The final selection of the proposed treatment processes was based on the effluent limits promulgated by the DNR in 1984.

Alternative Systems System 1, Lime Precipitation/Filtration/pH Adjustment, is defined by the U.S. EPA to be state-of-the-art technology for treatment of mine/mill water and was used to develop BATEA regulations (U.S. EPA, 1982a). Some mine seepage water, depending on its quality, volume, and point of interception, could be potentially treated by this type of system. While it is the least costly treatment system considered if all process water were to flow through it, the following factors are also important:

1) The system may not be able to meet final DNR water quality effluent limits;

2) The system would not remove either calcium or sulfate, and therefore, could not be used to control scaling in the mill process; and

3) The system would not remove thiosalts, and thereby may create the need for some "add-on" unit operation during winter months.



SYSTEM 1
INFLUENT
Ca(OH)2
SURGE, EQUALIZATION AND pH ADJUSTMENT (MIXED)
Ca(OH)2
SLUDGE TO DISPOSAL
LIME PRECIPITATION
POLYMER
MIXED MEDIA FILTRATION
H2SO4
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE /RECYCLE
BACKWASH
SYSTEM 2
INFLUENT
Ca(OH)2
SURGE, EQUALIZATION AND pH ADJUSTMENT (MIXED)
Ca(OH)2
Na2CO3
SLUDGE TO DISPOSAL
CARBONATE PRECIPITATION
H2SO4
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
TREATED EFFLUENT TO DISCHARGE/RECYCLE
BACKWASH
SYSTEM 3
INFLUENT
Ca(OH)2
SURGE, EQUALIZATION AND pH ADJUSTMENT (MIXED)
Ca(OH)2
FeS
SLUDGE TO DISPOSAL
SULFIDE PRECIPITATION
POLYMER
MIXED MEDIA FILTRATION
H2SO4
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE/RECYCLE
BACKWASH
SYSTEM 4
INFLUENT
Ca(OH)2
SURGE, EQUALIZATION AND SEDIMENTA-TION (UNMIXED)
Ca(OH)2
NaAlO4
SLUDGE TO DISPOSAL
SODIUM ALUMINATE PRECIPITATION
POLYMER
MIXED MEDIA FILTRATION
CO2
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE/RECYCLE
BACKWASH
SYSTEM 5
INFLUENT
SURGE, EQUALIZATION AND SEDIMENTA-TION (UNMIXED)
SETTLED SOLIDS TO TAILINGS THICKENER
Ca(OH)2
pH ADJUSTMENT
POLYMER
MIXED MEDIA
NH3
NH3 RICH CONDENSATE
MULTIPLE EFFECT EVAPORATOR
BRINE DRYER
(NH4)2 SO4 FOR SALE
BACKWASH
CO2
CLEAN CONDENSATE
ION EXCHANGE FOR ANION REMOVAL
Na2CO3
Ca(OH)2
CARBONATE PRECIPITATION
SLUDGE TO DISPOSAL
H2SO4
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
TREATED EFFLUENT TO DISCHARGE/ RECYCLE
BACKWASH
BACKWASH
SYSTEM 6
INFLUENT
SURGE, EQUALIZATION AND SEDIMENTA-TION (UNMIXED)
SETTLED SOLIDS TO TAILINGS THICKENER
Ca(OH)2
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
TO TAILINGS THICKENER
BACKWASH
NH3 RICH CONDENSATE
NH3
MULTIPLE EFFECT EVAPORATOR
BRINE DRYER
(NH4)2SO4 FOR SALE
CO2
ION EXCHANGE FOR ANION REMOVAL
CLEAN CONDENSATE
ION EXCHANGE FOR CATION REMOVAL
Ca(OH)2
H2SO4
pH TRIM
TREATED EFFLUENT TO DISCHARGE /RECYCLE
BACKWASH
CONDENSATE
HCl
HMP
VAPOR COMPRESSION EVAPORATOR
BRINE DRYER
DRIED BRINE TO LANDFILL
SYSTEM 7
INFLUENT
SURGE, EQUALIZATION AND SEDIMENTA-TION (UNMIXED)
SETTLED SOLIDS TO TAILINGS THICKENER
Ca(OH)2
H2SO4
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
TO TAILINGS THICKENER
BACKWASH
HMP
REVERSE OSMOSIS
HMP
BRINE
VAPOR COMPRESSION EVAPORATOR
BRINE
BRINE DRYER
DRIED BRINE TO LANDFILL OR SALE Na2SO4
CONDENSATE
PRODUCT WATER
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE/ RECYCLE
SYSTEM 8
INFLUENT
SURGE, EQUALIZATION AND SEDIMENTA-TION (UNMIXED)
SETTLED SOLIDS TO TAILINGS THICKENER
Ca(OH)2
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
TO TAILINGS THICKENER
BACKWASH
NaCl
ION EXCHANGE FOR CALCIUM REMOVAL
REGENERANT
HMP
REVERSE OSMOSIS
HMP
BRINE
VAPOR COMPRESSION EVAPORATOR
BRINE
BRINE DRYER
DRIED BRINE TO LANDFILL
CONDENSATE
PRODUCT WATER
TREATED EFFLUENT TO DISCHARGE/RECYCLE
SYSTEM 9
INFLUENT
Ca(OH)2
SURGE, EQUALIZATION AND pH ADJUSTMENT (MIXED)
Ca(OH)2
Na2CO3
SLUDGE TO TAILINGS POND
CARBONATE PRECIPITATION
H2SO4
pH ADJUSTMENT
POLYMER
MIXED MEDIA FILTRATION
BACKWASH
HMP
REVERSE OSMOSIS
HMP
VAPOR COMPRESSION EVAPORATOR
BRINE DRYER
DRIED BRINE TO LANDFILL OR SALE Na2SO4
CONDENSATE
PRODUCT WATER
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE/ RECYCLE
SYSTEM 10
INFLUENT
Ca(OH)2
H2SO4
SURGE, EQUALIZATION AND pH ADJUSTMENT (MIXED)
Ca(OH)2
LIME PRECIPITATION
POLYMER
MIXED MEDIA FILTRATION
TO TAILINGS THICKENER
BACKWASH
H2SO4
pH ADJUSTMENT
HMP
VAPOR COMPRESSION EVAPORATOR
BRINE DRYER
DRIED BRINE TO LANDFILL
PRODUCT WATER
TREATED EFFLUENT TO DISCHARGE/RECYCLE
SYSTEM 11 & 12
INFLUENT
Ca(OH)2
pH ADJUSTMENT
Na2S
LIME & SULFIDE PRECIPITATION
SLUDGE TO TAILINGS
MIXED MEDIA FILTRATION
BACKWASH
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE
SYSTEM 13
INFLUENT
pH ADJUSTMENT
INSOLUBLE STARCH XANTHATE
LIME & SULFIDE PRECIPITATION
SLUDGE TO TAILINGS
MIXED MEDIA FILTRATION
BACKWASH
pH ADJUSTMENT
TREATED EFFLUENT TO DISCHARGE
EXXON MINERALS COMPANY
CRANDON PROJECT
BLOCK FLOW DIAGRAMS WATER TREATMENT ALTERNATIVES 1-13
NONE
WISCONSIN
FOREST
D.R. SPRINGBORN
8/82
FIGURE 3.5-6
1

Alternative System 1 was refined by Exxon in the 1984 testwork into systems 11, 12, and 13. System 11 is the proposed system for treating mine and ground water for discharge.

System 2, Carbonate Precipitation/pH Adjustment/Filtration; System 3, Sulfide Precipitation/Filtration/pH Adjustment; System 4, Sodium Aluminate Precipitation/Filtration/pH Adjustment; and System 5, Filtration/Ion Exchange-Anion Removal/Carbonate Precipitation/pH Adjustment/Filtration could not meet the criteria of compliance with EPA drinking water standards and were consequently removed from further consideration. Additional information for these and other systems is available in CH2M Hill (1982). Subsequent to this screening evaluation, sulfide precipitation in conjunction with lime precipitation was found to be an acceptable treatment.

System 6, Sedimentation/Filtration/Ion Exchange-Anion Removal/Ion Exchange-Cation Removal/pH Adjustment, was technically unsuitable because of its unreliability and adverse economic impacts for this project. Dual bed ion exchange, while in widespread use to "polish" or demineralize relatively clean water streams, has few full-scale applications on raw effluents. Operating problems could be experienced with high concentrations of iron, calcium, and/or solids in the mine seepage water or raw influent, and possible thiosalt fouling of the anion exchange resins. These uncertainties negated further consideration of this system.

System 7, Sedimentation/Filtration/Reverse Osmosis/Vapor Compression Evaporation, should meet all screening criteria water quality standards based on projected influent water quality; however, the system is not sufficiently flexible to adequately treat water with contaminant levels higher than projected. In addition, the capital cost of this system is considerably higher than the previous six systems. Like System 6, high concentrations of iron, solids, and/or hydrocarbons in the mine seepage water or raw influent could cause operating problems. High concentrations of iron in the mine seepage water could cause fouling of the reverse osmosis (RO) unit membranes. High concentrations of colloidal solids, which would not settle in a simple sedimentation basin, could cause rapid clogging of the mixed media filtration unit. If calcium and sulfate concentrations are higher than anticipated in the raw influent, the achievable recovery of clean water during RO would be less than projected. If this were to occur, the capacity of the vapor compression evaporation unit would be too small to handle higher volumes of RO brine.

System 8, Sedimentation/Filtration/Ion Exchange-Calcium Removal/ Reverse Osmosis/Vapor Compression Evaporation, was designed to eliminate the operating uncertainties associated with System 7. A sodium-based ion exchange system has been added upstream from the RO unit to remove most of the calcium from solution. While this system does reduce the potential problems associated with calcium and sulfate, the operational uncertainties associated with higher than projected concentrations of iron or organics are similar to those in System 7.

System 8 is inflexible with respect to influent water quality and therefore, not suitable for installation in the Project. This system has not been used for raw effluents, but only in water "polishing" applications where influent water was already of high quality.

System 9, Carbonate Precipitation/pH Adjustment/Filtration/ Reverse Osmosis/Vapor Compression Evaporation, is the proposed system for treating reclaim water for mill uses and is described in Chapter 1.

System 10 employs lime precipitation, filtration, and vapor compression evaporation as an alternative to the proposed water treatment system. As shown on Figure 3.5-6, influent water enters a surge tank where pH adjustment occurs via addition of either calcium hydroxide or sulfuric acid. Water then passes through the lime precipitation unit where calcium hydroxide is added to form and settle insoluble metal hydroxides. Water leaving the lime precipitation unit will flow either through a pH adjustment system first, or directly to a mixed media filtration unit. Filtering media trap the very small particles which are, at intervals, removed by backwashing the filtration unit and piped to a tailings thickener. Filtered water then enters a vapor compression evaporation (VCE) unit where the water is evaporated with recirculating product stream producing a concentrated brine stream and a clean condensate stream suitable for reuse within the mill or for discharge to the environment. A scale inhibitor prevents scaling within the VCE unit. Clean effluent is recirculated to the mill as make-up water to the maximum extent possible. The concentrated brine is passed through a brine dryer which vaporizes the water, leaving a dried brine comprised primarily of calcium sulfate. This system is the least sensitive to variations in influent water quality and would produce an extremely high quality effluent. Both capital and operating costs for this system would be considerably higher than that for the proposed system with no marketable by-product.

System 11, Lime Precipitation/Sulfide Precipitation/Filtration/pH Adjustment, is a refinement of Alternative System 1 and is the proposed system for treating contaminated mine water and intercepted ground water for discharge. This system is described in Chapter 1.

System 12, Lime Precipitation/Starch Xanthate Treatment/Filtration/pH Adjustment, is another refinement of Alternative System 1. It is similar to System 11 which is described in Chapter 1, with the exception that starch xanthate is added to the clarifier as a polishing step in lime precipitation. This system is as effective on contaminated mine water or intercepted ground water as the proposed System 11. It has a higher operating cost (more expensive reagent) than sulfide precipitation and was therefore not selected as the proposed system.

The equipment needed for starch xanthate treatment consists of reagent feeders which are a minimal capital cost. For this reason, System 12 can be activated on short notice as a backup for System 11.

System 13, Carbonate and Sulfide Precipitation/Filtration/pH Adjustment, is a refinement of System 2 and could function as a backup for System 11 or 12.

Subsequent to the study of these 13 water treatment alternatives, slurry seeded reverse osmosis (SRO) was investigated as an alternative to conventional RO. SRO has the potential to eliminate RO pretreatment (lime-soda softening and filtration) and RO post-treatment (vapor compression evaporation [VCE] and sodium sulfate crystallization). This would result in a greatly simplified system.

This can be done with SRO since it can operate under gypsum saturation conditions, whereas these conditions must be avoided in conventional RO. This limitation on conventional RO is why the extensive pretreatment and post-treatment are required. The recycle of gypsum seeds, as well as the type of RO module used, prevents gypsum from scaling on the SRO module walls.

Although SRO is a new process, it actually uses standard equipment in a new application. It uses tubular RO membranes which are the oldest type of RO membranes. An SRO module can be converted to conventional RO.

SRO has the following potential advantages:

1) Lowers plant capital cost;

2) Lower operating cost; and

3) Decreases the number of unit operation in the water treatment plant.

However, SRO has been tested only at the pilot scale. Because there are no commercial installations of SRO, it has not been included in the current design. When this technology is further advanced, it may be evaluated in greater detail as an alternative to conventional RO.

3.5.7.2 Excess Water Storage

The use of two holding lagoons with a total capacity of 3.4 million gallons is the selected alternative for the retention of treated intercepted ground water and treated contaminated mine water prior to discharge. Treated mine and ground water would mix and be retained in the excess discharge lagoons to permit completion of quality test work prior to discharge to Swamp Creek. These lagoons (operating in series) will have a total retention time of approximately 48 hours at average flow rates and 24 hours at maximum flow rates.

The use of lagoons will permit the retention of greater volumes of water than what is practical with tanks. This will help to level out quality fluctuations and will also allow more time for remedial action to be taken to improve the quality of the discharge if this is found to be necessary.

The use of tanks to hold excess discharge water was originally considered for this purpose, but has been rejected because lagoons are less costly on a dollar per gallon retention basis for larger volumes of water.

3.5.7.3 Fire Water Storage Facility

The present plant design includes a 500,000-gallon steel tank to hold water for fire protection. This steel tank will be located in the water tank area just west of the tailings thickener. The level in this tank will be maintained from the excess discharge lagoons located just east of the tailings thickener. These lagoons have a total capacity of 3.4 million gallons. As an alternative, these lagoons might be used to serve both purposes of discharge lagoons and fire water tanks, thus eliminating the fire water tank. It is recognized that this would necessitate designing the system to assure a sufficient supply of fire protection water.

3.5.7.4 Excess Water Discharge Methods

Treated contaminated mine water and treated ground water from the inteceptor system will be discharged to Swamp Creek as one stream. If the intercepted ground water does not require treatment, it could be discharged to a wetland system or several systems, or directly to a nearby lake or lakes, or returned to the ground water system. These alternatives are discussed below. The process water could be discharged, after treatment, as previously discussed in Chapter 1.

Computer simulation of the effects of mining operations on the surface water systems indicates that the potential for measurable impacts is small.

Surface Discharge - The proposed method of discharging excess treated water from the Project site is by pipeline to Swamp Creek downstream from County Trunk Highway M. The pipeline length from the Project site to the point of discharge is approximately 6.1 miles.

An alternative to surface discharge into Swamp Creek would be surface discharge into a lake. Regulations permit discharge into a stream to utilize, where possible, 25 percent of the cross-sectional area or volume of water flow of the stream (not to extend more than 50 percent of the width) as a mixing zone. However, the discharge mixing zone into a lake is limited to 10 percent of a lake's total surface area (Wis. Admin. Code). Although there are lakes in the regional study area for which larger mixing zones would be available than Swamp Creek, lake water in the site area is generally softer than water in Swamp Creek (e.g., 16 mg/l $CaCO_3$ in Little Sand Lake versus 100 mg/l $CaCO_3$ in Swamp Creek). In general, the toxicity of metals to most aquatic life is inversely proportional to water hardness (U.S. EPA, 1975). Effluent limitations for a lake discharge, therefore, could be correspondingly lower than for Swamp Creek.

Wetlands have increasingly been considered viable alternative wastewater treatment systems. The use of wetlands in U.S. EPA Region V for the discharge and treatment of wastewater is relatively common and is expected to increase. Currently, 96 wetlands in Region V, mostly cattail marshes, receive wastewater discharge. The majority of these are in Wisconsin and Minnesota (Kadlec, 1981).

Wetlands for treating wastewaters have been used for small and large scale applications in Europe and the United States (U.S. EPA, 1982b). Wetlands such as marshes, swamps and upland vegetative systems have been shown to remove pollutants even from treated wastewaters. The development of wetlands for surface runoff treatment has been especially easy to justify because of accessory benefits to communities such as recreation, wildlife and fishing enhancement, recharge of ground water, and water quality renovation (U.S. EPA, 1982b).

Advanced or tertiary treatment of wastewater involves the removal of minute quantities of dissolved and suspended materials, organic materials, and biological organisms. Wetlands have a mixture of terrestrial and aquatic ecosystem functions. The hydrological cycle is the most important factor in maintaining the functional characteristics of wetlands. Water generally moves through a wetland at a slow rate. As a result, long retention times for water in the wetland allow deposition of suspended solids, adsorption of dissolved substances, and biochemical utilization of others.

Treatment provided by wetlands includes adsorption of dissolved nutrients (P, N) on soil surfaces. Bacterial action, such as denitrification, also occurs at these soil surfaces as well as utilization by plants of these nutrients. Wetland soils and plants are also important for the sorption of metals, many organic chemicals, such as phenols, and agricultural pesticides (Kadlec, 1981). Hydrocarbon compounds have been known to be utilized in wetlands in very short time periods (1 month) (Kadlec, 1981). In most instances, the additional water and nutrients from a wastewater discharge enable greater plant growth and more productive habitats.

The use of wetlands as polishing units in wastewater treatment is also cost-effective. Total phosphorus, BOD, and suspended solid loadings have been reduced by more than 95 percent during passage through a wetland without additional treatment equipment (Kadlec, 1981).

Data are available from some wetland systems which have established hydrological and constituent balances and assessed the pollutant removal capabilities for these ecosystems (U.S. EPA, 1982b). Examples can be found in New York, Minnesota and Michigan among others. However, further research needs to be conducted on long-term impacts to wetlands including bioaccumulation of trace metals and the interaction of individual pollutant removal mechanisms in various wetland systems. As a result, only preliminary discussions are presented herein regarding such factors as sensitivity of wetlands to hydrological changes, metals and their potential accumulation in soil, and organic loading. Similarly water quality standards for a wetland discharge would need to consider these factors.

Ground Water Discharge - Three alternative methods which involve discharge to ground water were also evaluated. These included infiltration basins, well injection, and a drain field. The ability to discharge to ground water would eliminate the need for a pipeline to Swamp Creek and would provide a possible mitigation technique for maintenance of the current hydrological conditions in the area. Some advantages and disadvantages of various methods of ground water discharge are discussed in the following paragraphs.

Infiltration Basins - Successful operation of an infiltration basin is dependent on its location with respect to local hydrogeological conditions. For example, the soil must be permeable enough to accept the volume of water to be discharged, but not allow it to rise into the pond. The aquifer below the pond must have sufficiently high transmissivity to allow lateral movement of the discharge water. A major problem with infiltration basins is a reduction in infiltration rate caused by an accumulation of sediment and other fine material in the bottom and sides of the basin. Clogging caused by growth of algae and bacteria may also occur and cause reduction of the infiltration rate.

Injection Wells - Injection wells are constructed like pumping wells with careful attention given to grouting of the well to avoid leakage around the casing and subsequent seepage to the surface. The discharge rate from injection wells can be reduced by clogging processes similar to those associated with infiltration basins. However, clogging can be controlled by water jetting, air surging, and chemical cleaning to remove bacterial growth and encrustation products.

Drain Field - Excess water could be discharged via a drain field system, such as that utilized with a sanitary septic system. A drain field would be subject to the same operating conditions as those cited above for the infiltration basin.

3.5.7.5 Water Treatment Waste Disposal

3.5.7.5.1 Temporary Disposal of Lime Precipitation Sludge

The water treatment plant is scheduled for completion in month 17 of construction. However, the first tailing pond would not be ready for use until month 29 and, therefore, a storage area for water treatment sludge would be required between months 17 and 29.

Four alternative facilities were evaluated for use in storing water treatment sludge:

1) A separate polyethylene-lined holding pond;
2) A temporary holding tank;
3) A temporary diked area within reclaim pond cell A; and
4) Permanent storage in reclaim pond cell A.

As proposed in Chapter 1, the water treatment sludge will be stored in cell A of the reclaim pond between months 17 and 29.

Because of the low projected mine inflow during months 18 through 30, it is expected that all of the mine drainage for this period can be contained in one cell of the reclaim pond. The water treatment facility will be operated for performance testing during this period, but current projections indicate that water will not have to be routinely treated for discharge. The sludge, which is produced from either water treatment plant shake-down testing or from treatment of relatively small volumes of water for discharge, will be permanently stored in cell A of the reclaim pond. There would be a small volume of sludge produced and it would have essentially the same composition as the sludge produced by pH adjustment between cells B and A in the reclaim pond. No separate sludge containment area within the reclaim pond is planned.

The proposed storage area for water treatment sludge will be less costly than the other alternatives and will not require any additional land disturbance.

3.5.7.5.2 Long-Term Disposal of Water Treatment Wastes

The water treatment facility will produce two waste products. One will be a by-product from the two lime-soda ash softening steps. This material will be primarily calcium carbonate and it will be disposed with the mill tailings to utilize the acid neutralizing capacity of the carbonate-bearing sludge.

The other waste product from the treatment facility results from the evaporative treatment of the brine generated in the reverse osmosis process. This product will be essentially sodium sulfate which, according to a limited marketing study, has potential use to Kraft paper mills in Wisconsin. Currently, sodium sulfate consumption by paper mills in Wisconsin is about 31 tons per day; the expected production of this material at the Crandon Project is 11 tons per day or 300 cubic feet per day. Other potential uses for the product include detergent manufacture and glass making. As the Project develops, more definitive studies will be made to firmly identify potential markets for this product.

If the sodium sulfate waste product cannot be marketed, alternative methods of disposal will have to be used. These include impoundment in a secure landfill, either off-site or on-site. On-site disposal could be accomplished by placing the material in a separately bermed area in one of the tailing ponds. This would be done in a manner that would prevent mixing of the sodium sulfate with the tailings.

Disposal of 300 cubic feet per day of sodium sulfate in a bermed portion of a tailing pond would require 3.2×10^6 cubic feet of space for a mine life of 29 years (assuming the water treatment plant operates for 29 years). This total volume of sodium sulfate represents less than 4 percent of the storage capacity of tailing pond T1 (8.6×10^7 cubic feet) or a fraction of 1 percent of the total storage capacity of the four ponds. Thus, the size of the tailing ponds should not require any modifications to include sodium sulfate disposal.

The sodium sulfate for disposal would be removed from the covered storage bunker at the water treatment plant with a front-end loader and transferred to a dump truck for transportation to the MWDF. The sodium sulfate would need to be covered progressively as it is dumped into the tailing pond. Sodium sulfate is water soluble and its disposal in the separate bermed area in the tailing pond may require a synthetic liner to hydrostatically isolate it from the water in the tailings and in the underdrain system.

3.5.7.6 Solid Waste

An on-site solid waste disposal facility is proposed for disposal of non-potentially hazardous Project waste and refuse. Potentially hazardous waste will be disposed off-site in an approved licensed facility. Additional detail for the mine refuse disposal facility (MRDF) is included in Chapter 1 and in the MRDF Feasibility Report.

As an alternative to an on-site facility, consideration was given to the disposal of all refuse and waste in an off-site facility. Among the facilities that were evaluated for off-site disposal the City of Antigo landfill was considered most feasible because of its capacity and more favorable location.

The main reasons for proposing an on-site disposal facility rather than an off-site facility are: (1) current and future availability of off-site disposal facilities is not a certainty, and (2) based on economics alone, an on-site facility is more cost effective than hauling to an off-site facility, and with expected increasingly higher off-site disposal costs it probably will improve further in the future.

3.5.7.7 Sanitary Waste Treatment

The Phase II Water Management Report by CH2M Hill for the Crandon Project was completed in January 1981. This report included an evaluation of three process alternatives for treating sanitary wastes. The alternatives were:

1) Septic tank system with soil absorption field;

2) Rotating biological contactor and clarifier between the septic tank and soil absorption field; and

3) Extended aeration and activated sludge between the tank and final absorption.

In the CH2M Hill Phase II study the septic tank system was initially selected. However, based on additional study of system performance, cost, space requirements, and associated impacts, it has been determined that a package wastewater treatment plant is a better alternative than a septic tank and soil absorption field, and as described in Chapter 1, is the proposed system for treating sanitary wastes. The package treatment plant will require a land area of approximately 0.1 acre, whereas the septic tank and absorption field and replacement field would require approximately 2.5 acres.

Alternative 1 to the proposed design is a septic system consisting of two 2,425-cubic foot rectangular septic tanks in series followed by a 1.24-acre soil absorption field. The soil absorption field has a complete replacement field and the septic tanks include a dosing chamber. The septic tank was designed by CH2M Hill in 1983. The soil absorption field was designed and engineered by STS Consultants, Ltd. (1984) and is described in their report entitled "Soils Report for Soil Absorption Field, Exxon Minerals Company, Crandon Project."

Alternative 2 includes disposal of the effluent from the treatment plant to spray irrigation or a seepage cell. Because of the short growing season, cold temperatures, and small volume of the effluent, the spray irrigation system would not be effective on a year round basis.

The discharge to a surface seepage cell would be subject to freezing in the winter rendering it ineffective. Even an underground seepage cell would require soils preparation similar to that for a leaching field for a septic system. The seepage cell would impact the environment in much the same way as the septic system. Consequently, alternative 2 offers little advantage over the proposed system or alternative 1.

3.5.7.8 Mine Air Heating and Energy Conservation

3.5.7.8.1 Mine Air Heating

During the winter months at Crandon, it will be necessary to heat a portion of the fresh air entering the main production shaft. The objectives are to prevent ice build-up and freezing of shaft utilities, and to condition the mine air for a more comfortable underground working environment. Air in the main production and hoisting shaft will be maintained at not less than 40°F.

Four major methods for supplying the required air stream heat were evaluated:

1) Direct-fired air heaters in which the heat and gaseous products of combustion mix directly with the air stream passing through the heater.

2) Direct-fired heat exchangers in which the combustion is contained and the heat transferred to the air stream by contact with the combustion chamber surfaces.

3) Indirect heat exchangers in which the air stream is heated by passing coils containing a circulating fluid warmed by a remote heat source.

4) Electric heaters in which the air stream is heated as it flows over energized elements.

Direct-fired natural gas air heaters have been selected for principal mine air heating service at the Crandon Mine. The advantages of such a system include:

1) Excellent control of temperature and energy consumption over a wide range of intake air temperatures; turn-down ratio ranges from 45:1 to 5:1 maximum.

2) Higher efficiency, approximately 90 percent, and thus lower energy costs.

3) Simple construction requiring minimum maintenance.

4) Lower first cost for the size of units required at Crandon.

A design day minimum temperature of -25°F was selected based on weather data from Laona, Wisconsin, for the period December 1966 through February 1976. The maximum operating period mine ventilation volume will be approximately 850,000 cubic feet per minute. About 60 M BTU/hour will be required to adequately heat the mine intake air on a design day. Air heating equipment utilization will vary widely, not only with temperature, but with the dynamics of required mine ventilation quantities during different periods of mine operation.

During the course of Project design, several sources of supplemental heat with possible application for intake air heating have been identified. These include:

1) Mine exhaust air expected to exit at an average temperature of approximately 55°F;

2) Mine drainage water expected to exit the mine at average temperatures of 50-60°F; and

3) Waste heat from mine/plant air compressor cooling.

At some underground mines, it has been practical to capture such waste heat sources for secondary use. The Crandon Mine plan excludes these sources from the principal design, but has recognized their potential application to developing mine operations. A study by Bovay Engineering, Inc. (1977) identified four systems for mine exhaust air heat exchange, including recirculating glycol methods, a refrigeration type cycle, and a direct air to air plate-type exchanger. The study also included an evaluation of heat recovery from ground water pumped through coils in the intake air shaft.

Unfortunately, the Crandon Mine will not have some of the special features that have allowed supplemental waste heat usage to be practical and effective at other mines. For example, it has been estimated (S. A. Scott & Company, 1978) that the exhaust air streams might theoretically contain up to 30 percent of the heat required for intake air heating. However, the exhaust air raises are at distances of 1,000 to 3,500 feet from the main shaft air intake, limiting the potential efficiency and practicality of a waste heat transfer system (recirculating glycol-coil exchange type). Exhaust air to intake air heat exchange is, of course, most likely feasible when the intake and exhaust air openings are adjacent to one another on the surface.

Water pumped from the Crandon Mine at assumed designed rates of up to 2,250 gallons per minute will contain some potentially recoverable heat; however, use of this heat must be evaluated in consideration of the desired water treatment plant entry temperature. Supplemental heat recovery systems at other mines have been most successful where mine water temperatures are considerably higher (90°F) than those expected at Crandon (50°F).

The waste heat from mine/plant compressor cooling may have the best potential for supplemental waste heat recovery. This source is relatively close to the air intake shaft, and an indirect recirculating glycol system might supply 1-2 percent of the required maximum intake air heating demand. Waste heat recovery from this source may be considered during final engineering.

Finally, the Crandon Mine plan and environmental setting will preclude the use of any intake air heating schemes based on ice formation underground. There will be no cave area or large near surface open stopes. Not only is the mine geometry and extraction sequence inappropriate, but the subsequent summer melting of stope ice would adversely impact the mine drainage and water treatment facilities functions.

3.5.7.8.2 Surface Plant Energy Conservation

Based on an average minimum design day temperature of -14°F, most surface facilities will require heating during the winter months. Peak demand has been estimated to be approximately 9 M BTU/h. Only the compressor plant will be self-heating during winter and will, as mentioned in the previous subsection, also be a source of potentially recoverable waste heat. Final engineering evaluation of this excess heat source may show it more practically used to supplement nearby surface facilities heating demands than converted for mine intake air heating use. Potential surface uses might include heating of the pump house or main shaft collar house.

The mine/plant final design will incorporate energy management as a primary objective toward cost effective project operation. Identified waste heat sources such as those discussed in subsection 3.5.7.8.1 will be re-examined for feasibility and applied for supplemental heating where practicable. Northern Wisconsin's climatological conditions are such that there are no current plans to include industrial scale solar techniques as a part of final mine/plant design.

3.5.8 Energy Sources

3.5.8.1 Fossil Fuels

The major use of heating fuel for the Project is the mine air heating system during the winter months. An average yearly usage of 73,324 thousand standard cubic feet of natural gas is required to meet this load. In addition to natural gas, propane and #2 distillage were evaluated as alternatives.

Both propane and #2 distillate would require a minimum of 5 days storage on-site, about 350,000 gallons of propane or 250,000 gallons of #2 distillate. The railcar traffic required to service the tanks during the extreme winter months would be greater than that needed for concentrate shipment.

The alternative fuels are not as efficient as natural gas and would require the use of additional land. The permit for a #2 distillate installation might be difficult to obtain; the NO_x

emissions, in particular, would be very close to allowable limits for an indirect fired fuel heater.

While propane is only about 5 percent less efficient than natural gas for mine heating, the need to store approximately 350,000 gallons of propane on the site and operate an evaporator and expansion tank makes it less desirable than natural gas. In addition, using propane would require unloading about two to three tank cars a day. The risk of a problem during the unloading process, while minimal, would still be present.

Use of propane as a fuel for mobile vehicles was evaluated as an alternative to gasoline or diesel fuel. However, most of the mobile equipment utilized for the Project is located underground. The MSHA regulations (Title 30 CFR Part 55 and 57) require the underground equipment to be electric or diesel driven and fitted with a scrubbing system. With the exception of light trucks and 3-5 automobiles, few surface equipment items can use propane fuel. Propane use would be less than 125 gallons per day equivalent of gasoline. This change would not ultimately affect the overall air emissions and their minor contributions would not alter the air quality or provide a problem in meeting standards.

As an alternative to the use of diesel fuel, the emergency generator system could be converted to natural gas. However, the existing natural gas pipeline at Crandon is only marginally adequate to support the present system load for the City of Crandon area and the proposed mine/mill site requirements at 100 percent capacity on a maximum cold day even without the emergency generators. To ensure service of the emergency generators, diesel fuel use would be required even with natural gas provisions. In addition, the generators will operate only approximately 30 minutes a week and when power interruptions occur during the operational phase.

In addition to the above energy alternatives, heating some of the buildings with wood-fired heaters or boilers has been considered. Currently, the alternative of heating with wood is not being pursued; however, it could become viable in the future depending on the costs and availability of other fuels.

3.5.8.2 Electrical

The use of a lower voltage power line (69 kV versus 115 kV) was addressed in the "Application for Authority to Construct 115,000 volt Transmission Line Venus to Exxon X-76" (Wisconsin Public Service Corporation, 1982). The CPCN Application indicates that the 69 kV alternative would cost approximately 35 percent more than the 115 kV project. The major differences in costs for the 69 kV power line are larger conductors (447 kcm for 115 kV versus 795 kcm for 69 kV) and the requirement to add a 115 kV/69 transformer at the Venus substation.

The use of self-generation was considered for some or all of the operating load requirements. However, it was not considered viable from economic or environmental standpoints. The need for process steam is minimal (i.e., building heating) and, therefore, a steam system with waste heat recovery is not practical. Environmental impacts associated with NO_x and TSP concentrations from a plant fired with coal or wood chips also would have to be considered. There also would be potential environmental impacts from fly ash disposal facilities. The use of the diesel generators or natural gas turbines on a continuous basis would increase NO_x and TSP emissions. In addition, the natural gas pipeline could not provide sufficient gas for a 10-20 mW plant without an expansion of the pipeline system from Laona to Crandon. This expansion would also have impacts.

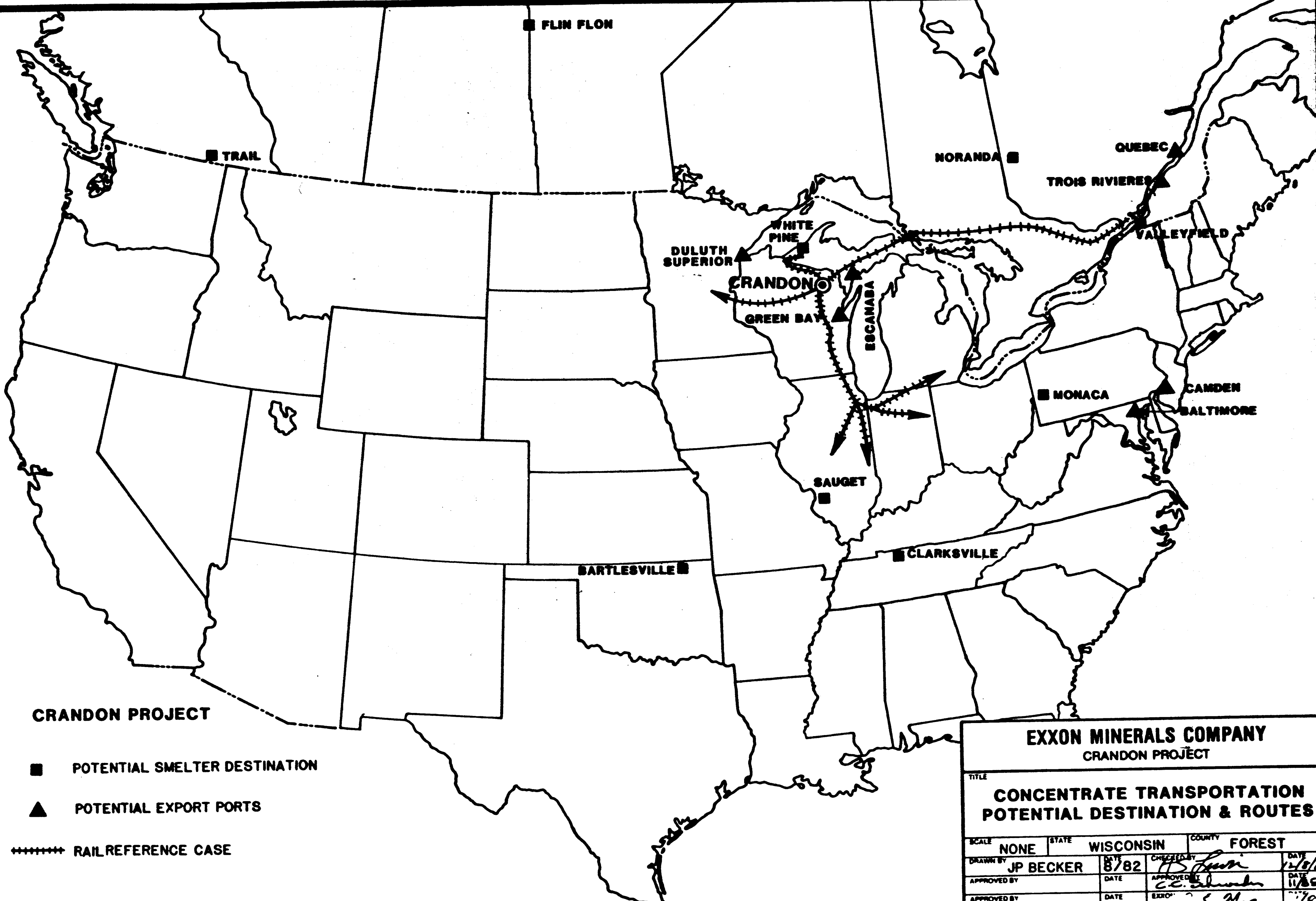
3.6 CONCENTRATE TRANSPORT

Transportation plays a key role in the overall economics of relatively low value, high volume materials, such as ore concentrates. Although the Crandon deposit is somewhat isolated, it is located near a good quality rail line and there are a number of transportation options after the product leaves the Crandon area.

Steady-state or point-to-point scenario transport of concentrates has not been determined for the Project; therefore, flexibility in loading and storage at the shipping point will be necessary to accommodate demands of various customers under different market conditions.

Crandon concentrates will be sold to various smelter/refineries, preferentially in the U.S. or Canada, to the extent these facilities can absorb Crandon production without upsetting their commercial requirements. Since the customers may vary from year to year, no steady state transport scenario is practical or realistic for the Project.

Transportation Modes and Directions, Continental Destinations - With the possible exception of short distance movements by truck to local Great Lakes ports or to the White Pine, Michigan, smelting facility, outbound shipments would be originated by the Soo Line Railroad. The Soo Line will be capable of transporting concentrates from the Project within the existing capacity in their daily freight trains passing Crandon. Potential destinations and routes for shipment of concentrates are shown on Figure 3.6-1. Amounts of concentrate to be produced and the approximate number of railcars required for concentrate shipment are presented in subsection 1.4.3.3.



CRANDON PROJECT

■ POTENTIAL SMELTER DESTINATION

▲ POTENTIAL EXPORT PORTS

+++++++ RAIL REFERENCE CASE

EXXON MINERALS COMPANY CRANDON PROJECT					
TITLE **CONCENTRATE TRANSPORTATION POTENTIAL DESTINATION & ROUTES**					
SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY JP BECKER	DATE 8/82	CHECKED BY [signature]		DATE 12/8/82	
APPROVED BY	DATE	APPROVED BY C.C. [signature]		DATE 11/85	
APPROVED BY	DATE	EXXON [signature]		DATE 11/85	
DRAWING NO	FIGURE 3.6-1		SHEET 1 OF 1		REVISION NO. 0

Shipments to western Canadian refineries would be transferred to Canadian railroads at border points. For destinations south or east of Crandon, the Soo Line Railroad would transfer the traffic to other railroads at Chicago. For destinations in eastern Canada, transport would either be via Sault Ste. Marie, Michigan, or via Chicago, depending upon the routing decision of the involved railroads.

All United States and Canadian refinery destinations suggested by the preliminary marketing strategy can be directly served by rail. Although opportunities exist for joint rail-water movements, in most cases the handling and storage charges at transfer points would make rail-water movements more expensive than direct rail transport.

Transport Modes and Directions, Overseas Export Destinations - To the extent export shipments are necessary to economically place Crandon concentrates, one or more of a variety of export routes and systems may be employed. Selection among these alternatives will depend on the expected volume of the movement, the duration of export, contracts, the export destination, and competitive factors which can be expected to change during the Project life.

Any of the various export shipment alternatives involves the use of established third part stevedoring and transportation companies. It is not foreseen that the Project would operate its own export terminal, be it in Wisconsin or elsewhere.

Export shipments will leave the Project site by rail in the same manner as continental shipments described in subsection 1.4.3.3. The concentrate will be unloaded and temporarily stored at a ship-loading terminal until an adequate parcel of 5,000-25,000 tons is accumulated. Parcel sizes will be determined by which of the three concentrates is shipped, customer requirements, and shipping economics.

Smaller parcels will be shipped as part cargoes on general purpose ocean-going vessels or on bulk cargo vessels. Larger parcels will be shipped as full cargo loadings on bulk cargo vessels.

There are a number of potential export terminal sites in the U.S. and Canada which are under evaluation:

1) Trois Rivieres, Quebec - This St. Lawrence River port currently handles a variety of concentrates, similar to Crandon's, on all-weather, year-around basis. This port is suggested as a preliminary reference case at this stage of development of the Project.

2) Quebec City, Quebec - This port is comparable to and competitive with Trois Rivieres. Any decision between Quebec City and Trois Rivieres would be on the basis of rates and service at the time an export movement materializes.

3) Duluth, Minnesota/Superior, Wisconsin/Green Bay, Wisconsin - These cities have existing general bulk storage and terminal facilities operated by recognized operating companies. These general operations are in addition to taconite, pellet and grain operations in the area. Concentrates are not routinely handled at present, although chrome concentrate is currently moving through Duluth and, historically, iron ore concentrate has been handled there. These ports, as other Great Lakes ports, suffer an important economic debit due to the limited 7 1/2 month overseas shipping season. The port at Green Bay poses an additional economic disadvantage because of its relatively shallow channel.

4) A variety of possibilities exist to expand or adapt various privately-owned bulk terminal operations, and to integrate Project concentrate movements. Integrations would involve sharing dock and some handling or loading facilities at:

    a) Inland Steel Company's limestone operations at Port Inland, Michigan; or

    b) C&NWRR taconite, pellet terminal at Escanaba, Michigan; or

    c) Burlington Northern taconite pellet terminal at Superior, Wisconsin; or

    d) A coal facilitiy at Escanaba, Michigan, currently operated by C. Reiss Coal Company

In general, these facilities would require greater initial capital outlays by the third-party operations than would integration into an existing general bulk operation. Such a commitment would likely require through-put assurances from the Project. If and when sustained export movements appear practical and economic, then these alternatives could become realistic.

3.7 FINAL USE ALTERNATIVES FOR FACILITIES/RECLAIMED MINE DEVELOPMENT AREA

Upon closure of the Crandon Project, Exxon Minerals Company proposes to remove all above ground Project facilities and reclaim the mine development area (see Section 1.5). This action will be taken if no alternative use(s) of the facilities proves to be beneficial at the time of Project closure. Alternative uses for the Project facilities are described in subsection 3.7.1 and alternative final uses for the reclaimed mine development land in subsection 3.7.2.

3.7.1 Project Facilities

3.7.1.1 Sale or Lease of Milling Facility for Future Producer

After closure of the Crandon Mine the Project facilities would be tendered for other beneficial uses prior to inaugurating demolition and final site reclamation. Planning for such uses should occur as early as possible so as to provide appropriate execution time. In addition to basic plant facilities, some equipment might also be utilized.

The first use to be considered should be that of concentrating ores from other deposits which might be found and developed during the period in which mining occurs at Crandon. If ores are owned by independent parties and the Project facilities at closure are not otherwise economically utilizable by Exxon, the alternative of sale or lease of specific Crandon facilities for use in the concentrating of their ores would be considered on economic merits. In that event, plans for use of the facilities would be included in that applicant's EIR and related documents.

3.7.1.2 Light Industrial Uses

Because of the time between now and the closure of the Crandon Mine (Project Year 32), the future use of facilities beyond the mine life is conjectural. Office and shop facilities, warehouses, power transformation equipment, and basic shop equipment as well as the access road and railroad spur may cause considerable segments of the plant to be of interest for business purposes other than mining. Use of the facilities as an industrial complex following Project closure was recommended by representatives of the Towns of Lincoln and Nashville during a meeting with Exxon Minerals Company and the DNR in August 1984. If such a use proves to be feasible for all or part of the Project facilities prior to removal of the facilities and reclamation of the land, an amended Reclamation Plan containing a description of the new proposed use could be submitted to the DNR in accordance with NR 132.12(3)(a).

The existence of substantial facilities at Crandon may result in overcoming inherent disadvantages of location for mining related industries. Such disadvantages when compared to centers such as Wausau, Green Bay, and Milwaukee suburbs include transporation cost and potential lack of diversified skilled labor. Labor, however, may not be a disadvantage because of the skilled mining labor force available upon closure of the Crandon Project.

Plant facilities of key interest for light industrial uses would be shops, warehouses, fuel storage, power transmission, water treatment, office complex and railroad. Technology uses would probably require shops, warehouses, and office complex facilities, as well as road access.

Table 3.7-1 lists some specific types of industries which might be interested in locating in the Crandon area if facilities were available.

3.7.1.3 Radioactive Waste Repository

Upon termination of Project operations, the underground mine workings will not be suitable for a radioactive waste repository. Information is presented below on the U.S. Department of Energy's (DOE) programs to identify potential repository sites and the reasons the Crandon Mine will be unsuitable for such a facility.

The U.S. Department of Energy's Office of Crystalline Repository Development (OCRD) has "identified three regions of crystalline rock exhibiting potential for locating repository sites and recommended these regions for further study" (OCRD Geologic Characterization Report, May 1983, p. 5). The North Central Region includes Minnesota, Wisconsin, and the Upper Peninsula of Michigan. Crystalline rocks are defined as "intrusive igneous and high-grade metamorphic rocks rich in silicate minerals, with a grain size sufficiently coarse that individual mineral grains can be distinguished with the unaided eye" (ibid. p. 1). No other rock types are being considered in the North Central Region because "the Department of Energy's (DOE) program emphasized disposal in mined repositories deep underground in geologically stable formations" (ibid, p. ix) and crystalline rocks are the only rock types which meet those guidelines.

Two factors eliminate the Project's facilities from consideration as a high level nuclear waste repository.

TABLE 3.7-1

POST-MINING POTENTIAL INDUSTRIAL AND TECHNOLOGICAL USES OF CRANDON FACILITIES

Light Industrial

Manufacturing
Small Boats
Plastic Components
Machine Tools
Machine Parts (turning, milling, forging, stamping)
Electronic Assembly
Cabinet Manufacture
Sash and Mill Work
Auto Engine Rebuilding

Technology

Paper Research
Forest Product Research
Computer Software Design
Bio-Medical Research
Genetic Engineering

First, the deposit is not located in crystalline rock. The OCRD Report (ibid. Plate 2) identifies and locates all bodies of crystalline rock in Wisconsin. The two bodies of crystalline rock nearest the Crandon deposit lie approximately 10 miles to the south and southeast.

The second factor which eliminates the Crandon facilities from consideration is the DOE guideline emphasizing that "mined repositories" (ibid. p. ix) must be built and designed specifically for a high level Nuclear Waste Repository. This is further emphasized in the OCRD report, Section 1.3 (ibid. p. 6) which states "The Crystalline Rock Project is just beginning conceptual design studies, and a conceptual design is expected to be completed by 1985. The repository will be subject to NRC Construction, authorization, and licensing."

In addition, late in July 1983, State Senator Joseph Strohl, Chairman of the Wisconsin Radioactive Waste Review Board, issued a statement indicating that the Department of Energy apparently has precluded several Wisconsin counties from further consideration as the site of a radioactive waste terminal storage facility. Among the counties listed as those meriting no further consideration was Forest County, the location of the Crandon Project (Rhinelander Daily News, 1983).

"'These 11 counties (Forest County and 10 others) were removed from DOE's list because the granite formations there are thought to be not suited for the construction of a national repository for high level nuclear waste,' Strohl explained" (Wisconsin Radioactive Review Board, 1983).

3.7.2 Reclaimed Mine Development Area

The proposed final uses of reclaimed land associated with major Project facilities are the same as the existing land uses described in Section 2.9. These final uses include forestry, recreation and agriculture and are discussed in greater detail in the Reclamation Plan.

During a meeting with Exxon Minerals Company and the DNR on August 8, 1984, representatives of the Towns of Lincoln and Nashville recommended alternative uses of the MWDF area; these included agricultural and intensive forestry (i.e., pine plantation) uses and recreational uses such as camping, cross-country skiing, hunting and development of a golf course.

Agricultural use of the MWDF is not considered feasible, primarily because of the high potential for erosion of the reclamation cap. Development of a pine plantation on the MWDF is not consistent with the requirements of NR 132.08(2)(g) which requires reestablishment of a variety of plants indigenous to the area immediately prior to mining. If, because of changing conditions later in the life of the Project, one of these alternative uses proves to be more beneficial in all or part of the area to be reclaimed, an amended Reclamation Plan could be submitted to the DNR in accordance with NR 132.12(3)(a).

Recreational uses such as camping, cross-country skiing and hunting would be compatible with the proposed plan for revegetating the reclaimed area. However, general use of the reclaimed areas for the proposed final land uses will be at the discretion of the owner at the time of issuance by the DNR of a certificate of completion for the Reclamation Plan. Development of a golf course is not compatible with the proposed plan for revegetating the reclaimed MWDF.

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CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

CRANDON PROJECT

ENVIRONMENTAL IMPACT REPORT

REVISED
NOVEMBER 1985

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CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

The purpose of this chapter is to document the potential environmental and socioeconomic consequences of the construction, operation, and post-operation phases of the Crandon Project. The impacts associated with the proposed and alternative actions, as described in Chapters 1 and 3, respectively, are discussed. The documentation of existing conditions, presented in Chapter 2, provided the basis from which the consequences were evaluated.

Mitigative measures that will be taken to lessen potential impacts are also discussed. The environmental consequences of the alternative actions, presented in Chapter 3, are discussed when the effects differ from those of the proposed actions.

Various geographic units (e.g., site area, environmental study area, regional study area, local study area) are used in this chapter to denote the reference area for discussion purposes. These geographic units are defined in either the introduction to Chapter 2 or in those cases where a new reference unit is introduced, it is defined in this chapter.

The discussion of environmental consequences was based on the design life of the Project and is presented for the three main phases of the Project: Construction (Section 4.1), Operation (Section 4.2), and Post-Operation (Section 4.3). The construction period is scheduled for approximately 3 years, operation for 29 years, and post-operation, which includes closure and reclamation, for 4 years (Section 1.1, Figure

1.1-4). The total Project life is approximatley 36 years. The environmental consequences of alternative Project facilities are described in Section 4.4.

The area that could be disturbed during construction of major surface facilities provided the basis for determining potential site-specific environmental consequences. The pertinent dimensions and areal coverage of the major Project facilities are presented in Table 4.0-1 and are illustrated in graphic form on Figure 4.0-1. For most of the facilities the actual area disturbed will be less than what is presented in Table 4.0-1; however, a worst-case analysis was conducted and potential impacts were based on the maximum amount of area that could be disturbed. The methods used to estimate the wetland acreages presented in this chapter are accurate within 10 to 15 percent.

A summary of potential impacts during construction, operation, and reclamation of the Project and proposed contingency/mitigation actions is presented below.

<u>Summary of Potential Environmental Impacts During Construction, Operation, and Reclamation of the Crandon Project</u> - Potential impacts of the mine construction, operation, and reclamation were identified. Some are short-term; others will be of longer duration. A wide range of technologies was evaluated before methods judged suitable to mitigate potential impacts and allow environmentally acceptable operation at costs projected to be economically viable were selected.

<u>Meteorology and Air Quality</u> - No discernible effect on meteorology is likely during construction and operation.

TABLE 4.0-1

AREAS DISTURBED DURING CONSTRUCTION OF PROJECT FACILITIES

FACILITY	LENGTH miles	WIDTH feet	AREAL COVERAGE acres
Mine/Mill Site	Irregular	Irregular	115
Access Road[a]	3.0	100	35
Railroad Spur and Siding[b]	2.7	100	45
Water Discharge Pipeline	6.1	50	35
Haul Road/Tailings Transport Pipeline[c]	0.9	100	10
Reclaim Pond/MRDF/MWDF[d]	Irregular	Irregular	495
Total	---	---	735

[a]Includes right-of-way for the transmission line.

[b]Area disturbed at the siding and several deep cuts will be approximately 150 feet in width.

[c]Length is from the interface point at the eastern side of the mine/mill site to the interface point at the southwest corner of the reclaim pond.

[d]Includes the 25-acre construction support area and 40-acre borrow area.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE CONSTRUCTION ZONES FOR THE CRANDON PROJECT

REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY [signature]	DATE 1/27/86
APPROVED BY	DATE	D.S. Moe	DATE 12/19/86
DRAWING NO FIGURE 4.0-1	SHEET 4 OF 36	REVISION NO 0	

Construction-related impacts on air quality are expected to be minor and will be from mobile equipment operation, consisting of fugitive dust and tail pipe exhaust. Concentrations of these constituents are expected to be considerably below primary and secondary federal and state ambient air quality standards at the Project boundary. Emissions which may be expected from the operation of diesel equipment underground will be controlled through special clean-burning diesel engines, equipped with catalytic scrubbers to prevent air pollution. Dust and particulates will be controlled by watering dirt roads, minimization of disturbance and speedy reclamation of exposed land. Dust collection systems will be installed at suitable points within the mine/mill facilities. Emissions should have no deleterious effect on the environment, nor will there be any hazard to public health and safety.

Geology and Soils - An unavoidable impact of Project construction is the disturbance of the topsoil layer and humus material in those areas designated for Project facilities. During construction, salvageable topsoil will be removed and stockpiled for redistribution during final grading. Those areas will be reseeded with indigenous and introduced plant species. Construction of the mine/mill involves about 115 acres; 70 percent of the site will be covered with buildings, parking lots and roads. The remaining 30 percent will be landscaped or maintained in its natural state.

Construction of the MWDF, MRDF, and reclaim pond involves disturbance of approximately 495 acres. Where practical, topsoil will be removed and stockpiled during construction of the MWDF. The total land disturbed for these facilities at any one time will be no greater than about 285 acres.

Ground Water - No noticeable ground water effects will occur during the construction phase of the Project. The expected mine inflow will remain below 200 gallons per minute during construction and the accompanying ground water declines will only be a few feet in the mine area. These minimal declines will cause no measurable effect on the surface water bodies within the Project site area and have no effect on current ground water users in the area.

Based on the mine development plan, mine inflow volume is projected to begin to increase substantially in Project Year 5 and reach an expected steady-state value of approximately 1,270 gallons per minute after Year 6. With this inflow pattern, ground water drawdowns and the accompanying surface water effects are expected to begin to occur in Project Years 6-8. These effects will increase slightly to a steady-state condition and continue throughout the remaining Project operating period. For the steady-state mine inflow condition, maximum ground water drawdown is approximately 58 feet in the mine area reducing to a drawdown of approximately 3 feet at distances 1-2 miles away from the mine area.

This zone of influence will develop in much the same way as with a well. If any resident's well were to be affected, EMC would replace the water supply. This could be accomplished with either a new or deeper well. Once the mine is closed and the area reclaimed, the water table should return to about its premining level with no adverse effects on water quality.

About half of the material brought from beneath the surface can be returned underground to fill the mined-out voids. Remaining waste rock and mill process waste materials will be placed in a waste disposal facility. Areas within this facility will be developed as needed, used for about 6 years, then sealed and revegetated. The tailings disposal area is carefully engineered with a bottom seal to retard seepage, drains to return waste water to a water treatment plant, and top seal installed at the end of the pond's life to retard the entrance of surface water or precipitation into the restored areas. These sophisticated techniques ensure limited seepage from the ponds, thus protecting the quality of the ground water. The facility will operate within the requirements of NR-182 which provides that ground water quality at the compliance boundary meets drinking water standards.

Surface Water - Surface water impacts to the lakes, streams and springs will be minor. Lake declines of a few inches and stream flow reductions of a few percent will occur for average meteorological and flow conditions. Flow reductions in the two springs (Hoffman and Martin) may be larger on a percentage basis but flows from these springs are small. The percentage reductions in stream flow are projected to be higher when stream flows are lower, but low stream flow conditions occur only during a small portion of the time.

The water quality of local lakes and streams will be protected by the water collection and treatment system which EMC plans to include in the mine/mill construction and operations. These systems will treat wastewater to the point where that quantity of water which is in excess of the mill requirements can meet the applicable effluent standards prior to discharge.

Construction will generate some impacts to wetlands and other surface water bodies in the vicinity of the Project. It is physically impossible to avoid impacting wetlands in the Project area entirely. The Project was designed, however, with the requirement "to minimize impacts to wetlands" [NR 132.06(4)] and less than 60 acres of wetlands will be affected.

Aquatic Ecology - No adverse impacts to endangered or threatened species are expected from construction or operation of the Project. Erosion and sedimentation as a result of site clearing activities and construction of the discharge pipeline, stream crossing structures, access road and railspur may have some minor effects on aquatic life. Those should be localized and temporary and will be mitigated by an erosion control plan.

Swamp Creek is dominated by fish species that are relatively insensitive to turbidity and sedimentation. The minor increases in turbidity during construction should have a minimal impact on the overall fish community. The quality and quantity of discharge water to Swamp Creek will meet applicable state and federal standards.

During the operation period, effects of reductions in lake levels or stream flow rates on aquatic biota will be minor during average climatic conditions. Under dry climatic conditions, the potential for impacts increases; however, major changes in the fish and aquatic insect communities are unlikely in Deep Hole and Little Sand lakes. In Duck Lake, changes in species composition and abundance of wetlands are possible under dry conditions and the likelihood of winterkills of fish will increase. Because the existing aquatic community of Skunk Lake is sparse, impacts to it will be limited. Because Oak Lake is perched, it will not be affected by mine dewatering.

Hydrologic Impact Contingency/Mitigation Actions - The Hydrologic Impact Contingency Plan for the Project is designed to provide assurance that no significant adverse effects will occur to site area lakes, springs, and streams as a result of mine dewatering. The Plan consists of monitoring, analysis of data, trigger points, and migitation actions. The mitigation actions for springs and streams consist of supplementing the flow with ground water from nearby wells. For lakes, the Plan includes level control structures to maintain lake levels in Little Sand and Duck lakes. Supplementation of flow into Skunk Lake is also part of the Plan.

Terrestrial Ecology - The clearing of vegetation during Project construction will result in some loss of wildlife habitat. The impacts on plants and wildlife resources will occur largely during the construction phase in areas where clearing of vegetation for installation of surface facilities occurs. The wildlife habitats to be disturbed are common in the region, mostly northern hardwood and aspen-birch forest. Subsequent reclamation will allow the areas to be returned to plant communities dominated by native species.

Of 148 acres of shallow marsh in the wetland study area, 1.2 acres will be removed or altered, affecting four wetlands. Three shrub swamps will be affected, and of the 146 acres of shrub swamp in the wetland study area 9.7 acres will be removed or altered. Of the 146 acres of deciduous swamps in the wetland study area, 6.6 acres will be altered or removed, affecting a total of seven wetlands. In the coniferous swamp community 34.4 acres will be altered or removed from the 946 acres in the wetland study area, affecting 12 swamps. Four bogs will be affected, and of 320 acres of bog community in the wetland study area, 6.8 acres will be removed or altered.

Cultural Resources - During archaeological and historical inventory and evaluation work in the site area, several cultural resources were identified. No adverse effects on known archaeological or historical resources will occur during either construction or operation. In fact, current and proposed site management practices foster enhanced protection for cultural resources identified during the inventories by prohibiting unauthorized access to those areas where sites are located.

Noise - During Project construction, noise that will be noticeable to area residents located near the Project site will be typical of site preparation activities. Engine noise from diesel equipment and drilling noise will be audible, as well as blasting noise for shaft sinking. Equipment will be selected with considerable attention paid to limiting noise levels whenever possible. Nighttime surface construction activities will also be limited.

Shaft sinking will be a 24-hour activity and will require some blasting work. The noise from the blasting will decrease as the shaft deepens. Within about one month of beginning shaft construction, noise from shaft sinking should no longer be audible to area residents.

The main shaft sinking and the mine waste disposal facility (MWDF) construction activities will be the primary contributors to the estimated daytime sound level changes. However, only three locations are estimated to have total daytime ambient sound louder than 45 dB with the EMC field office being the only location with a change from background of more than 5 dB. Estimated nighttime sound levels will be below 45 dB at all locations except the EMC field office where the sound level is projected to be 46 dB. Nighttime construction activities at the MWDF are not expected to occur during the operation phase.

The actual underground mine operating noise will not be perceptible to area residents. However, two mine ventilation fans located on the surface will emit a low-pitched tone slightly above background levels that will be periodically audible in the local area surrounding the Project site. Equipment selection will keep this noise to a minimum.

The locomotive and other train noises will be similar to those currently heard in the Northwoods. Switching of cars in the yard during concentrate loadout will produce noise which should be of only short durations and confined primarily to daytime hours.

Noises generated within the mill building will be attenuated by building design features and should be imperceptible at the Project boundary. The trees, area land forms, and distance to receptor locations will also provide major natural forms of noise attenuation.

<u>Land Use and Aesthetics</u> - The major effect of the Project on land use will occur during construction when existing land uses are changed to accommodate mining related facilities. Forestry, recreation,

and agriculture will be the main land uses affected. About 570 acres of forest land will be unavailable for hunting and other forms of recreational use due to security fencing around Project facilities.

Some change in land forms will occur due to initial grading of the ground surface. The change in the land forms have been planned to blend into the surroundings with little noticeable impact. The headframe, the tallest structure on the site, will be visible at varying distances from the site depending on intervening landscape features.

These potential impacts and the proposed mitigative measures are discussed in this chapter. In addition to the measures cited above, reclamation of the property will continue after closure of the mine and mill facilities. Upon closure EMC proposes to remove all above ground Project facilities and reclaim the mine development area to the land uses that existed prior to mining. This action will be taken if no other alternative use(s) of the facilities proves to be beneficial at the time of closure.

Socioeconomics - Development of the Project will benefit local residents by increasing employment and income and generating additional tax revenue. Population growth will be modest, disbursed over a wide area, and limited by EMC's local hiring policy. Therefore, the rural nature of sociocultural environment will not be substantially affected. The overall beneficial economic and fiscal impacts of the Project may be shared by the Forest County Potawatomi and Sokaogon Chippewa communities.

The modest increase in population will lead to modest and manageable increases in spending for public facilities and services. No major capital improvements will be needed to accommodate the population growth.

The brief peaks in traffic volumes will not be a hazard to the traveling public. Minor improvements in roadways should minimize impediments to traffic flow. No new public roads will be needed.

The Project should generate substantial amounts of state and federal tax revenue. Purchases by the Project could have beneficial effect on business activity state-wide.

4.1 CONSTRUCTION

4.1.1 Meteorology and Air Quality

4.1.1.1 Local Meteorology

The Crandon Project is not expected to have any discernible impact on local meteorology. The climate of the environmental study area is continental. During most of the year, the environmental study area is in the path of eastwardly moving pressure systems of the prevailing westerly air movements. Terrain in the vicinity of the site area is rolling but does not greatly inhibit pressure system air movement. The physical facilities will not alter wind patterns off-site.

Under some conditions the mine exhaust ventilation shafts will cause water vapor plumes. In the mine exhaust shafts only the smallest droplets remain in the air stream and eventually are discharged from the shaft. Once outside the shafts, the contained moisture will condense further and deposit rapidly in cold weather or evaporate in warm weather. In general, these water vapor plumes will be visible when the atmospheric air temperature is at or below dew point temperature. This will mainly occur between late autumn and early spring. There are no consequences except visibility of the water vapor plumes.

4.1.1.2 Ambient Air Quality

Air emissions of the Project construction phase result primarily from the equipment used, and in the clearing, excavation, and grading of the land for the mine/mill surface facilities, access road, railroad spur, reclaim pond, mine refuse disposal facility (MRDF), and mine waste disposal facility (MWDF).

Air emission sources include site preparation activities, drilling and blasting, fugitive dust resulting from mobile equipment, wind blown fugitive particulates, temporary power generation and mine air heating. Construction phase air emission sources and rates are presented in the December 1985 Revised Air Quality Permit Application Report (RAQPAR) (Exxon Minerals Company, 1985).

Total suspended particulates (TSP) constitute the major portion of the air emissions during the construction phase, averaging approximately 212 tons per year, of which over 90 percent are fugitive emissions from excavation, hauling, loading and dumping and grading activities (see Table 4.2-1). The estimated maximum TSP emissions for the construction phase will occur during the second year and is approximately 239 tons per year (see Table 4.2-1).

Other estimated maximum air emission constituents during construction phase activities are sulfur dioxide - SO_2 (21.7 tons per year), nitrogen oxides - NO_x (66.8 tons per year), carbon monoxide - CO (167.0 tons per year), hydrocarbons - HC (29.4 tons per year) and lead - Pb (0.001 tons per year). Most of these emissions are from the temporary power generation and mobile equipment tailpipe exhaust (see the December 1985 RAQPAR).

Although air quality emissions during construction were not modeled, the largest contributions from the construction phase sources have air emission rates for TSP which are essentially equal in type, mode of release and total quantity to those estimated for operational sources (see Table 4.2-1 and the December 1985 RAQPAR). Since the estimated air emission rates for construction and operation phase TSP sources are essentially equal (Table 4.1-1) and the activities which

TABLE 4.1-1

COMPARISON OF TOTAL CONSTRUCTION AND OPERATION AIR EMISSION RATES IN TONS PER YEAR[a]

CONSTITUENT	EMISSION RATE[b] (TONS PER YEAR) CONSTRUCTION	OPERATION
TSP	239.2	244.0
SO_2	21.7	29.2
NO_x	66.8	62.6
CO	167.0	130.1
HC	29.4	8.4
Pb	0.001	0.18

[a]See Appendices B and D of the December 1985 Revised Air Quality Permit Application Report.

[b]Estimated maximum annual rates.

generate the dust are the same, the results of the operation activities air quality impacts modeling are also considered representative of impacts from the construction phase. The effect of these emissions on the ambient air quality will be minor. Concentrations of air quality constituents are expected to be considerably below the primary and secondary federal and state ambient air quality standards at the modeled Project boundary (see Table 4.2-2).

Similarly, the model predicted ambient concentrations provided in the December 1985 RAQPAR (Exxon Minerals Company, 1985) conservatively estimate the SO_2, NO_x, CO, HC and Pb quantities expected to result from Project activities. In addition, the estimated emission rates for the air quality parameters used for the modeling in the December 1985 RAQPAR (Exxon Minerals Company, 1985) are higher than the rates presented for these same parameters in the construction phase in Table 4.1-1. Therefore, separate modeling for construction phase air quality was not warranted. Model predicted ambient air quality parameter concentrations resulting from estimated operation phase emissions are presented in Table 4.2-2 (see also the December 1985 RAQPAR).

Mitigative measures will be implemented during construction to minimize air quality impacts. On-site roadways and excavation areas will be watered, if necessary, to control fugitive dust. Frequently traveled on-site roads will be paved early in construction to minimize fugitive dust generation. In addition, trucks carrying crushed rock or fine particles will be covered or water sprayed as required when long distance transport is necessary.

Areas subject to cut-and-fill operations will be temporarily revegetated after final grading for soil stabilization and dust control. This activity will start during the first year and continue through completion of construction.

After final grading of embankment slopes, temporary or permanent vegetation will be planted for soil stabilization and to reduce wind blown dust. Soil additives will be applied to off-site haul roads, if necessary, to reduce generation of dust by vehicles.

Drilling activities will be conducted using water injection to the drill bit and will be virtually 100 percent effective in controlling total suspended particle (dust) emissions. Dust emissions from blasting will be reduced because of particle settling during their air transport in the mine and the watering of broken rock (muck) piles prior to handling. Muck pile wetting will be a standard operating procedure. Mobile equipment used for handling of rock and transporting personnel, equipment, and materials will employ a ceramic filter and recirculation of gas emissions of TSP, NO_x, HC and CO.

4.1.2 Geology and Topography

4.1.2.1 Soils

Site preparation will result in the disturbance of the topsoil layer and humus material in construction areas. For the majority of the Project site, limitations of topography, soil depth, and clearing and grubbing operations will impede topsoil removal and preservation. Salvageable soil will be stockpiled for redistribution during final grading and revegetation. The construction plan for the mine/mill site, described in subsection 1.3.1, Facilities Construction, includes rough grading of the 46.6-ha (115-acre) site, stockpiling of topsoil, and reseeding of areas not required in early phases of construction development. About 70 percent of the mine/mill site area will be covered by buildings, parking lots, and roads. The remaining 30 percent of the site area will either not be disturbed or will be landscaped to reduce erosion potential.

Salvageable topsoil covering approximately 200 ha (495 acres) will be removed and stockpiled in the course of construction of the MWDF, reclaim pond, MRDF, construction support area, and the contingency borrow area. The tailing ponds will be constructed sequentially as they are needed which will also minimize erosion and amount of area disturbed at any given time. Site area soils (glacial till) will be used for pond liners in the mine waste disposal area. Soil material from the confines of the pond areas will be used for the pond embankments, liners, and underdrains.

No impact is predicted from freezing of the soil during mine shaft construction. Soil removed to construct the shaft will be stockpiled and will be available for fill material.

4.1.2.2 Landscape

Construction impacts to the landscape will occur in the mine/mill site area, the mine waste disposal and reclaim pond area, along road/rail access routes, pipeline corridors, and the haul road. These impacts will be from the initial modification of the surface topography for construction activities, whereas the reshaping and creation of new permanent landforms will occur during the operation and reclamation phases of the Project.

The construction of the mine/mill facilities will have minimal impacts on the original landscape. Site preparation will create new drainage swales and grading of filled areas will produce new embankment slopes. New embankments will be of the same order of magnitude in height and slope as surrounding topographic features; however, the contours will be more regular than some of the original ground surfaces.

The total area disturbed for the MWDF, MRDF, reclaim pond and adjacent facilities will be approximately 200 ha (495 acres). As each tailing pond is developed, vegetation will be cleared for a distance of approximately 15 m (50 feet) from the toe of the outer embankments of each pond. No disturbance to the existing land forms or vegetation will occur outside this zone.

When completed, the MWDF will consist of four ponds excavated to an average depth of approximately 14 m (46 feet) below the existing ground surface. When constructed, embankments will extend as high as 30 m (98 feet) above the original ground surface. The impacts during construction will be temporary since filling of the excavated ponds and placement of embankment material will begin early in the operations phase of the Project, and contouring and shaping of new landforms are included in the post-operation phase of the Project. When the grades of the embankments have been established, herbaceous plant species (grasses and legumes) will be planted to stabilize the soil surface. A fence will be erected around the perimeter of each pond and a road will be constructed between the toe of the embankments and the fence. These long-term changes in landscape are described in subsections 4.2.2 and 4.3.2.

Detailed drawings of the MWDF and discussion of construction, including dimensions of the ponds, landscape disturbance and erosion control, are presented in Chapter 1 and the MWDF Feasibility Report. The Reclamation Plan contains further documentation on the physical and vegetation aspects of reclamation of this facility during the construction phase. An assessment of the potential visual impacts of the MWDF in relation to the surrounding undisturbed environment and mitigative measures are presented in subsection 4.2.9.2.

Construction impacts to the landforms along the road and rail access routes will be minimal. Cut-and-fill operations will modify certain existing grades and will produce an overall reduction in relief along these routes. New embankments will have the same general degree of slope as surrounding ground surfaces in the site area.

4.1.2.3 Minerals

Waste rock to be removed during mine shaft construction will not have any economically recoverable mineral resources. Gravel in the glacial till overlying the bedrock at the location of the mine shaft is not considered of sufficient quality to be used as a mineral resource. Only a small amount of this material is to be removed in the excavation of the shaft.

4.1.3 Ground Water

The Crandon facilities, shown on Figure 4.1-1, will affect the hydrologic regime in the site area. The construction activities are planned for approximately 3 years as described in detail in Chapter 1. Based on the expected mine inflow during the construction phase of the mine and mill facilities, only minor localized dewatering of the main aquifer will occur. The rate of drawdown and extent of dewatering which will occur may vary depending upon the actual inflow to the mine as it is being constructed. Hydrologic evaluations of the potential reduction of the potentiometric surface of the ground water indicate that the effects will not be detrimental to the hydrologic regime (Appendix 4.1A; Prickett & Associates, 1984).

4.1.3.1 Ground Water Hydraulics

The ground water at the site exists in the glacial deposits overlying the bedrock. The saturated portion of the glacial deposits is defined as the main aquifer. Glacial deposits in the aquifer consist of stratified drift, till and outwash. Ground water movement occurs primarily in the stratified drift because of its relatively higher permeability when compared to other glacial units. The stratified drift is overlain by saturated and unsaturated till in most areas within the site.

Changes in the potentiometric surface and drawdown due to proposed hydrologic actions were determined using the finite element computer model described in Appendix 4.1A. The model was developed

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. Schmidt	DATE 12/6/-
APPROVED BY	DATE	APPROVED BY J.F. Wallace	DATE 1-27-85
APPROVED BY	DATE	EXXON D.S. Moe	DATE 12/9/8-

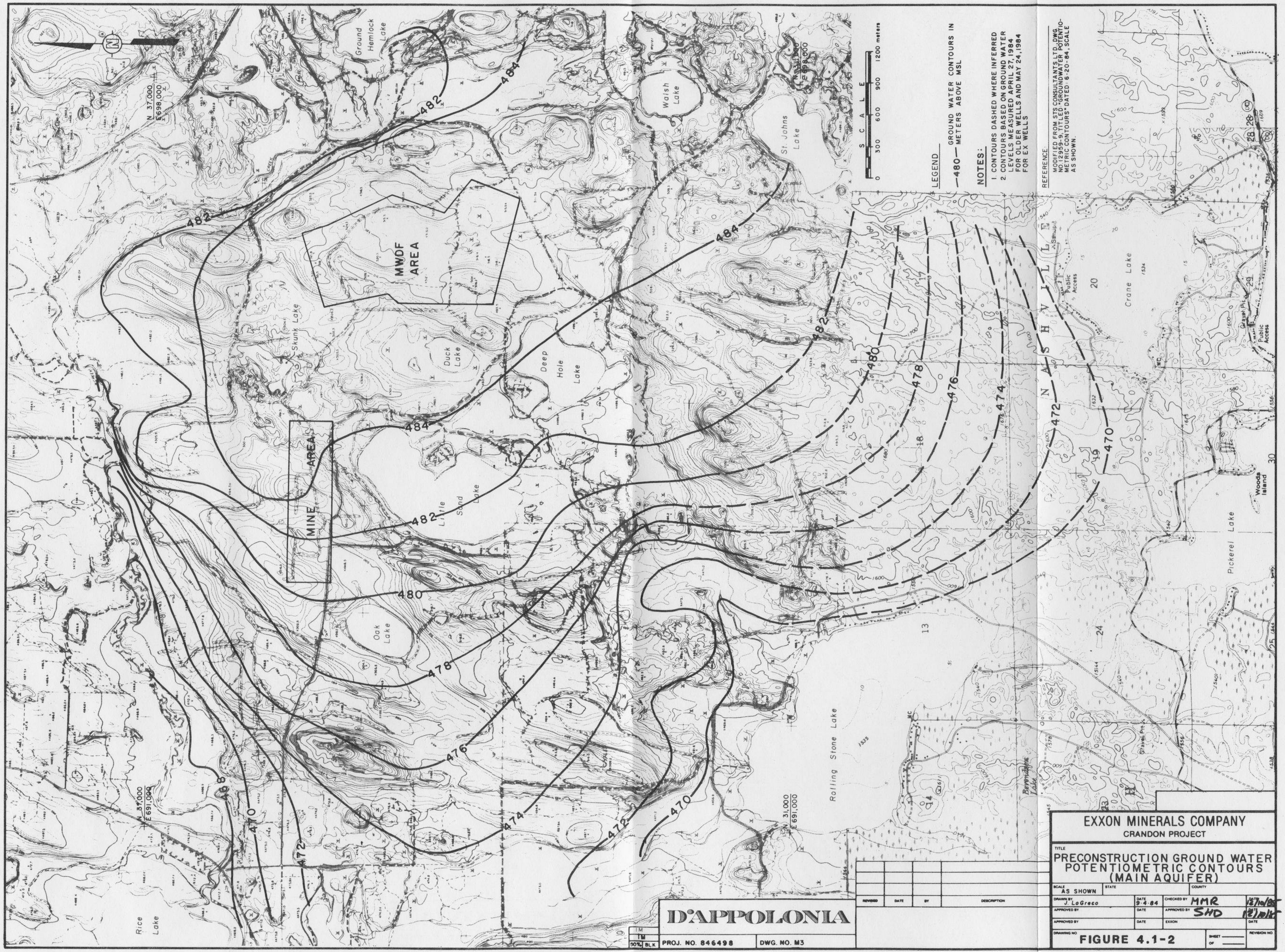
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

DRAWING NO **FIGURE 4.1-1** SHEET 4 OF 36 REVISION NO 0 using site geologic and hydrologic data and it was calibrated to reflect the existing potentiometric surface and hydrologic mass balance.

Based on the expected buildup of mine inflow as described in the High Capacity Well Approval Application for the mine ground water inflow control and drainage systems, only minor ground water declines are expected during the construction period. These declines will only be a few feet and are not expected to cause any adverse ground water effects. Appendix 4.1A describes the modeling conditions and reduced ground water impacts for the current Project plan compared to the previous Project design for which most of the ground water modeling study work was completed.

Based on the previous Project plan, ground water impacts would have been evident during the construction period as mine inflow buildup occurred; however, with the current design the mine inflow will not exceed approximately 0.013 m^3/s (200 gallons per minute) throughout the construction phase and will not begin to increase appreciably until Project Year 5. This slow mine inflow buildup will delay all the impacts previously expected by Project Year 3 until after Project Year 5, well into the operation phase. Therefore, except for some minor declines of approximately a few feet in the mine area, the preconstruction potentiometric surface for the main aquifer shown on Figure 4.1-2 is expected to remain nearly the same throughout the Project construction phase. The discussion of ground water impacts during the operation phase is presented in subsection 4.2.3.



Ground Hemlock Lake
Walsh Lake
St. Johns Lake
MWDF AREA
Skunk Lake
Duck Lake
Deep Hole Lake
MINE AREA
Little Sand Lake
Oak Lake
Rolling Stone Lake
Crane Lake
Pickerel Lake
Rice Lake
NASHVILLE
N 37,000
E 698,000
N 37,000
E 691,000
N 31,000
E 691,000
484
482
480
478
476
474
472
470
468
SCALE
0 300 600 900 1200 meters
LEGEND
—480— GROUND WATER CONTOURS IN METERS ABOVE MSL
NOTES:
1. CONTOURS DASHED WHERE INFERRED
2. CONTOURS BASED ON GROUND WATER LEVELS MEASURED APRIL 27, 1984 FOR OLDER WELLS AND MAY 24, 1984 FOR EX WELLS
REFERENCE:
MODIFIED FROM STS CONSULTANTS LTD., DWG. NO. 12959-9, TITLED "GROUNDWATER POTENTIOMETRIC CONTOURS" DATED: 6-20-84, SCALE AS SHOWN.
D'APPOLONIA
PROJ. NO. 846498
DWG. NO. M3
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
PRECONSTRUCTION GROUND WATER POTENTIOMETRIC CONTOURS (MAIN AQUIFER)
SCALE AS SHOWN
STATE
COUNTY
DRAWN BY J. LoGreco
DATE 9-4-84
CHECKED BY MMR
APPROVED BY SHD
DRAWING NO
FIGURE 4.1-2
SHEET
OF
REVISION NO.

4.1.3.2 Ground Water Quality

Mine refuse disposal facility (MRDF) construction and operation, the only construction phase activity that could potentially affect ground water quality, will be permitted and constructed in accordance with applicable state and local regulations. The MWDF will not be in operation during the construction phase. Mine/mill and MWDF construction phase activities will not cause hydrologic actions which affect ground water quality.

Based on the minor ground water inflows expected, no water quality changes are expected due to changed flow conditions.

4.1.3.3 Local Ground Water Use

During the mine construction period no adverse effects are expected to the use of local ground water.

4.1.4 Surface Water

Ground water contribution to a surface water body (i.e., streams, water table wetlands and spring lakes) is termed base flow, while the total flow of a stream includes ground water discharge and surface water runoff.

The small quantity of mine dewatering during construction (<0.013 m^3/s [<200 gallons per minute]) will lower the potentiometric surface a few feet in the main aquifer in the area of the mine; however, this will not cause any discernible reduction in the amount of ground water discharge, or base flow, into the streams, springs, lakes and related wetlands lakes that border the site area.

4.1.4.1 Wetlands

Although impacts to wetlands associated with the mine dewatering activities, primarily the impacts associated with changes to the potentiometric surface, are expected to be insignificant, there may be impacts associated with surface activities such as construction of the MWDF, access road, railroad spur and water discharge pipeline.

An analysis of impacts to perched wetlands during phases 1-5 of the MWDF development was completed by IEP, Inc. (1982) for the earlier MWDF design. Reanalysis of impacts during these five developmental phases was not performed for the current MWDF design because the analysis for the earlier MWDF design is considered representative for the downsized proposed facility. Also, the changes in wetland water balances reported by IEP, Inc. (1982) during the five MWDF construction phases were minor and indicated no hydrologic impacts to wetlands during these periods.

4.1.4.2 Surface Water Quality

Construction activities have the potential to cause soil erosion and generate sediments which could reach streams and wetlands and affect water quality. To minimize this, the Project erosion control plan presented in the Mining Permit Application will be followed during construction and operation to minimize erosion potential and prevent any discernible increase in silt loading on site area streams and lakes. Large exposed surface areas such as the mine/mill site will have surface water runoff patterns to drainage basins located on the periphery of the facility. Other surface areas (i.e., access road, railroad) will have surface water drainage patterns through filter fabric (i.e., approximately 99 percent effective), which will ensure removal of residual sediment loadings. Areas where these and other erosion control procedures and facilities will be used are described in the Mining Permit Application. Proper design and timely placement of these erosion control facilities should prevent any discernible increase in sediment loading to site area waters.

4.1.4.3 Surface Water Use

There are no known consumptive users of surface water within the Project site area, and no effects on surface water are expected during the construction period.

4.1.5 Aquatic Ecology

4.1.5.1 Aquatic Habitats

The greatest potential for impacts on the aquatic environment surrounding the mine/mill complex will occur during the construction phase, particularly those periods associated with clearing the site and constructing the access road and railroad spur. Erosion and sedimentation are the primary concerns during construction. Erosion and subsequent sedimentation can impair water quality and in some instances adversely affect aquatic organisms.

4.1.5.1.1 Streams

The mine/mill site and the MWDF are situated far enough from Swamp Creek and the other streams in the area that impacts associated with on-site construction (i.e., erosion and subsequent sedimentation) will be negligible. Potential impacts to wetland areas adjacent to the mine/mill site and the MWDF site are discussed in subsection 4.1.4. However, impacts to Swamp Creek are possible as a result of sedimentation associated with the following activities:

1) Laying the water discharge pipeline from the mine/mill site to Swamp Creek and installing the discharge structure adjacent to Swamp Creek;

2) Building the access road from State Highway 55 to the mine/mill site; and

3) Building the railroad spur from the existing Soo Line Railroad to the mine/mill site.

Based on current construction plans, pipeline and discharge structure installation should cause negligible impacts to the environment. The width of the right-of-way (15m [50 feet]) and the amount of land that will have to be disturbed (14 ha [35 acres]) to lay the 356-mm (14-inch) pipe are relatively small. Morever, the discharge structure will be on the stream bank so disturbance of the stream bed will not be necessary. Some disturbance and local turbidity will occur when the riprap is added to the stream bank at the point of discharge. This disturbance and turbidity will be localized and temporary.

Construction of the access road from State Highway 55 to the site will include building a bridge across Swamp Creek. A potential for sedimentation exists during construction, especially in the immediate vicinity of the bridge crossing. Given the erosion and sedimentation control measures described in Chapter 1, subsection 1.3.1.3, impacts from this construction activity should be minimal. Furthermore, the possibility of local impacts occurring at the bridge crossing will be reduced because the bridge will completely span the stream and the stream bed will not be disturbed.

Construction of the railroad spur and its bridge over Swamp Creek from the existing Soo Line tracks to the mine/mill site will create the same potential problems that were discussed above with regard to the access road. Again, runoff and erosion control measures will be implemented as described in Chapter 1, subsection 1.3.1.9, to minimize any impacts on aquatic habitat in Swamp Creek.

4.1.5.1.2 Lakes

Construction of the Project will not involve direct physical impact to lakes. With the exception of the water discharge pipeline, none of the Project facilities will be constructed within 305 m (1,000 feet) of lakes. As discussed in subsection 4.1.4, the effect of reduced ground water discharge on site area discharge lakes will be negligible during the construction period. Therefore, any changes in lake levels attributed to Project construction are expected to have no discernible effect on aquatic habitats.

4.1.5.2 Aquatic Biota

4.1.5.2.1 Fish

In evaluating the potential for impacts, it is important to determine the inherent sensitivity of the community potentially affected. A total of 34 species of fish have been identified from Swamp Creek (Wisconsin DNR, 1974; Ecological Analysts, Inc., 1983; EA Science and Technology, 1984a; Chapter 2, Section 2.5). Based on life history data, 7 of these species were rated as sensitive to sedimentation/ turbidity, 11 as non-sensitive, and 14 as intermediate (Table 4.1-2). Sensitive species were generally those that require clear water (i.e., low turbidity) and clean substrates (i.e., little sedimentation). Intermediate species were generally those that require clear water or clean substrates, but not necessarily both. Northern pike, yellow perch, and black crappie are examples of such species. Non-sensitive species generally are not limited by water clarity or substrate type. With the exception of the hornyhead chub, all the sensitive species listed in Table 4.1-2 are uncommon or not present in Swamp Creek

TABLE 4.1-2

SENSITIVITIES OF SWAMP CREEK FISHES TO TURBIDITY AND SEDIMENTATION RANKINGS BASED ON LIFE HISTORY DATA FROM TRAUTMAN (1957); SCOTT AND CROSSMAN (1973); CLAY (1975); AND PFLEIGER (1975)

COMMON NAME	SCIENTIFIC NAME	SENSITIVITY*
Brook trout	Salvelinus fontinalis	S
Brown trout	Salmo trutta	S
Largescale stoneroller	Campostoma oligolepis	S
Blacknose dace	Rhinichthys atratulus	S
Longnose dace	Rhinichthys cataractae	S
Pearl dace	Semotilus margarita	I
Creek chub	Semotilus atromaculatus	NS
Hornyhead chub	Nocomis biguttatus	S
Fathead minnow	Pimephales promelas	NS
Bluntnose minnow	Pimephales notatus	NS
N. Redbelly dace	Phoxinus eos	S
Golden shiner	Notemigonus crysoleucas	NS
Brassy minnow	Hybognathus hankinsoni	NS
Common shiner	Notropis cornutus	I
Blackchin shiner	Notropis heterodon	I
Blacknose shiner	Notropis heterolepis	S
White sucker	Catostomus commersoni	NS
Shorthead redhorse	Moxostoma macrolepidotum	I
N. hogsucker	Hypentilium nigricans	S
Central mudminnow	Umbra limi	NS
Northern pike	Esox lucius	I
Brook stickleback	Culaea inconstans	I
Black bullhead	Ictalurus melas	NS
Yellow bullhead	Ictalurus natalis	NS
Tadpole madtom	Noturus gyrinus	NS
Yellow perch	Perca flavescens	I
Iowa darter	Etheostoma exile	I
Johnny darter	Etheostoma nigrum	NS
Rock bass	Ambloplites rupestris	I
Largemouth bass	Micropterus salmoides	I
Bluegill	Lepomis macrochirus	I
Pumpkinseed	Lepomis gibbosus	I
Black crappie	Poxomis nigromaculatus	I
Mottled sculpin	Cottus bairdi	I

*S = Sensitive, defined as highly susceptible; would be extirpated under continuous turbid conditions or if sedimentation was severe.

I = Intermediate; can withstand periodic high turbidities and some sedimentation.

NS = Not sensitive; unlikely to be affected adversely except in the most severely polluted conditions.

downstream of Rice Lake, suggesting that habitats suitable to those sensitive species are lacking in the lower half of Swamp Creek. These sensitive species are also rare to locally common in Swamp Creek upstream of Rice Lake, suggesting that habitat is a limiting factor in the upper reaches of Swamp Creek.

Stream fishes are all adapted to periods of high turbidity (Muncy et al., 1979). For example, most streams become moderately to highly turbid during periods of heavy surface water runoff (i.e., during storm events, following snowmelt), and during such periods, fish rely on their other senses to find food. Furthermore, sight-feeding fish may switch to alternative prey items during periods of high turbidity (Swensen, 1978). Similarly, sight feeders can feed in turbid conditions, although their efficiency is reduced (Vinyard and O'Brien, 1976; Gardner, 1981). It is only when turbidity is severe or prolonged that fishes in general, and sight feeders in particular, are adversely affected.

Because Swamp Creek is dominated (25 of 34 species) by species that are non-sensitive or intermediate in sensitivity to turbidity and sedimentation, the likelihood of these factors causing a major impact to the overall fish community in Swamp Creek is small.

The techniques for constructing the access road and railroad spur bridge crossings over Swamp Creek (see Chapter 1, subsections 1.3.1.3 and 1.3.1.9) will limit erosion and resulting runoff of sediments to the creek. These erosion and sedimentation control measures will ensure that any changes in stream turbidity attributed to construction activities will be localized and temporary. Therefore, there should be no impacts to the fish populations in Swamp Creek.

4.1.5.2.2 Macroinvertebrates

Increased sedimentation can affect the macroinvertebrate fauna of a stream. Heavy sediment deposition can physically bury benthic organisms and also alter the habitats present in streams. Where this occurs, community structure changes from species that prefer gravel substrates to species tolerant of unconsolidated fine-grained sediments. Construction of the access road and railroad spur bridges and the proposed discharge into Swamp Creek are expected to increase sedimentation rates only slightly and, therefore, not alter the benthic community. Organisms that prefer depositional habitats are dominant in Swamp Creek downstream of Rice Lake (Ecological Analysts, Inc., 1983; EA Science and Technology, 1984a) and should not be affected by a small increase in sedimentation from the proposed discharge or from the various on-site and ancillary construction activities. Rheophilic (riffle) organisms, which are likely to be affected most by increased sedimentation, are scarce in the gravel substrates in this segment of Swamp Creek and, therefore, are not likely to be affected by the proposed discharge. Furthermore, gravel habitats, which are uncommon in Swamp Creek downstream of Rice Lake, are dominated by organisms which were also abundant in the sand and silt substrates (Ecological Analysts, Inc., 1983; EA Science and Technology, 1984a).

In the swifter upper portions of Swamp Creek, more reophilic, sensitive macroinvertebrate taxa are present. However, populations of such taxa should not be affected because temporary local disruptions or displacements will be compensated by recolonization via drifting organisms. Impacts should be further minimized because the railroad will cross the stream where currents are relatively slow and fine sediments predominate, and few rheophilic taxa would be expected. The access road bridge, though located in a section of the stream with a higher velocity, is at the downstream end of this section. Thus most sediments that are displaced would not be deposited in the riffle portions of Swamp Creek.

4.1.5.2.3 Plankton

Phytoplankton and zooplankton populations are comprised of species which are largely transported with water movement. They also have very short life cycles, rapid reproductive stages, and spore forms which are highly resistant to environmental stresses. As a result, although individuals of the plankton populations may be adversely affected by the temporary increase in water turbidity or sedimentation, there will be no large effect on the plankton populations. There will also be no effect on the organisms utilizing the plankton as energy (food) sources. Therefore, no significant changes are expected to occur in the phytoplankton and zooplankton populations.

4.1.5.2.4 Periphyton and Aquatic Macrophytes

Periphyton and aquatic macrophyte species are sessile (i.e, attached, rooted) organisms. The temporary increase in water turbidity and sedimentation will affect the periphyton and aquatic macrophyte individuals immediately downstream of the construction activity. Photosynthetic activity will be reduced and some individual plants may be eliminated. However, all of these effects will be temporary and water clarity and substrate type will be essentially unchanged after completion of construction. As a result, photosynthetic activity and recolonization of available substrates will readily occur and there will be no long-term effect on the periphyton and aquatic macrophyte populations. No changes in community structure are expected. Therefore, there will be no effect on the organisms utilizing these species for habitat or as food sources.

4.1.5.3 Endangered and Threatened Species

Algal-leaved pondweed, *Potamogeton confervoides*, the only aquatic endangered or threatened species observed in the site area is listed as a threatened aquatic plant in the State of Wisconsin. The plant was identified from samples collected at Duck Lake. Because the Project will not affect the water quality of Duck Lake, there should be no adverse impact on *P. confervoides* and, therefore, no adverse impacts on aquatic endangered or threatened species are expected from Project construction.

4.1.6 Terrestrial Ecology

The most obvious impact of the proposed Project to the local terrestrial ecosystem resources will be the clearing of vegetation during construction activities and the resultant loss of habitat. However, the habitats to be disturbed are common in the region and the nature of this impact will be similar to that associated with the large clearcuts which are a common forestry practice in the region. The projected impacts to vegetation, wildlife, and endangered or threatened species are discussed below.

4.1.6.1 Vegetation

4.1.6.1.1 Upland Communities

Over the 36-year life of the Project, site preparation, facilities construction and reclamation will require the clearing of vegetation from approximately 298 ha (735 acres) of land. This loss of vegetation will be reversible since the disturbed areas will be reclaimed during operation and closure phases of the Project. Clearing and reclamation will be conducted in several phases so that the entire area is not disturbed in any one year (Section 1.3, Table 1.3-1).

Approximately 90 percent of the proposed disturbed area consists of northern hardwood and aspen-birch forest (Table 4.1-3). This community type is the most common in the environmental study area and surrounding region (see Chapter 2, subsection 2.6.3). A recent forest inventory indicated that the forest land to be disturbed consists primarily of medium or well-stocked poletimber. The total volume of all merchantable timber within the areas to be disturbed was estimated to be

TABLE 4.1-3

APPROXIMATE ACREAGE OF EACH VEGETATION TYPE DISTURBED DURING PROJECT CONSTRUCTION[a,b]

VEGETATION TYPE	MINE/MILL SITE HECTARES (ACRES)	ACCESS ROAD HECTARES (ACRES)	RAILROAD SPUR HECTARES (ACRES)	DISCHARGE WATER LINE HECTARES (ACRES)	TAILINGS PIPELINE HECTARES (ACRES)	RECLAIM POND/MRDF MWDF[c] HECTARES (ACRES)	ALL AREAS HECTARES ACRES	ALL AREAS PERCENT OF TOTAL
Northern Hardwood (including Aspen-Birch and Clearcuts)	46.6 (115)	9.5 (23.4)	14.1 (34.9)	9.4 (23.1)	3.8 (9.4)	182.3 (450.2)	265.7 (656.0)	89
Coniferous Swamp	--- ---	1.1 (2.7)	0.7 (1.8)	1.5 (3.8)	0.3 (0.6)	10.3 (25.4)	13.9 (34.3)	5
Deciduous Swamp	--- ---	0.1 (0.2)	--- ---	0.4 (0.9)	--- ---	2.2 (5.5)	2.7 (6.6)	<1
Shrub Swamp	--- ---	0.1 (0.3)	0.2 (0.4)	0.2 (0.6)	--- ---	3.4 (8.3)	3.9 (9.6)	1
Bog	--- ---	--- ---	0.3 (0.8)	0.3 (0.7)	--- ---	2.1 (5.3)	2.7 (6.8)	<1
Shallow Marsh	--- ---	--- ---	--- ---	0.3 (0.9)	--- ---	0.1 (0.3)	0.4 (1.2)	<1
Agriculture	--- ---	3.4 (8.4)	2.9 (7.1)	2.0 (5.0)	--- ---	--- ---	8.3 (20.5)	3
Totals	46.6 (115)	14.2 (35)	18.0 (45)	14.0 (35)	4.0 (10)	200.5 (495)	297.7 (735)	100

[a]Vegetation map of the site area is presented in Chapter 2, subsection 2.6.3.

[b]Locations of the proposed facilities are shown on Figure 4.0-1.

[c]Includes the 10.1-ha (25-acre) construction support area and 16.2-ha (40-acre) borrow area.

12,677 cords of pulpwood and 798,707 board feet of sawtimber. The 1982 market value of this merchantable timber was estimated to be $127,080 (Steigerwaldt, 1982). The value of this timber will be recovered through sales during clearing operations. The estimates of merchantable timber were based on a wider corridor width for the access road, haul road/tailings transport pipeline corridor and railroad spur, and a larger mine/mill site and MWDF area than what are currently proposed; therefore, the volume and value estimates are higher by approximately 25 percent than what is actually expected to be disturbed.

Fugitive dust and air emissions from construction activities will have minimal effects on vegetation. Dust will be created by site clearing, grading, vehicular traffic and the action of wind on exposed soils. Implemention of dust control measures will substantially reduce the quantity of dust from the construction activities. These dust control measures include paving several site roads, watering unpaved roads and excavation sites, and planting vegetation to stabilize exposed soils (see Chapter 1, subsection 1.3.5 and the Reclamation Plan for further details). The effects of dust on vegetation adjacent to the construction areas are expected to be minimal and similar in nature to those currently occurring adjacent to unpaved roads throughout the region.

Estimated emission rates of particulates, SO_2 and NO_x from the proposed Project are given in subsection 4.1.1 and the December 1985 Air Permit Application. These estimated emission rates reflect a conservative meteorological data base, and initial assumptions which were used for the air quality modeling (see the December 1985 Air

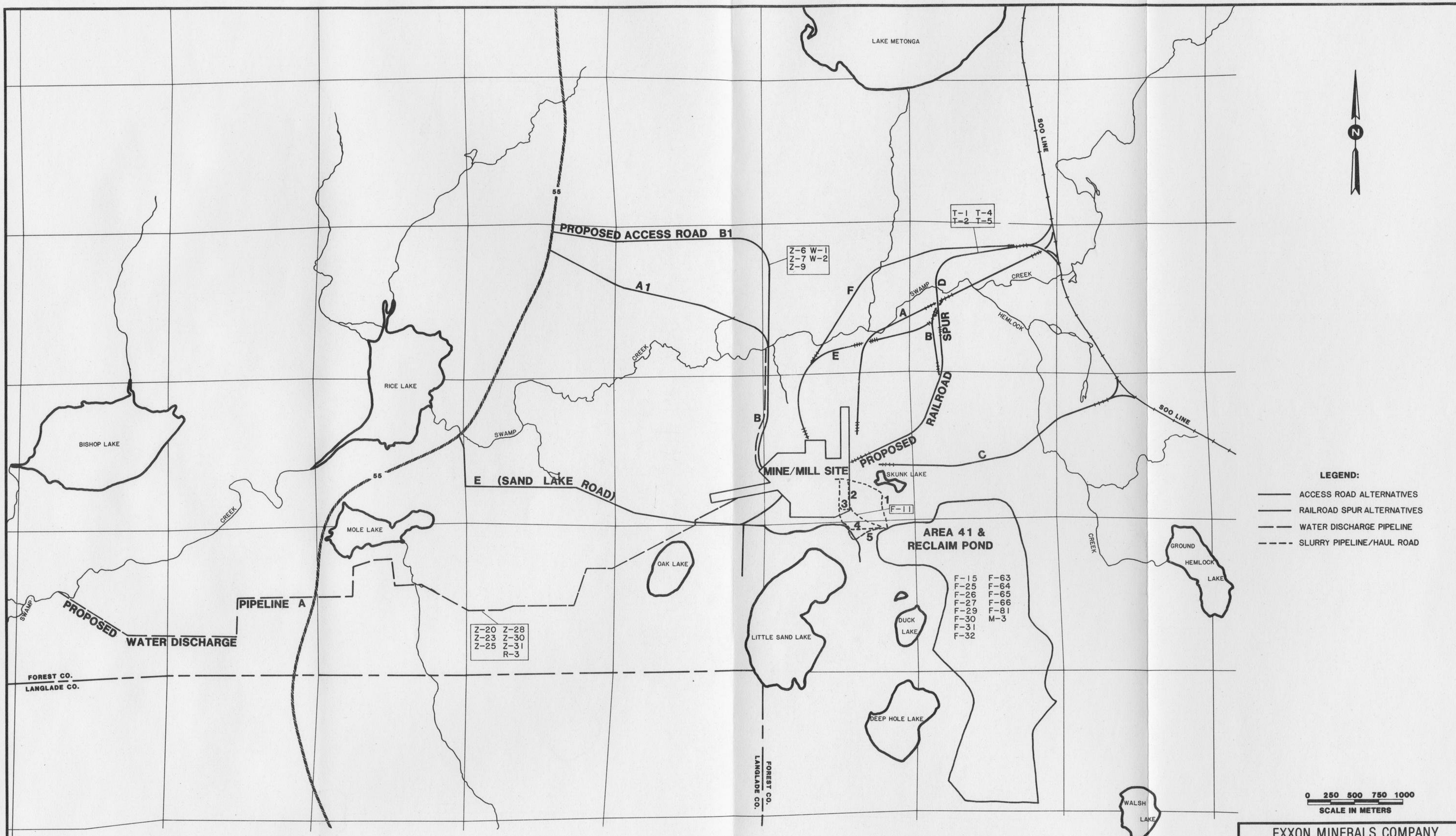
Permit Application). However, the air quality parameter concentrations predicted are still well below the ambient air quality standards (see Chapter 1, subsection 1.3.5 and the December 1985 Air Permit Application. The concentrations predicted are also less than any reported to cause damage to vegetation (U.S. EPA, 1982a,b,c). The mitigative measures to control air emissions are presented in Chapter 1, subsection 1.3.5.

4.1.6.1.2 Wetland Communities

An assessment of the wetlands within and adjacent to the Project site was conducted in accordance with Wisconsin Administrative Code NR 132.06(4) (NAI and IEP, Inc., 1982; IEP, Inc., 1982, 1983). The primary objective of this assessment was to map these wetlands, evaluate and compare their functions, and relate these data to Project siting activities. These data were also to be utilized to determine environmental consequences of proposed Project activities. The study area included the wetlands located within the Project boundary and those outside the boundary which were sufficiently close to be potentially affected.

Of 158 wetlands that were mapped, inventoried, and evaluated in the wetland study area, 30 will be affected through partial or total reduction in size during construction of the MWDF, reclaim pond, access road, railroad spur, haul road/tailings transport pipeline, and water discharge pipeline. No wetlands will be affected during construction of the mine/mill site and MRDF.

Figure 4.1-3 illustrates the relationship of potentially affected wetlands to the proposed Project facilities. The locations of



REVISED	DATE	BY	DESCRIPTION
1	12-26-85	DRS	UPDATED MINE/MILL SITE & MWDF AREA

Typical Representation: Refinements May Be Made During Final Design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **WETLANDS ASSOCIATED WITH PROPOSED PROJECT FACILITIES**

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY C.A. HACKER	DATE 12/82	CHECKED BY H. S. [illegible]	DATE 12/10/82		
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 12/82		
APPROVED BY	DATE	EXXON	DATE		
DRAWING NO. **FIGURE 4.1-3**			SHEET 1 OF 1	REVISION NO. 1	

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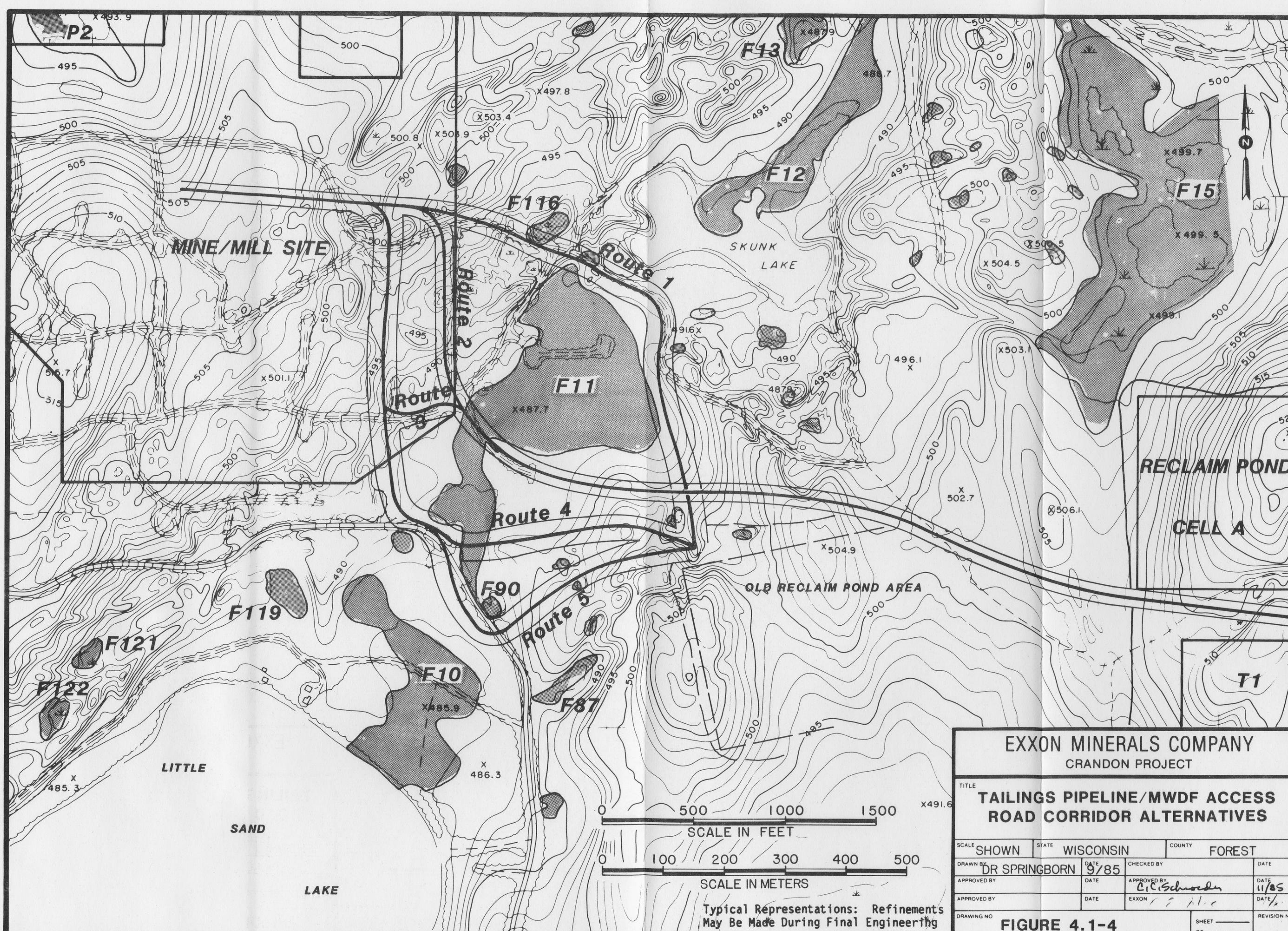
alternative facilities are also shown on Figure 4.1-3. Figures 4.1-4 through 4.1-11 present more specifically the relationship of these wetlands to proposed facilities and the alternatives evaluated.

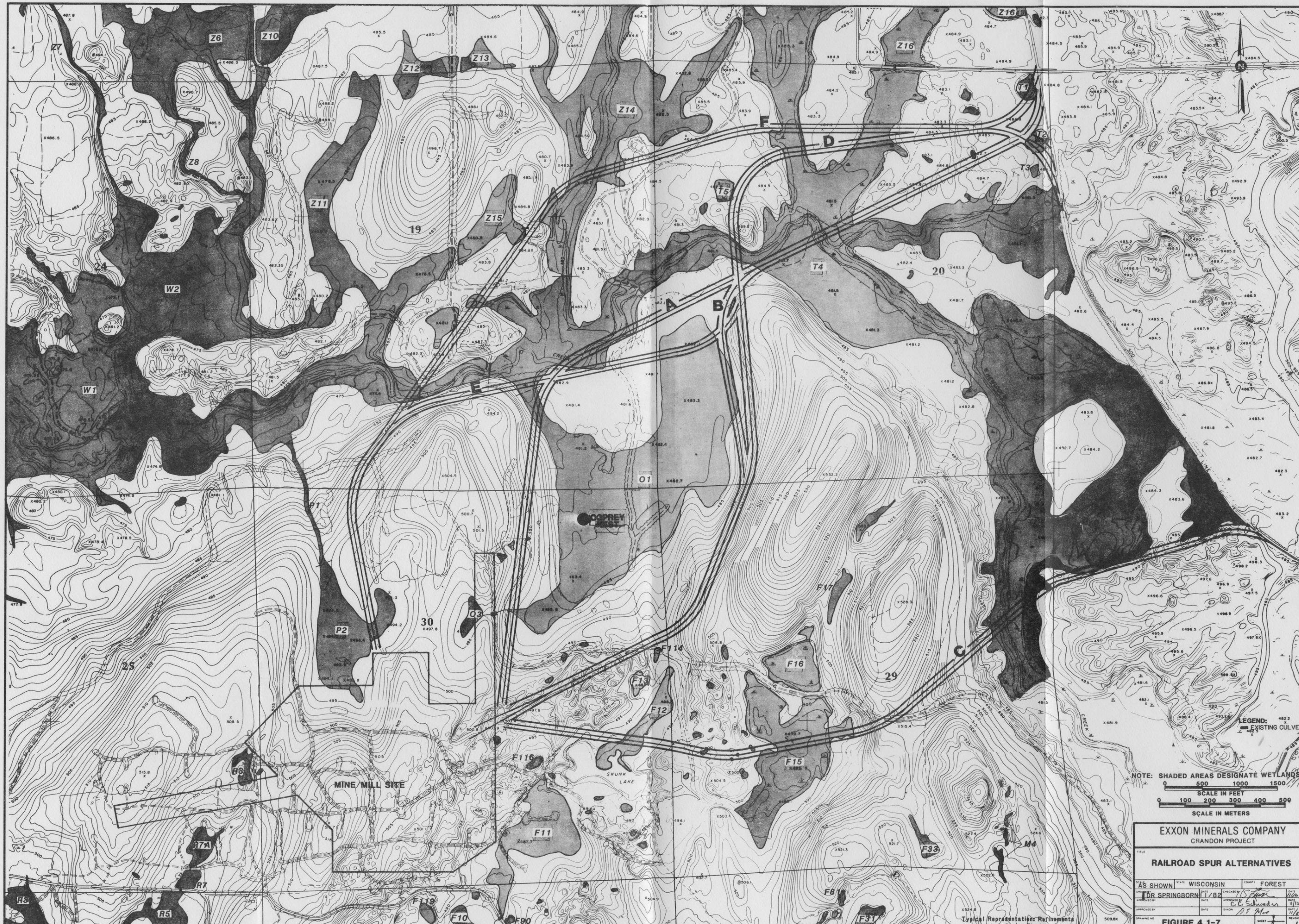
The reductions in wetland acreage will not occur simultaneously; removal will occur in the first four of five different construction phases over a 23-year period. These phases are described in Chapter 1, Section 1.3. To facilitate impact analysis and presentation of material, however, these phases were treated collectively. The correlation between construction dates for the above Project facilities and the phases is shown in Table 4.1-4.

The 30 affected wetlands include 7 deciduous swamps, 12 coniferous swamps, 3 shrub swamps, 4 bogs, and 4 shallow marshes.

Impacts to wetland vegetative communities were assessed on the basis of the scores that were assigned to each of the 30 wetlands in the Biological Function Model (the model) presented as part of the Wetlands Assessment Reports (NAI and IEP, Inc., 1982; IEP, Inc., 1982, 1983) and the amount of acreage that will be affected. This model utilized a semi-quantitative approach based on physical and biological factors (elements) which govern biological function. Each element, and the conditions under which they occur, were assigned numerical values based on their importance in the model. Although the numerical range of the model is 29-158 and the mean is 93, the actual range of scores for the 158 study area wetlands was 44-131 and the mean was 78.7. Wetlands with model scores higher than the actual mean were considered to be more important in biological function than other wetlands in the study area. Therefore, in this evaluation the relative impact of the Project on


P2
MINE/MILL SITE
Route 1
Route 2
Route 3
Route 4
Route 5
F10
F11
F12
F13
F15
F87
F90
F116
F119
F121
F122
SKUNK LAKE
LITTLE SAND LAKE
OLD RECLAIM POND AREA
RECLAIM POND CELL A
T1
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
TAILINGS PIPELINE/MWDF ACCESS ROAD CORRIDOR ALTERNATIVES
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 9/85
CHECKED BY
APPROVED BY
DATE 11/85
DRAWING NO
FIGURE 4.1-4
SHEET
OF
REVISION NO


ROUTE B-1
ROUTE A-1
ROUTE E
SAND
LAKE
ROAD
MINE/MILL SITE
W1
W2
23
24
25
26
30
19
P1
P2
O1
T4
C3
Z1
Z6
Z7
Z8
Z9
Z11
Z12
Z13
Z14
Z15
Z17
Z18
Z19
Z20
Z21
Z22
Z23
R3
R5
R7
R7A
R8
F11
F12
F116
F119
F121
F122
F122A
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
Typical Representation: Refinements May Be Made During Final Design.
LEGEND:
EXISTING CULVERT
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
ACCESS ROAD ALTERNATIVES
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY R.C. DIETZ
DATE 11/82
CHECKED BY
APPROVED BY
C.C. Schroeder
DATE 11/13/85
EXXON
DRAWING NO
FIGURE 4.1-6
SHEET
OF
REVISION NO
1



EXXON MINERALS COMPANY
CRANDON PROJECT
RAILROAD SPUR ALTERNATIVES
AS SHOWN
WISCONSIN
FOREST
FIGURE 4.1-7
NOTE: SHADED AREAS DESIGNATE WETLANDS
SCALE IN FEET
0 500 1000 1500
SCALE IN METERS
0 100 200 300 400 500
LEGEND:
EXISTING CULVERT
Typical Representation; Refinements May Be Made During Final Design.
MINE/MILL SITE
SKUNK LAKE
A
B
C
D
E
F
19
20
25
29
30
W1
W2
Z6
Z7
Z8
Z10
Z11
Z12
Z13
Z14
Z15
Z16
T1
T3
T4
T5
O1
O3
P1
P2
F10
F11
F12
F15
F16
F17
F31
F33
F90
F114
F116
F119
M4
R5
R7
R8


MINE/MILL SITE
BORROW AREA
WATER
RECLAIM POND
CELL A
CELL B
CSA
CELLS
1 2 3
MRDF
WASTE DISPOSAL PONDS
T1
T2
T3
T4
OAK LAKE
LITTLE SAND LAKE
SKUNK LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
25
29
30
31
32
36
Typical Representations Refinements May Be Made During Final Design.
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-114C
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 10/85
CHECKED BY
APPROVED BY C.C. Schroeder
DATE 11/13/85
EXXON
DATE 11/13/85
DRAWING NO
FIGURE 4.1-8
SHEET
OF
REVISION NO

MINE/MILL SITE
SKUNK LAKE
WATER RECLAIM PONDS
R1
R2
WASTE DISPOSAL PONDS
T4
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-114B
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY R.C. DIETZ
DATE 11/82
CHECKED BY
APPROVED BY
EXXON
DRAWING NO
FIGURE 4.1-9
SHEET 1 OF 1
REVISION NO 1

MINE/MILL SITE
WATER RECLAIM POND
TAILS POND
TAILS POND
TAILS POND
SKUNK LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
HEMLOCK CREEK
25
29
30
31
32
36
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
Typical Representation; Refinements May Be Made During Final Design.
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-103
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY C.A. HACKER
DATE 11/82
CHECKED BY
DATE 11/16/82
APPROVED BY C.C. Schroeder
DATE 11/13/85
EXXON
DATE 11/85
DRAWING NO
FIGURE 4.1-10
SHEET 1 OF 1
REVISION NO 1

WATER RECLAIM POND
TAILS POND
TAILS POND
TAILS POND
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
Typical Representations; Refinements May Be Made During Final Design.
LEGEND:
EXISTING CULVERT
NOTE: SHADED AREAS DESIGNATE WETLANDS
0 500 1000 1500
SCALE IN FEET
0 100 200 300 400 500
SCALE IN METERS
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
WASTE DISPOSAL POND
ALTERNATIVE 41-121
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY C.A. HACKER
DATE 11/82
APPROVED BY C.C. Schroeder
DATE 11/13/85
DATE 11/85
DRAWING NO
FIGURE 4.1-11
SHEET 1 OF 1
REVISION NO 1

TABLE 4.1-4

SUMMARY OF WETLAND ACREAGES REMOVED DURING PROJECT CONSTRUCTION PHASES 1 THROUGH 4

PHASES	CONSTRUCTION YEARS	PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE	WETLAND SIZE ha	WETLAND SIZE (Acres)	WETLAND AREA REMOVED ha	WETLAND AREA REMOVED (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[a]
1	1	Haul Road/Tailings Transport Pipeline	F11	CS[b]	7.26	(17.99)	0.20	(0.50)	78
	1	Access Road Corridor	W1	CS	6.14	(15.19)	0.72	(1.80)	101
	1	Access Road Corridor	W2	CS	16.76	(41.42)	0.13	(0.33)	102
	1	Access Road Corridor	Z6	CS	17.94	(44.41)	0.25	(0.62)	95
	1	Access Road Corridor	Z7	DS[c]	1.39	(3.46)	0.09	(0.23)	79
	1	Access Road Corridor	Z9	CS	4.20	(10.40)	0.10	(0.25)	102
	1	Railroad Spur Corridor	T1	B[d]	0.77	(1.91)	0.16	(0.40)	72
	1	Railroad Spur Corridor	T2	B	0.67	(1.65)	0.18	(0.45)	93
	1	Railroad Spur Corridor	T4	CS	18.09	(44.78)	0.90	(2.22)	118
	1	Railroad Spur Corridor	T5	CS	0.57	(1.41)	0.02	(0.05)	78
	2	Water Discharge Pipeline	R3	SM[e]	8.68	(21.44)	0.13	(0.31)	116
	2	Water Discharge Pipeline	Z20	SM	17.03	(42.09)	0.18	(0.47)	99
	2	Water Discharge Pipeline	Z23	CS	42.98	(106.10)	1.11	(2.75)	93
	2	Water Discharge Pipeline	Z25	SM	6.46	(15.96)	0.25	(0.60)	108
	2	Water Discharge Pipeline	Z28	B	6.59	(16.26)	0.14	(0.35)	106
	2	Water Discharge Pipeline	Z30	CS	117.72+	(290.90+)	0.72	(1.78)	109
	2	Water Discharge Pipeline	Z31	SS[f]	2.95	(7.30)	0.23	(0.57)	98
1 - 4	1 - 4	Reclaim Pond/MWDF	F15	DS	13.80	(34.09)	0.08	(0.20)	96
	1 - 4	Reclaim Pond/MWDF	F29	SS	1.39	(3.43)	0.08	(0.20)	95
	1 - 4	Reclaim Pond/MWDF	F30	DS	0.02	(0.05)	0.02	(0.05)	53
	1 - 4	Reclaim Pond/MWDF	F31	CS	2.42	(6.00)	2.42	(6.00)	83
	1 - 4	Reclaim Pond/MWDF	F32	DS	0.22	(0.55)	0.22	(0.55)	53
	1 - 4	Reclaim Pond/MWDF	F81	SM	0.14	(0.35)	0.14	(0.35)	58
	2, 13	Reclaim Pond/MWDF	F66	CS	6.56	(16.20)	6.56	(16.20)	94
	5	Reclaim Pond/MWDF	F25	DS	1.42	(3.53)	0.08	(0.20)	70
	5	Reclaim Pond/MWDF	F27	DS	1.68	(4.18)	1.68	(4.18)	57
	12	Reclaim Pond/MWDF	M3	DS	1.68	(4.18)	1.09	(2.70)	73
	19	Reclaim Pond/MWDF	F63	CS	3.89	(9.64)	2.69	(6.65)	90
	19	Reclaim Pond/MWDF	F64	B	1.83	(4.53)	1.83	(4.53)	78
	19	Reclaim Pond/MWDF	F65	SS	1.01	(2.52)	1.01	(2.52)	96

[a] Model Range: 29-158; Model Mean: 93; Actual Range: 44-131; Actual Mean: 78.7
[b] Coniferous Swamp
[c] Deciduous Swamp
[d] Bog
[e] Shallow Marsh
[f] Shrub Swamp

wetlands is considered greater to a higher scoring wetland when compared to another wetland with a lower model score. The major elements which contributed most to the high model scores of some wetlands were: (1) being dominated by one of the high scoring wetland types, (2) having a large amount of edge (interspersion) because of the presence of a variety of wetland types, (3) favorable water/cover ratio, (4) having favorable surrounding habitat conditions, (5) having a high percentage bordering open water, and (6) being of large size (Table 4.1-5). These and other elements in the model are fully discussed in the Wetlands Assessment Report, Appendices C and E (NAI and IEP, Inc., 1982).

Sedge/Blue-Joint Grass Shallow Marsh - Of 60 ha (148 acres) of shallow marsh in the 4,735-ha (11,700-acre) wetlands study area, 0.49 ha (1.21 acres) will be disturbed and/or removed during construction (Table 4.1-6). Four marshes will be affected by Project activities, F81, R3, Z20, and Z25.

Wetland F81 scored considerably lower than the actual mean because of the element conditions for biological function (Table 4.1-5). One of the major contributing factors for the low biological function score was the small size of this wetland (0.14 ha [0.35 acre]). Although all 0.14 ha (0.35 acre) of wetland F81 will be removed during construction of the reclaim pond (Figure 4.1-8), the effect will be minor because of its low biological function score which indicated low importance in the study area and regional contexts.

Only a small area of wetlands, K3, Z20, and Z25, will be affected during construction. The disturbance to these wetlands will be

TABLE 4.1-5

SUMMARY OF MAJOR ELEMENTS USED TO DESCRIBE AND EVALUATE THE BIOLOGICAL FUNCTION OF WETLANDS

	MAJOR ELEMENTS					
WETLAND NO.	DOMINANT WETLAND TYPE*	AMOUNT OF EDGE	WATER/COVER RATIO	SURROUNDING HABITAT VARIABILITY	% BORDERING OPEN WATER	SIZE
Access Road Corridor						
W1	CS	Med	Low	Med	Med	Large
W2	CS	Med	Low	Med	Med	Large
Z6	CS	Med	Low	High	Low	Large
Z7	DS	Low	Low	High	Med	Med
Z9	CS	Med	Low	Med	Med	Large
Railroad Spur Corridor						
R3	SM	Med	Low	Med	Med	Large
T1	B	Low	Low	High	Low	Med
T2	B	High	Low	High	Low	Med
T4	CS	High	Low	High	Med	Large
T5	CS	High	Low	Med	Low	Med
Water Discharge Pipeline						
Z20	SM	High	Low	Med	Low	Large
Z23	CS	Med	Low	Med	Low	Large
Z25	SM	Med	High	High	Med	Large
Z28	B	High	High	High	Low	Large
Z30	CS	High	High	Med	Low	Large
Z31	SS	Med	High	Med	High	Large
Haul Road/Tailings Transport Pipeline						
F11	CS	Low	Low	Med	Low	Large
Reclaim Pond/MWDF						
F15	DS	High	Low	Med	Low	Large
F25	DS	Med	Low	Med	Low	Med
F27	DS	Med	Low	Med	Low	Med
F29	SS	High	Low	Med	Low	Med
F30	DS	Low	Low	Med	Low	Small
F31	DS	Med	Low	Med	Low	Large
F32	DS	Low	Low	Med	Low	Small
F63	CS	Med	Low	Med	Low	Large
F64	B	Low	Low	Med	Low	Large
F66	CS	High	Low	Med	Low	Large
F65	SS	Med	High	Med	Low	Large
F81	SM	Low	High	Med	Low	Small
M3	DS	Med	Low	Med	Low	Med

*Wetland type abbreviations are defined in Table 4.1-4.

TABLE 4.1-6

ACREAGES OF WETLAND TYPES REMOVED DURING PROJECT CONSTRUCTION[a]

WETLAND NO.	DOMINANT WETLAND TYPE[b]	WETLAND TYPES: SHALLOW MARSH ha	(Acres)	SHRUB SWAMP ha	(Acres)	DECIDUOUS SWAMP ha	(Acres)	CONIFEROUS SWAMP ha	(Acres)	BOG ha	(Acres)	TOTAL AREA REMOVED ha	(Acres)
Study Area Total:		60	(148)	59	(146)	59	(146)	383	(946)	130	(320)		
Access Road Corridor													
W1	CS							0.72	(1.80)			0.72	(1.80)
W2	CS			0.13	(0.33)							0.13	(0.33)
Z7	DS					0.09	(0.23)					0.09	(0.23)
Z6	CS							0.25	(0.62)			0.25	(0.62)
Z9	CS							0.10	(0.25)			0.10	(0.25)
Railroad Spur Corridor													
T1	B									0.16	(0.40)	0.16	(0.40)
T2	B									0.18	(0.45)	0.18	(0.45)
T4	CS			0.18	(0.44)			0.72	(1.78)			0.90	(2.22)
T5	CS							0.02	(0.05)			0.02	(0.05)
Water Discharge Pipeline													
Z20	SM	0.03	(0.09)					0.15	(0.38)			0.18	(0.47)
Z23	CS							1.11	(2.75)			1.11	(2.75)
Z25	SM	0.19	(0.46)							0.06	(0.14)	0.25	(0.60)
Z28	B									0.14	(0.35)	0.14	(0.35)
Z30	CS					0.35	(0.86)	0.28	(0.69)	0.09	(0.23)	0.72	(1.78)
Z31	SS			0.23	(0.57)							0.23	(0.57)
R3	SM	0.13	(0.31)									0.13	(0.31)
Haul Road/Tailings Transport Pipeline													
F11	CS							0.25	(0.63)			0.25	(0.63)

TABLE 4.1-6 (continued)

WETLAND NO.	DOMINANT WETLAND TYPE[b]	WETLAND TYPES: SHALLOW MARSH ha	(Acres)	SHRUB SWAMP ha	(Acres)	DECIDUOUS SWAMP ha	(Acres)	CONIFEROUS SWAMP ha	(Acres)	BOG ha	(Acres)	TOTAL AREA REMOVED ha	(Acres)
Reclaim Pond/MWDF													
F15	DS					0.08	(0.20)					0.08	(0.20)
F25	DS					0.08	(0.20)					0.08	(0.20)
F27	DS			1.00	(2.49)	0.68	(1.69)					1.68	(4.18)
F29	SS			0.08	(0.20)							0.08	(0.20)
F30	DS					0.23	(0.57)					0.23	(0.57)
F31	CS					0.58	(1.45)	1.83	(4.55)			2.41	(6.00)
F32	DS					0.22	(0.55)					0.22	(0.55)
F63	CS							2.39	(5.90)	0.30	(0.75)	2.69	(6.65)
F64	B									1.83	(4.51)	1.83	(4.51)
F65	SS			1.01	(2.52)							1.01	(2.52)
F66	CS			1.27	(3.13)			5.29	(13.07)			6.56	(16.20)
F81	SM	0.14	(0.35)									0.14	(0.35)
M3	DS					0.32	(0.80)	0.77	(1.90)			1.09	(2.70)
TOTALS		0.49	(1.21)	3.92	(9.68)	2.65	(6.55)	13.92	(34.37)	2.75	(6.83)	23.75	(58.64)

[a]Source: IEP, Inc. (1983).

[b]Wetland type abbreviations are defined in Table 4.1-4.

temporary and will have no long-term effect on the biological function of the wetlands.

Alder Shrub Swamp - Three shrub swamps (F29, F65 and Z31) will be affected during Project construction. Of the 59 ha (146 acres) of shrub swamp occurring in the wetland study area, 3.84 ha (9.48 acres) will be removed during Project construction (Table 4.1-6). Shrub swamps are one of the three most abundant types in the region. In this context, the loss of the biological function associated with these wetlands is considered minor.

Wetland Z31 scored above the model mean and will have 0.23 ha (0.57 acre) altered during construction of the water discharge pipeline, which will be only a short-term alteration.

Green Ash/Aspen Deciduous Swamp - Seven deciduous swamps, wetlands F15, F25, F27, F30, F32, M3, and Z7, will be affected during Project construction. Of the 59 ha (146 acres) of deciduous swamps in the wetland study area, 2.65 ha (6.55 acres) will be removed (Table 4.1-6); deciduous swamp is one of the three most common wetland communities in the region, therefore the impacts are considered minor.

Black Spruce/Tamarack Coniferous Swamp - Of 383 ha (946 acres) of coniferous swamps in the wetland study area, 13.92 ha (34.37 acres) will be directly affected during construction activities (Table 4.1-6). Of all the wetland community types occurring in the region, coniferous swamp is the most common. The coniferous swamps that will be affected include the following: F11, F31, F63, F66, T4, T5, W1, W2, Z6, Z9, Z23, and Z30.

Wetland T4, Z6, W1 and W2 were distinguishable from other wetlands in the regional context with respect to their biological function value. Although this loss of coniferous swamp will have an effect on the biological function of these wetlands, the magnitude of the effect will be minor in the regional context in view of the common occurrence of this type.

Wetlands F66, Z9, Z23 and Z30 scored on or somewhat above the model mean, which distinguished their biological function from those of other wetlands in the region. All of wetland F66 (6.56 ha [16.20 acres]) will be removed during construction of tailing pond T4 (Figure 4.1-8). The biological function value of this wetland will be totally eliminated; however, the magnitude of this consequence in the regional context will be minor because of the common occurrence of coniferous swamp wetlands. The access road will remove 0.10 ha (0.25 acre) of Z9 (4.20 ha [10.4 acres]) and the water discharge pipeline (Figure 4.1-5) will affect 1.11 ha (2.75 acres) out of 42.98 ha (106.1 acres) of Z23 and 0.72 ha (1.78 acres) of Z30, a very large wetland (117.72+ ha [290.90+ acres]). The effects of these losses on biological functions will be minimal because of the small acreages disturbed compared to the sizes of these wetlands.

Wetlands F31 and F63 scored below the model mean but above the actual mean, distinguishing them from other wetlands in the study area but not in the regional context. During construction of the reclaim pond and tailing pond T1, all of wetland F31 will be eliminated (Figure 4.1-8). Approximately 65 percent of F63 will be eliminated during construction of tailing pond T4. The magnitude of this reduction in biological function will be minor in the regional context in view of the commonness of this type of wetland.

Wetlands F11 and T5 scored below the actual mean, indicating that they were not above average in biological function compared to other wetlands in the study area. The area of F11 that will be removed during construction of the haul road/tailings transport pipeline (Figure 4.1-4) is small compared to the size of the wetland and the environmental consequences will be minimal.

Leatherleaf Bog - Four bogs (wetlands F64, T1, T2 and Z28) will be affected during construction of the Project (Table 4.1-4). Of 129.6 ha (320 acres) of bogs in the wetland study area, 2.75 ha (6.83 acres) will be affected during construction activities (Table 4.1-6). As a community, the bog is one of the least common wetland types in the region; however the only bog with a rating more significantly above the mean was Z28 and only a small portion of this large wetland will temporarily alter by construction of the water discharge pipeline.

Summary of Wetland Acreages Affected During Construction - Of 60 ha (148 acres) of shallow marsh in the wetland study area, 0.49 ha (1.21 acres) will be removed or altered, affecting four wetlands. Three shrub swamps will be affected, and of the 59 ha (146 acres) of shrub swamp in the wetland study area 3.92 ha (9.68 acres) will be removed or altered. Of the 59 ha (146 acres) of deciduous swamps in the wetland study area, 2.65 ha (6.55 acres) will be altered or removed, affecting a total of seven wetlands. In the coniferous swamp community 13.92 ha (34.37 acres) will be altered or removed from the 383 ha (946 acres) in the wetland study area, affecting 12 swamps. Four bogs will be affected, and of 129.6 ha (320 acres) of bog community in the wetland study area, 2.75 ha (6.83 acres) will be removed or altered.

Mitigation - Mitigation procedures and actions will protect the biological function values of wetlands up-gradient and down-gradient from construction zones. During construction activities, temporary retaining berms will be used to contain runoff water and prevent disruption of wetland hydrology. Where wetlands must be crossed, standard construction practices within wetlands will be followed (Chapter 1, Section 1.3). The stream banks at bridge crossings will be protected, e.g., by sheet piling and rip-rap, to prevent erosion and surface water runoff. Surface water drainage with the potential for high suspended solids content will be directed through retention ponds, which will allow settling of the suspended solids before entering the wetlands. Bales of hay and filter fabric will be used as needed to control soil erosion and reduce sedimentation in localized areas. Erosion and surface water runoff will also be controlled by topsoil application and reseeding to reduce the exposure of bare ground. Specific techniques for erosion control are presented in the Reclamation Plan. Landscape plantings will be established around major surface facilities as they are completed. Contaminated surface water runoff will be treated prior to being discharged.

4.1.6.2 Wildlife

Observations during the inventory of existing conditions in upland and wetland communities indicated that the majority of wildlife species inhabiting the study area used both of these communities as habitat (Section 2.6; NAI and IEP, Inc., 1982). The wildlife composition of wetland communities reflected the degree of interspersion of wetland and upland habitats rather than the specific characteristics of a wetland community. Changes in wildlife carrying capacities will result from losses of both upland and wetland habitat during Project construction. The effects on wildlife were assessed using representative species as indicators of change in carrying capacity.

Carrying capacity is defined as the number of animals of a given species that a habitat will support, as determined by observations over a period of years. The carrying capacity of various habitat types is not constant and will change on a short-term or long-term basis. Fluctuations in weather, habitat alteration or destruction, and plant succession are environmental factors that could cause changes in the carrying capacity for a given species.

Five representative indicator species were selected: the southern red-backed vole (*Clethrionomys gapperi*) and white-tailed deer (*Odocoileus virginianus*) were chosen as representative mammals; the veery (*Catharus fuscescens*) and ruffed grouse (*Bonasa umbellus*) as representative birds; and the wood frog (*Rana sylvatica*) as a representative herptile. Both the general ecological literature and site-specific reports (Section 2.6; NAI and IEP, Inc., 1982) were reviewed before the indicator species were selected. In addition, game and nongame status was considered so that the consequences of the proposed Project on recreational values of wildlife could be evaluated.

4.1.6.2.1 Mammals

Southern Red-backed Vole - The southern red-backed vole was captured in the northern hardwood communities and was the only species trapped during the 1981 wetlands assessment in all four wooded wetland types (deciduous swamp, coniferous swamp, shrub swamp, and bog) in the study area (Section 2.6; NAI and IEP, Inc., 1982). This species prefers wet and mesic habitats (Merritt, 1981) such as occur in the above four wetland types.

The literature on density estimates for this species throughout North America was summarized by Terman (1966). Two studies from the Midwest were reported; in Minnesota, densities ranged from 0 to 4.56 voles/ha (0 to 11.3 per acre), and in Michigan they ranged from 0.20 to 1.81 voles/ha (0.50 to 4.50 per acre). Population estimates in the wetland study area were calculated only for the coniferous swamp type. The density in this wetland type was 0.68 voles/ha (1.7 per acre) (NAI and IEP, Inc., 1982). According to Merritt and Merritt (1978), the average home range for this species varies from 0.009 to 0.50 ha (0.02 to 1.24 acres).

The average density of 0.68 voles/ha (1.70 per acre) found in the wetland study area was used to assess the impact of habitat losses on this species. This figure is probably a low estimate for these wetland types but is a reasonable average for the overall acreage that will be affected during construction.

The potential effect of habitat loss on the carrying capacity of southern red-backed voles is shown in Table 4.1-7. A loss of approximately 1,250 voles could occur; however, this loss is considered

TABLE 4.1-7

ESTIMATED POTENTIAL EFFECT OF HABITAT LOSS ON CARRYING CAPACITY OF FIVE INDICATOR SPECIES

		ESTIMATED NUMBER LOST[a]				
HABITAT TYPE	ACRES LOST	WOOD FROG (50/ACRE)[b]	VEERY (0.22/ACRE)	RUFFED GROUSE (0.02/ACRE)	SOUTHERN RED-BACKED VOLE (1.7/ACRE)	WHITE-TAILED DEER (0.03/ACRE)
Coniferous Swamp	34.4	1,720	8	<1	59	1
Deciduous Swamp	6.6	330	2	<1	11	<1
Bog	6.8	340	2	<1	12	<1
Shrub Swamp	9.7	485	2	<1	17	<1
Marsh	1.2	60	n.u.[c]	n.u.	n.u.	n.u.
Upland	676.0	33,800	149	14	1,149	20
TOTALS	735.2	36,760	162	15	1,250	22

[a]Losses reflect cumulative totals and do not account for replacment habitat that will be available to support wildlife after reclamation of disturbed areas. Overall losses at any given time will be less than the cumulative totals indicated because of the phased construction disturbance/reclamation schedule.

[b]Estimated carrying capacity for the study area in number per acre.

[c]Not utilized as habitat by this species.

minor in the site area and regional contexts because of the wide distribution of this species. Southern red-backed voles occupy a primary and secondary consumer level and hence its absence could affect species higher in the food web. Because there are other small mammals available as "buffer" prey which are not highly associated with wetland habitats, such as deer mice and white-footed mice, the loss of voles will be negligible.

The data in Table 4.1-7 indicate cumulative losses associated with all construction activities and do not account for replacement habitat that will be provided in areas reclaimed during the construction and operation phases. When the reclaimed land areas are taken into consideration, losses at any given time will be less than the cumulative totals presented in Table 4.1-7.

White-tailed Deer - Deer density was estimated in the Project area during the spring and autumn of 1977 (Section 2.6). The trail count method of McCaffrey (1976) provided a pre-hunting season estimate of 6.9 deer per 259 ha (1 square mile). This figure was approximately one-half of the overwinter management goal of 15 deer per 259 ha of deer range proposed by the DNR for that region (Johnson, 1981). Deer densities in northern Wisconsin were, however, increasing in the late 1970's following a series of mild winters. More recent estimates based on the sex-age-kill method from the 1981 hunting season indicated a high density of approximately 19 deer per 259 ha of deer range in Management Unit 44 which encompasses the site area (Eckstein, 1982).

For assessing the reduction in carrying capacity and its effect on white-tailed deer, the overwinter estimate of 19 deer per 259 ha (1 square mile) for 1981, as determined by the DNR, was utilized. This figure, although unusually high, projects a total decrease of approximately 22 deer because of loss of habitat during Project construction activities (Table 4.1-7). This decrease represents approximately 3 percent of the total deer harvested from Management Unit 44 in 1981. The potential effect of the Project in a more typical year in terms of total deer lost would be less.

4.1.6.2.2 Birds

Veery - The veery was recorded in upland communities (aspen/birch, northern hardwoods, young aspen) in 1978 and in each of the wooded wetland types on the site during the 1981 surveys. Preferred habitat is damp deciduous woods (Peterson, 1980), swamps, bogs, brushy areas, and deciduous woods (Barter et al., 1975).

The veery is a summer resident throughout Wisconsin (Barter et al., 1975). Mean density estimates for this species in May 1981 in the wetland study area ranged from 2.3/40.5 ha (100 acres) (coniferous swamp) to 87.1/40.5 ha (shrub swamp). In June the estimates ranged from 10.3/40.5 ha (bog) to 44.9/40.5 (shrub swamp) (NAI and IEP, Inc., 1982). Average densities of 16/40.5 ha and 11/40.5 ha were recorded on two different transects during June 1978 in a mixture of both upland and wetland habitats in the wetland study area (Section 2.6, Table 2.6-20).

For comparison to the site-specific data given above, Aune (1978, 1979, 1980, 1981) reported breeding densities of veerys consistently between 10 and 12 singing males per 40.5 ha (100 acres) (total 20 to 24 birds/40.5 ha) in a mixed wetland area of Waukesha

County, Wisconsin. His study area included tamarack and aspen groves, shrub community, and wet meadow.

For assessing the loss of carrying capacity for this species, a mean density of 22 birds/40.5 ha (100 acres) was assumed (average of June 1981 wetland surveys). This figure compares favorably with Aune's (1978, 1979, 1980, 1981) breeding estimates for veerys in southeastern Wisconsin. Using this estimate, the loss of carrying capacity for veerys on the site area will be approximately 162 birds (Table 4.1-7). Because this species is common throughout northern Wisconsin, this loss will be negligible.

Ruffed Grouse - Drumming counts of ruffed grouse on the site area in the spring of 1978 indicated an average of 1.4 males/40.5 ha (100 acres) (total 2.8 grouse/40.5 ha) (Chapter 2, Section 2.6). Kubisiak et al. (1980) reported that grouse densities between 1968 and 1977 in the Stone Lake Experimental Area, Oneida County, varied from a low of 0.5 drumming males/40.5 ha to a high of 1.8/40.5 ha, with a mean of 1.0/40.5 ha.

For assessing the effect on carrying capacity for this species, the average density reported by Kubisiak et al. (1980) of 1.0 drumming male/40.5 ha (100 acres) (total 2.0 grouse/40.5 ha) was used. Based on this population density, an estimated decrease of approximately 15 grouse will occur because of habitat reduction (Table 4.1-7). This reduction in grouse carrying capacity will be minor and the effect on recreational hunting is considered negligible.

4.1.6.2.3 Amphibians and Reptiles

Wood Frog - In the 1981 surveys conducted in the wetland study area, wood frogs were common in all major wetland types except coniferous swamp and marsh (NAI and IEP, Inc., 1982). This species was abundant near open water in spring, and was frequently seen in upland habitats in summer in the site area (Chapter 2, Section 2.6).

For estimating the loss of carrying capacity for wood frogs, a population density of 20.2 frogs/ha (50 per acre) was assumed based on the minimum home range size as reported by Bellis (1961). This figure is considered conservative because there is no evidence that wood frogs are territorial. More site-specific estimates of wood frog densities are not available.

Project construction will result in a reduction of the site area's carrying capacity for wood frogs (Table 4.1-7). This should not, however, be of regional importance.

4.1.6.3 Threatened and Endangered Species

4.1.6.3.1 Mammals

There are no mammalian species listed as threatened by the DNR and only three as endangered: pine marten (*Martes americana*), Canada lynx (*Lynx canadensis*), and timber wolf (*Canis lupis*). Only the timber wolf is federally listed as endangered (Wisconsin DNR, 1979). There is no evidence of any use of the Project site area by these species (Chapter 2, subsection 2.6.5.2).

4.1.6.3.2 Birds

Of the eight bird species listed as endangered by the DNR, only the bald eagle (*Haliaeetus leucocephalus*) and osprey (*Pandion* haliaetus) occur in the wetland study area. The eagle is also listed as federally threatened. Of the six species listed as threatened by the DNR only the Cooper's hawk (Accipter cooperii) and red-shouldered hawk (Buteo lineatus) have been observed in the environmental study area (Chapter 2, subsection 2.6.5.2).

The location and status of bald eagle and osprey nests near the Project site area are summarized in Chapter 2, Section 2.6. Both species are presumed to be using the lakes in the vicinity for preying upon fish and waterfowl. As the proposed construction activities are expected to have minimal effect on open water, no major loss of feeding habitat for either eagles or ospreys is expected.

Project construction activities will result in the loss of approximately 266 ha (656 acres) of upland, wooded habitat and some wooded wetlands (Table 4.1-3) utilized by the Cooper's hawk. The species' diet is chiefly birds and some mammals with its preferred habitat being "broken woodlands" and "river groves" (Peterson, 1980). Populations of Cooper's hawks appear to be increasing and the species has recently been removed from the Audubon Society's "Blue List" of threatened species (Tate and Tate, 1982). From a regional perspective, there appears to be no shortage of suitable habitat for this species and the consequences from Project construction activities should be minimal.

4.1.6.3.3 Amphibians and Reptiles

The status of threatened and endangered herptiles in the Project site area is summarized in Chapter 2, subsection 2.6.5.2. There are no federally listed endangered or threatened amphibians or reptiles in the site area. Of the ten species of amphibians listed as either endangered or threatened by the DNR, only two, wood turtle (Clemmys insculpta) and Tremblay's salamander (Ambystoma tremblayi), have ranges and habitat preferences that make their occurrence in the environmental study area possible. None of the amphibians or reptiles listed by the DNR as either threatened or endangered have been observed in the Project area (Chapter 2, subsection 2.6.5.2). Neither the wood turtle nor Tremblay's salamander have been reported in Forest County (Vogt, 1981). Because neither of these species has been sighted in the vicinity of the Project site area, the effects of construction activities should be inconsequential.

4.1.7 Cultural Resources

No adverse effects or other impacts on cultural resources will derive from construction of the mine/mill site, MWDF, MRDF and reclaim pond sites, or construction in corridors for power transmission, transportation (haul road, access road and railroad spur), and pipelines (tailings transport and water discharge). Current Project site management practices foster enhanced protection for cultural resources identified during the inventories by prohibiting unauthorized access to areas where sites are located. Identified archaeological sites eligible for the National Register of Historic Places are thus protected from vandals. Tables 4.1-8 and 4.1-9 provide the impact analysis for cultural resources identified and interpreted during archaeological and historical inventories and evaluations (see Salzer and Birmingham, 1978; MacDonald and Mack Partnership, 1982; Overstreet and Brazeau, 1982; Overstreet 1982, 1983).

TABLE 4.1-8

IMPACT ANALYSIS FOR ARCHAEOLOGICAL SITES IN THE CRANDON PROJECT AREA

SITE	DESCRIPTION	IMPACT SOURCE*	MITIGATION
4855	Prehistoric	East exhaust	None, site determined insignificant by evaluation.
4854	Historical sugar camp	Mine/mill site	Mitigation completed by mapping and removal of artifacts
4856	Historic logging	Mine/mill site	Mitigation completed by mapping and removal of artifacts.
4849	Prehistoric	None anticipated	None, site determine insignificant by evaluation
4850	Recent logging	None anticipated	Site to be preserved in place
4851	Recent logging	None anticipated	Site to be preserved in place
4852	Historic midden	None anticipated	Site to be preserved in place
4853	Historic and prehistoric	None anticipated	Site to be preserved in place.
4857	Natural rock fractures	None anticipated	None, site determined insignificant by evaluation
4858	Natural rock	None anticipated	None, site determined insignificant by evaluation

TABLE 4.1-8 (continued)

SITE	DESCRIPTION	IMPACT SOURCE*	MITIGATION
4862	Historic	None anticipated	Isolated find, insignificant, lacks archaeological context
47Fr149	20th Century logging	None anticipated	None, site determined insignificant by evaluation
Not Assigned	Historic settlement	Rail corridor	None, site determined insignificant by evaluation
Not Assigned	Recent structure	Rail corridor	None, site determined insignificant by evaluation
47Fr121	Prehistoric	None anticipated	Site to be preserved in place
47Fr143	Prehistoric	None anticipated	Site to be preserved in place
47Fr145	Historic logging	None anticipated	Site to be preserved in place
47Fr146	Historic logging	None anticipated	Site to be preserved in place
47Fr148	Historic logging	None anticipated	Site to be preserved in place
47Lg23	Historic logging	None anticipated	Site to be preserved in place
47Fr144	Historic logging	None	Site located outside of Project area
47Fr150	Historic homestead	Mine/mill site	None, site determined insignificant by evaluation
47Fr151	Historic logging	None	Site located outside of Project area

*See Figure 4.0-1 for location of Project facilities.

TABLE 4.1-9

IMPACT ANALYSIS FOR HISTORICAL SITES
IN THE CRANDON PROJECT AREA

SITE	DESCRIPTION	IMPACT SOURCE*	MITIGATION
4859	Utilitarian, gable roofed residence 1964	None anticipated	None, structure determined insignificant by evaluation
4859	Utilitarian tool barn, ca. 1920	None anticipated	None, structure determined insignificant by evaluation
4859	Utilitarian hay barn, ca. 1920	None anticipated	None, structure determined insignificant by evaluation
4860	Utilitarian gable roofed residence	None anticipated	None, structure determined insignificant by evaluation
4861	Utilitarian gable roofed shack, post-1930	None anticipated	None, structure determined insignificant by evaluation

*See Figure 4.0-1 for the location of Project facilities.

4.1.8 Noise

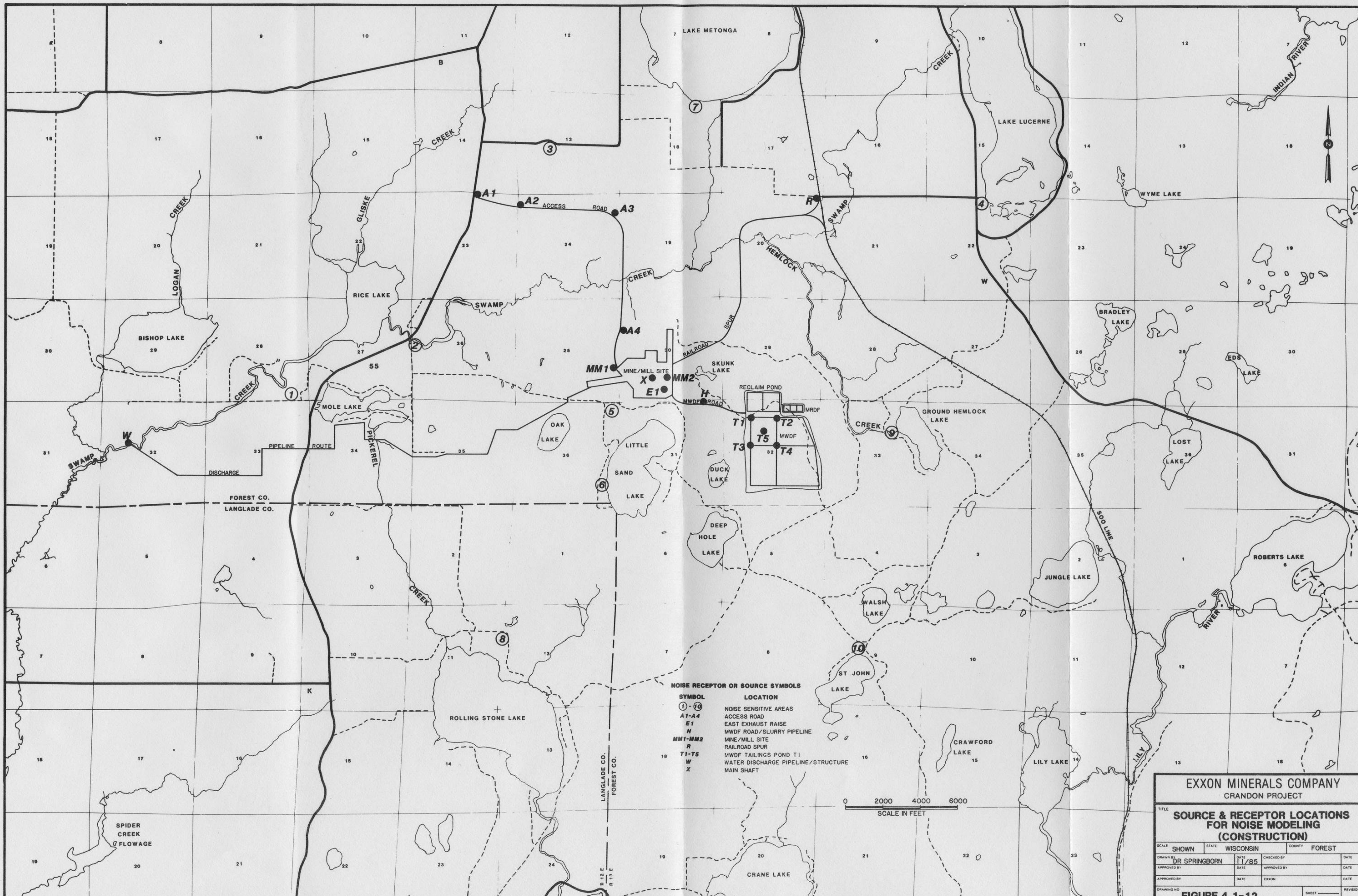
The noise-sensitive areas in the environmental study area have been described in Section 2.8. Background sound level measurements at six locations representative of these noise-sensitive areas were obtained in 1977 during the summer and winter and at an additional four locations in the winter and summer of 1983. The locations representing noise-sensitive areas are presented on Figure 4.1-12 and their approximate distances from the principal construction phase activities within the Project boundary are listed in Appendix 4.1B.

Construction activity will occur in several phases which includes: site clearing, grading, and excavation; equipment erection; facility fabrication; and finish work and landscaping. The following activities were included in the modeling of the construction phase noise sources:

1) Mine/mill site (MM1, MM2);
2) MWDF area (T1, T2, T3, T4, T5);
3) Access road (A1, A2, A3, A4);
4) Railroad spur (R);
5) Haul road (H);
6) Tailings transport pipeline (H); and
7) Water discharge structure (W).

The noise source locations used for the modeling are shown on Figure 4.1-12.

Daytime construction noise was based upon the "worst-case" assumption that construction activities will occur simultaneously at the mine/mill site locations, MWDF area, access road, railroad spur, haul

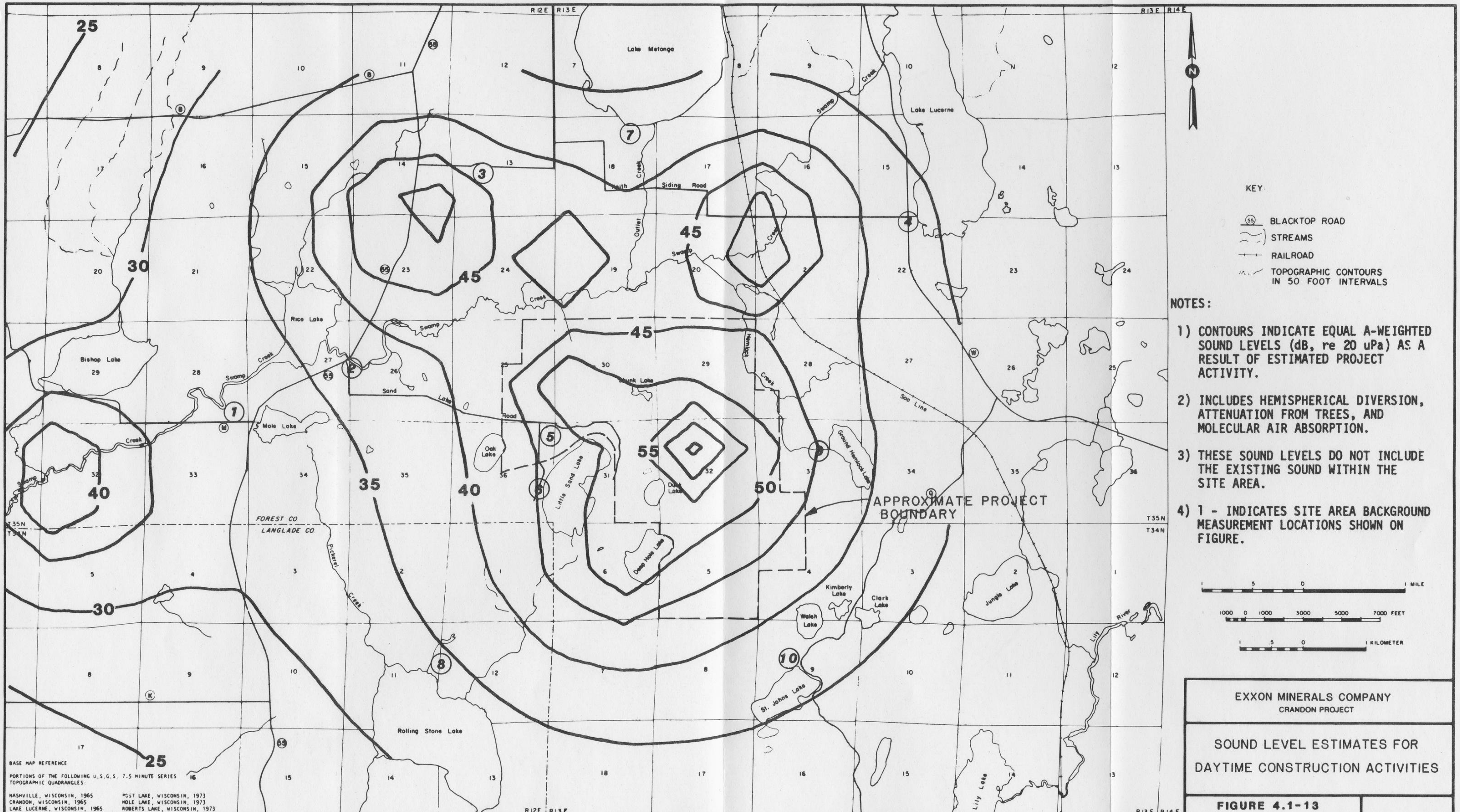

LAKE METONGA
LAKE LUCERNE
WYME LAKE
INDIAN RIVER
CREEK
GLISKE
LOGAN
RICE LAKE
BISHOP LAKE
SWAMP
ACCESS ROAD
A1
A2
A3
A4
MM1
MINE/MILL SITE
MM2
X
E1
H
MWDF ROAD
RAILROAD SPUR
HEMLOCK
R
SKUNK LAKE
RECLAIM POND
MRDF
T1
T2
T3
T4
T5
MWDF
GROUND HEMLOCK LAKE
BRADLEY LAKE
EDS LAKE
LOST LAKE
MOLE LAKE
PICKEREL
PIPELINE ROUTE
DISCHARGE
W
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
FOREST CO.
LANGLADE CO.
SOO LINE
ROBERTS LAKE
JUNGLE LAKE
RIVER
WALSH LAKE
ST JOHN LAKE
ROLLING STONE LAKE
CRAWFORD LAKE
LILY LAKE
LILY
SPIDER CREEK FLOWAGE
CRANE LAKE
LANGLADE CO.
FOREST CO.
R 12 E
R 13 E
55
K
B
NOISE RECEPTOR OR SOURCE SYMBOLS
SYMBOL — LOCATION
1-10 — NOISE SENSITIVE AREAS
A1-A4 — ACCESS ROAD
E1 — EAST EXHAUST RAISE
H — MWDF ROAD/SLURRY PIPELINE
MM1-MM2 — MINE/MILL SITE
R — RAILROAD SPUR
T1-T5 — MWDF TAILINGS POND T I
W — WATER DISCHARGE PIPELINE/STRUCTURE
X — MAIN SHAFT
0 2000 4000 6000
SCALE IN FEET
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
SOURCE & RECEPTOR LOCATIONS FOR NOISE MODELING (CONSTRUCTION)
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 11/85
CHECKED BY
APPROVED BY
EXXON
DRAWING NO
FIGURE 4.1-12
SHEET
OF
REVISION NO

road, tailings transport and water discharge pipelines, and the water discharge structure location. Nighttime construction noise was based only on the simultaneous construction activity at the mine shaft, and east and west exhaust raise locations in the mine/mill site, modelled at Locations MM1 and MM2, respectively, but no equipment noise sources from the MWDF area, access road, railroad spur, haul road, tailings transport and water discharge pipelines, and the water discharge structure location (see Figures 4.1-12 and 4.1-14). As shown in Appendix 4.1B, the estimated noise effect associated with the construction phase traffic increase on Highway 55 is small and, therefore, has not been included in the computer calculations.

Sound power levels for the equipment associated with the excavation activities are presented in Appendix 4.1B. With these source sound power levels modelled at the locations on Figure 4.1-12, the resulting sound pressure levels can be calculated at any receiver location. The model accounts for hemispherical divergence, atmospheric losses and attenuation from trees (see Appendix 4.1B). Using the computer model described in Appendix 4.1B, plots of equi-A-weighted sound level contours were prepared from these computer calculations (see Figures 4.1-13, 4.1-14, 4.2-9 and 4.2-10). The computer model allowed this multiplicity of calculations for a general grid in addition to the computations at the noise sensitive receiver locations.

4.1.8.1 Construction Phase Noise Impact Assessment

The State of Wisconsin does not have community noise control regulations or standards. The U.S. EPA has identified a day-night sound level of 55 dB as requisite to protect public health and welfare with a



NOTES:

1) CONTOURS INDICATE EQUAL A-WEIGHTED SOUND LEVELS (dB, re 20 uPa) AS A RESULT OF ESTIMATED PROJECT ACTIVITY.

2) INCLUDES HEMISPHERICAL DIVERSION, ATTENUATION FROM TREES, AND MOLECULAR AIR ABSORPTION.

3) THESE SOUND LEVELS DO NOT INCLUDE THE EXISTING SOUND WITHIN THE SITE AREA.

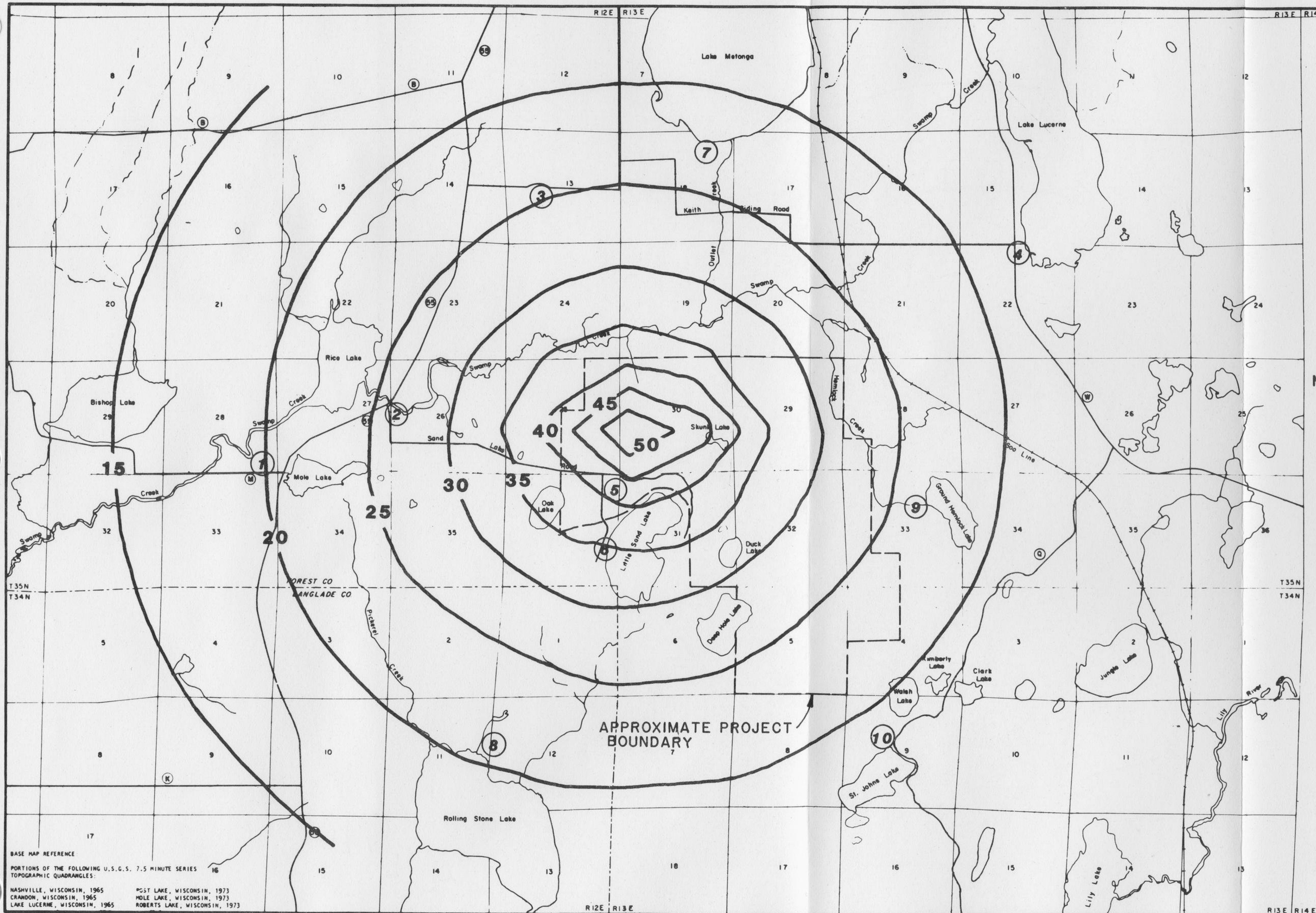
4) 1 - INDICATES SITE AREA BACKGROUND MEASUREMENT LOCATIONS SHOWN ON FIGURE.

EXXON MINERALS COMPANY

CRANDON PROJECT

SOUND LEVEL ESTIMATES FOR DAYTIME CONSTRUCTION ACTIVITIES

FIGURE 4.1-13



KEY

- 55 BLACKTOP ROAD
- STREAMS
- RAILROAD
- TOPOGRAPHIC CONTOURS IN 50 FOOT INTERVALS

NOTES:

1) CONTOURS INDICATE EQUAL A-WEIGHTED SOUND LEVELS (dB, re 20 uPa) AS A RESULT OF ESTIMATED PROJECT ACTIVITY.

2) INCLUDES HEMISPHERICAL DIVERSION, ATTENUATION FROM TREES, AND MOLECULAR AIR ABSORPTION.

3) THESE SOUND LEVELS DO NOT INCLUDE THE EXISTING SOUND WITHIN THE SITE AREA.

4) 1 - INDICATES SITE AREA BACKGROUND MEASUREMENT LOCATIONS SHOWN ON FIGURE.

1 .5 0 1 MILE

1000 0 1000 3000 5000 7000 FEET

1 .5 0 1 KILOMETER

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SOUND LEVEL ESTIMATES FOR NIGHTTIME CONSTRUCTION ACTIVITIES

FIGURE 4.1-14

conservative margin of safety (U.S. EPA, 1974). Since sound levels in most communities in the United States generally exceed this level, the agency has identified an L_{dn} of 65 dB as its short-term goal and an L_{dn} of 55 dB as its long-term goal.

The A-weighted sound level contours presented on Figures 4.1-13 and 4.1-14 represent results for average conditions. Higher or lower sound levels could occur depending upon atmospheric conditions, such as temperature inversions which cause focusing or defocusing. The extreme fluctuations of sound pressure levels (refractive focusing or defocusing) predicted by Thompson (1981) (in the order of 10 to 20 dB) were estimated from measurements at locations in complex terrain with the presence of mountain tops and air mass drainage effects which are not present in the site area. Nevertheless, refractive focusing (or defocusing) may occur, but the magnitude of any increase or decrease in sound levels will be less than 20 dB because of the filtering (attenuation) effect of the forest (Roth, 1983).

The total "worst-case" sound level contribution from construction phase activity at the noise sensitive locations is shown in Table 4.1-10. Background and construction activity sound levels and the change from the background sound levels are also included in this table. Computed background sound levels resulting from the truncation of the measured histograms to eliminate short duration, high level intrusions are identified by footnote in Table 4.1-10 and the method used to obtain these values was discussed in subsection 2.8.2. The values resulting from the combination of the contributed construction activity sound levels with the adjusted background data are used in this evaluation.

TABLE 4.1-10

CONSTRUCTION PHASE EFFECT ON BACKGROUND SOUND LEVELS[a]

LOCATION	BACKGROUND L_d	BACKGROUND L_n	BACKGROUND L_{dn}	CONSTRUCTION NOISE L_A DAY	CONSTRUCTION NOISE L_A NIGHT	TOTAL[b] NOISE DURING CONSTRUCTION L_d	TOTAL[b] NOISE DURING CONSTRUCTION L_n	TOTAL[b] NOISE DURING CONSTRUCTION L_{dn}	CHANGE L_d	CHANGE L_n	CHANGE L_{dn}
WINTER											
1	42.8	29.8	41.9	32.0	20.1	43.1	30.2	42.3	0.3	0.4	0.4
2	37.9	28.5	38.1	36.6	25.7	40.3	30.3	40.3	2.4	1.8	2.2
3	39.3	23.9	38.0	43.3	24.2	44.8	27.1	43.1	5.5	3.2	5.2
4	43.7 (43.4)[c]	35.1	44.2 (44.1)[c]	36.6	18.0	44.5 (44.2)[d]	35.2	44.8 (44.6)[d]	0.8 (0.8)[d]	0.1	0.5 (0.5
5	42.4	50.5 (37.7)[c]	56.4 (45.2)[c]	49.0	45.2	49.9	51.6 (45.9)[d]	57.8 (53.2)[d]	7.5	1.1 (8.2)[d]	1.5 (8.0
6	51.6 (42.1)[c]	19.0	49.5 (40.2)[c]	44.7	34.6	52.4 (46.6)[d]	34.7	50.8 (46.0)[d]	0.8 (4.5)[d]	15.7	1.2 (5.8
7	44.8	41.8	48.8	37.5	22.1	45.5	41.8	49.0	0.7	0.0	0.2
8	34.2	30.8	37.9	35.9	22.6	38.1	31.4	39.7	3.9	0.6	1.8
9	33.4	30.0	37.1	44.4	23.6	44.7	30.9	43.7	11.3	0.9	6.6
10	33.4	31.0	37.8	37.1	18.7	38.6	31.2	39.8	5.2	0.2	2.0
SUMMER											
1	46.6	42.7	49.9	32.0	20.1	46.7	42.7	50.0	0.1	0.0	0.1
2	42.1	39.7	46.5	36.6	25.7	43.2	39.9	46.9	1.1	0.2	0.4
3	47.1 (44.4)[c]	44.1	51.1 (50.5)[c]	43.3	24.2	48.6 (46.8)[d]	44.1	51.5 (51.0)[d]	1.5 (2.5)[d]	0.0	0.5 (0.5)
4	63.8	47.0	62.3	36.6	18.0	63.8	47.0	62.3	0.0	0.0	0.0
5	58.6	26.5	56.6	49.0	45.2	59.1	45.3	58.0	0.5	18.8	1.4
6	38.0	38.6	44.9	44.7	34.6	45.5	40.1	47.8	7.5	1.5	2.9
7	47.5	41.3	49.3	37.5	22.1	47.9	41.4	49.5	0.4	0.1	0.2
8	40.7	39.6	46.2	35.9	22.6	41.9	39.7	46.5	1.2	0.1	0.3
9	42.7	27.4	41.4	44.4	23.6	46.6	28.9	45.0	3.9	1.5	3.7
10	38.6	28.1	38.4	37.1	18.7	40.9	28.6	40.2	2.3	0.5	1.8

[a] All sound levels are A-weighted in dB.

[b] Background plus construction phase noise.

[c] Measured background values were adjusted to reduce the contribution from short duration, high sound pressure level sources (Tans, 1984).

[d] Construction phase change in values based on adjusted background data.

During winter construction phase activities, estimated day-night sound levels will meet the U.S. EPA long-term goal of 55 dB at all locations. During the summer, estimated day-night sound levels from construction phase activities will meet the short-term goal of 65 dB at all locations and the long-term goal of 55 dB will be met at all locations except for Locations 4 and 5 (Table 4.1-10). Presently, day-night sound levels exceed the U.S. EPA long-term goal at Locations 4 and 5.

Both the Federal Highway Administration (FHWA) and the Department of Housing and Urban Development (HUD) have adopted criteria to assess noise impact and to minimize the effect of noise on people consistent with the 55 dB L_{dn} established by EPA (see Appendix 4.1B). Based on these criteria, the expected community reaction to L_{dn} sound levels will be slight to moderate, if any, at all measurement locations. Under certain meteorological conditions, Project-related sound levels can be greater or considerably less than those projected. These fluctuations above or below the projected construction phase sound levels will not affect public health and welfare and will be short-term in nature. See subsection 4.2.8.3 for a discussion of the effects of noise on wildlife.

With the exception of Location 6, construction phase L_{dn} sound levels do not exceed 45 dB at any location for which the background measured L_{dn} did not exceed 45 dB. At most locations the estimated changes to background are less than 5 dB. Additional discussion of the data in Table 4.1-10, including estimated L_{dn}, L_d, L_n changes compared to background sound levels, is presented in Appendix 4.1B.

4.1.8.2 Noise Effects of Blasting During Mine Construction

Blasting operations during shaft sinking will not constitute a principal sound emitting activity. During construction of the main shaft, blasting may be required to reduce in size any large boulders that are encountered in the glacial till. Also, blasting will be necessary when bedrock is encountered during shaft sinking. Noise generated from a confined shaft blast will be of a short duration high pressure level, and will not be unlike intermittent noises already present in the site area (e.g., chainsaws, motor boats, and snowmobiles).

Air blast effects, and noise and concussion, will be primarily controlled by the use of low charge weight per delay blasting practices. The deep shaft collars, headframe structures, and/or collar blasting doors will attenuate the intermittent air blast effects of shaft sinking to the extent that even immediate construction site annoyance will be minimal and any possibility of site structure damage eliminated.

4.1.8.3 Seismic Effects of Blasting During Mine Construction

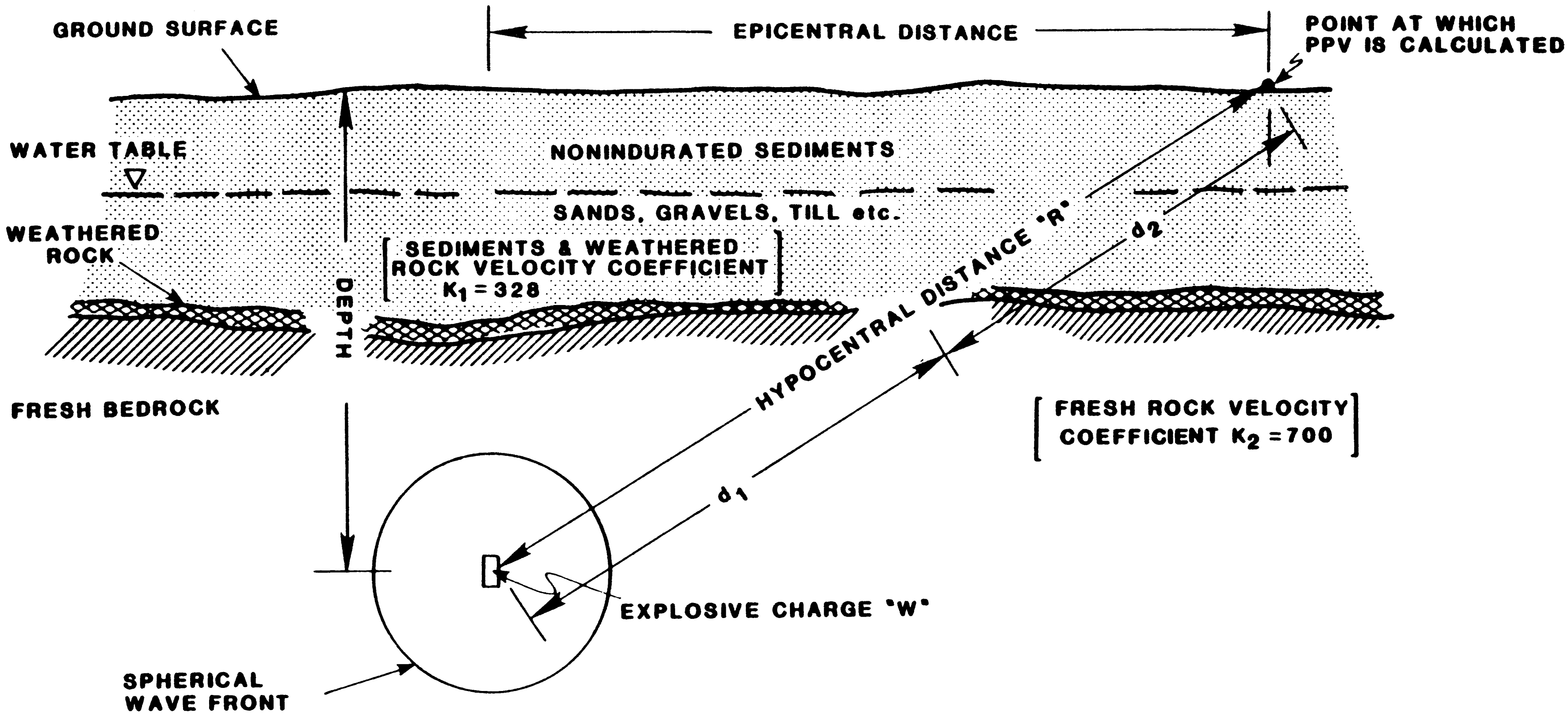
Prior to any blasting operations at the Crandon site, a Pre-Blasting Survey will be conducted in accordance with NR 132.07 (5). Procedural details for the documented inspection of all permanent structures within a 0.8-km (0.5-mile) radius of the blasting sites are a part of the Project Monitoring and Quality Assurance Plan. Similarly referenced is the Blast Monitoring Plan, for use in verifying mining design parameters during initial mine construction and operational blasting events.

Seismic effects from construction phase blasting activities were evaluated using the empirical relationship suggested by Ambraseys and Hendron (1968) and are illustrated on Figure 4.1-15. Peak particle velocities were estimated considering the explosives charge weight, its detonation depth, and the character of the geomedia propagating the resultant stress wave. Investigators responsible for blasting effects studies, such as U.S. Bureau of Mines (USBM), Canada Centre for Mineral and Energy Technology (CANMET), and VIBRA-TECH, have recommended threshold values of 50.8 mm/s (2.0 inches per second) and 5.08 mm/s (0.2 inches per second) for blast induced seismic damage and human response, respectively.

The evaluation of the peak particle velocity versus epicentral observation distance plots indicates that seismic intensity in the immediate mine/mill area will be maintained at less than the 50.8 mm/s (2.0 inches per second) potential seismic damage limits. Furthermore, none of the planned construction phase blasting events will produce noticeable (5.08 mm/s [0.2 inches per second]) seismic pulses at the 0.8-km (0.5-mile) mine/mill site monitoring boundary (see Figure 4.1-16).

4.1.8.4 Noise Mitigative Controls

The primary objective of the noise mitigative controls is to reduce off-site sound level contributions from the construction of Project facilities. Abatement of all construction phase sound is not possible. Two types of mitigative measures will be used to reduce the



METHOD OF ESTIMATING "WEIGHTED" PEAK PARTICLE VELOCITY

PEAK PARTICLE VELOCITY (PPV)(mm/sec) $= (1.8)\left[\frac{d_1}{R}K_1 + \frac{d_2}{R}K_2\right]\frac{W^{\alpha}}{R^{\beta}}$

WHERE:

K_1 = VELOCITY COEFFICIENT FOR NON-INDURATED SEDIMENTS (328)
K_2 = VELOCITY COEFFICENT FOR FRESH ROCK (700)
d_1 = DISTANCE WAVE FRONT TRAVELS IN NON-INDURATED SEDIMENTS, (m)
d_2 = DISTANCE WAVE FRONT TRAVELS IN FRESH ROCK(m)
R = HYPOCENTRAL DISTANCE (m)
W = CHARGE WEIGHT (kg)
α = 0.73 β = 1.75

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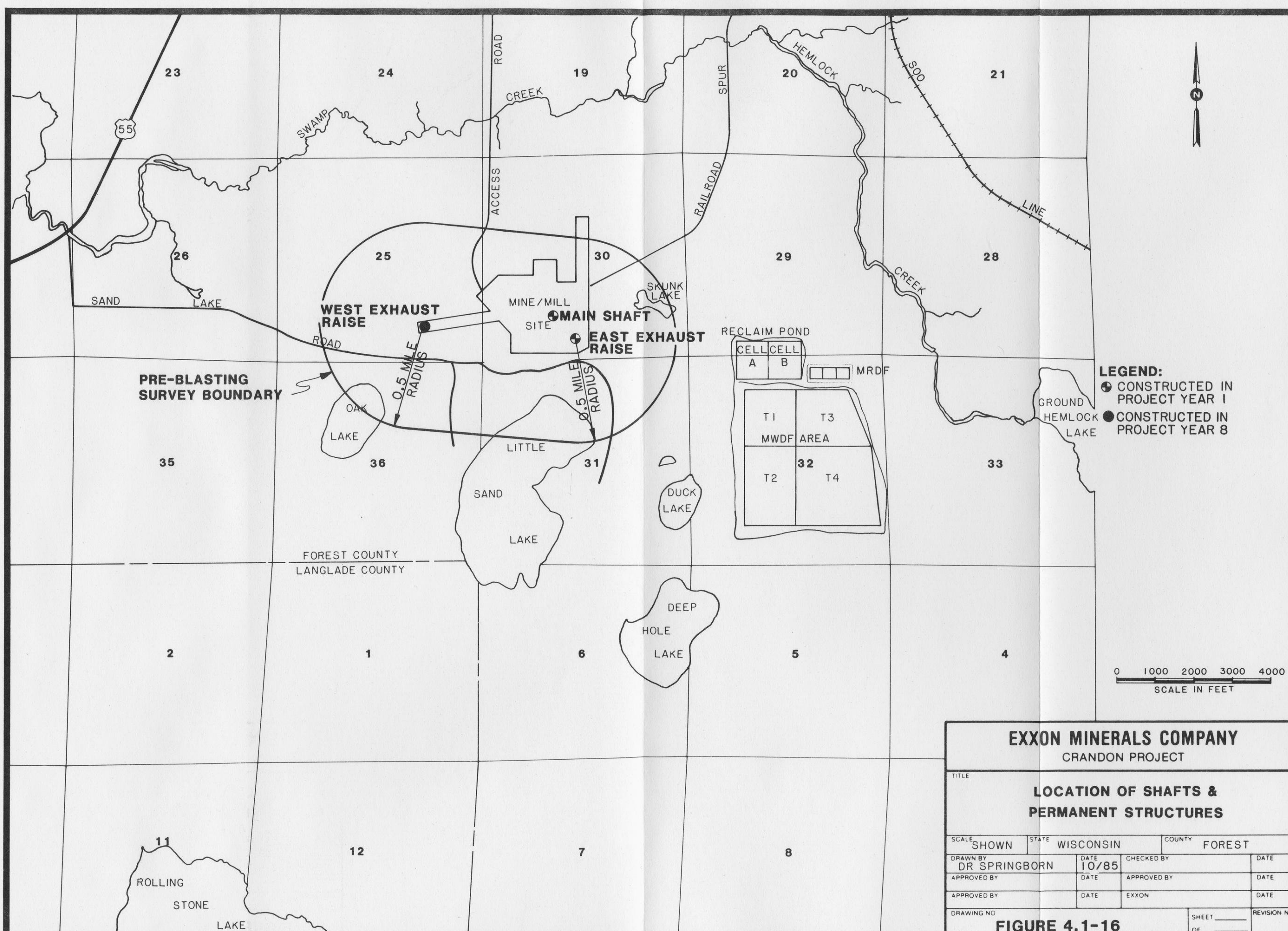
TITLE: CRANDON BLASTING VIBRATION ESTIMATE PEAK PARTICLE VELOCITY MODEL			
SCALE: NONE	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY	DATE	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	ESSION	DATE
DRAWING NO: FIGURE 4.1-15	SHEET ___ OF ___	REVISION NO	


23
24
19
20
21
ROAD
ACCESS
SWAMP
CREEK
55
SPUR
RAILROAD
HEMLOCK
CREEK
SOO
LINE
N
26
25
30
29
28
SAND
LAKE
ROAD
WEST EXHAUST
RAISE
MINE/MILL
SITE
MAIN SHAFT
EAST EXHAUST
RAISE
SKUNK
LAKE
RECLAIM POND
CELL
A
CELL
B
MRDF
PRE-BLASTING
SURVEY BOUNDARY
0.5 MILE
RADIUS
0.5 MILE
RADIUS
OAK
LAKE
LITTLE
SAND
LAKE
T1
T3
MWDF AREA
T2
T4
32
GROUND
HEMLOCK
LAKE
LEGEND:
CONSTRUCTED IN
PROJECT YEAR 1
CONSTRUCTED IN
PROJECT YEAR 8
35
36
31
33
DUCK
LAKE
FOREST COUNTY
LANGLADE COUNTY
DEEP
HOLE
LAKE
2
1
6
5
4
0 1000 2000 3000 4000
SCALE IN FEET
11
12
7
8
ROLLING
STONE
LAKE
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
LOCATION OF SHAFTS &
PERMANENT STRUCTURES
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 4.1-16
SHEET
OF
REVISION NO

noise from sources which are most likely to affect residential areas. They are administrative and engineering controls.

Administrative controls generally modify construction procedures or work practices and thus serve to reduce, eliminate, or shorten the duration of the noise emanations. These procedures are generally directed at controlling worker's actions, and therefore, controlling the noise produced by those actions. Engineering controls are associated with physical changes to the noise source. They may take the form of source relocation, replacement, or modification (e.g., the addition of an improved muffler to a diesel engine). Engineering controls are specific to the noise generator. Planned administrative and engineering controls are described below:

Administrative

1) Posting of speed limits;

2) Limiting engine idling of mobile equipment during periods of inactivity;

3) Limiting certain activities to daytime hours, where feasible. Such activities, as currently proposed, include daytime construction only of the MWDF, access road, railroad spur and general surface facilities; and

4) Construction contractors will be encouraged to substitute quiet processes or machinery for noisy processes or machinery.

Engineering

1) Installation and maintenance of mufflers on all internal combustion engines;

2) Maintenance of equipment to assure proper operating conditions thus minimizing their noise emissions; and

3) Construction contractors will be encouraged to provide quieted versions of the machinery to be used on the site.

4.1.9 Land Use and Aesthetics

4.1.9.1 Local Land Uses

4.1.9.1.1 Forestry

The impacts of Project construction on land classified for forestry use will be limited to the duration of Project life and will be reversible. Within the environmental study area, approximately 19,830 ha (49,000 acres) are classified for forestry use. Of this total, less than 1 percent, or 298 ha (735 acres), as identified below and in Table 4.1-3, is likely to be disturbed during construction of the Project.

Project Facility	Approximate Area Disturbed ha	acres
Mine Waste Disposal Area (including Reclaim Pond)	200.5	495
Mine/Mill Facilities	46.1	115
Access Road	14.2	35
Railroad Spur	18.0	45
Haul Road/Tailings Transport Corridor	2.0	5
Water Discharge Pipeline	14.0	35
TOTAL	297.7	735

Relative to the total Project acreage, the disturbed area will account for approximately 19 percent of the 3,224-ha (7,960-acre) total. Merchantable timber will be harvested in those areas designated for construction purposes. An appraisal of merchantable forest products within the Project area and recommendations for a forest management program are presented in Steigerwaldt (1982). This program was developed for all Exxon fee owned lands as well as that acreage on which Exxon only holds a land purchase option. Landscaping techniques will create small, isolated areas of forested land within the immediate area of the Project facilities. These landscaping activities will further serve to decrease the total area of disturbance.

The Exxon-controlled forestry acreage in the vicinity of the proposed Project facilities that is not disturbed during construction activities will be managed to maintain maximum forestry use and minimum disturbance. Advice of professional forestry consultants and the DNR will be sought to ensure a sound timber management program is developed.

Reclamation of the Project area at the end of mine life will permit about 95 percent of the acreage disturbed to revert to its original forestry use. In this sense, the disturbance of most forestry lands will be minimal, of relative short duration and reversible. The Reclamation Plan contains further information on the procedures and schedule for reclaiming land disturbed during construction activities.

4.1.9.1.2 Agriculture

Within the Project boundary there is only a small area of land classified as agricultural. There are no agricultural lands or old agricultural-related fields having agricultural potential within the mine/mill site, haul road/tailings transport corridor, or the reclaim pond and MWDF area.

Both the access road and railroad spur will cross agricultural acreage currently being utilized for livestock production and forage crops. Approximately 6 ha (15 acres) will be removed from agricultural use. However, all of this area will be allowed to return to its original agricultural land use following mine closure and final reclamation. Construction of the water discharge pipeline will temporarily affect approximately 2 ha (5 acres) of agricultural land; however, this area will be reclaimed within 1 year and can return to agricultural use.

4.1.9.1.3 Recreation

Construction of the Project should not adversely impact any of the following recreational resources:

1) Water-based activities: swimming, boating, water skiing, fishing, or canoeing;
2) Land-based activities: camping, hiking, bicycling, or horseback riding; and
3) Snow-based activities: cross-country skiing or snowmobiling.

The fencing of property to provide security for the proposed facilities will preclude the use of approximately 231 ha (570 acres) of forest land for hunting and other forms of recreation. The acreage, thus removed from the total hunting area in Forest County, will be less than 1 percent and, except for local residents, the consequence is considered minor. Upon mine closure and reclamation, the fence around the mine/mill site will be removed and the area can then be opened for recreational activities. A security fence will be maintained around the MWDF area during the 30-year long-term care period and no forestry or recreation uses will be permitted within the confines of the fenced area.

4.1.9.1.4 Residential

Construction activities will not displace or alter any residences. Therefore, the effect of construction on residences or land classified as residential will be minimal.

Construction of the Crandon Project will result in minimal changes to the ambient air quality, as described in subsection 4.1.1, and to the level of noise immediately adjacent to the facilities (subsection 4.1.8). The magnitude of any changes will decrease with distance from the facilities. Domestic water wells within the near vicinity will be impacted as the water table is drawn down during mine dewatering. Exxon will mitigate this impact by deepening the affected wells, constructing new wells, or providing potable water. Otherwise, residential areas concentrated in lakeshore developments should not be affected by Project development. During construction, aesthetic values will be impacted only by the presence of the headframe which will project about 23 m (75 feet) above the level of the trees. However, because of the forested vegetation, the number of residential locations to be visually impacted will be minimal. Except for the access road and railroad spur, Project construction activities will not be readily visible from residential areas.

Exxon Minerals Company currently owns 22 homes in the area of Little Sand Lake. These homes are in varying stages of construction and completeness, with approximately twelve being available for use on a year-round basis if properly renovated. Those homes which can be converted to year-round use could be available to the local housing stock on a lease basis. Of the remaining homes, several could possibly be utilized on a seasonal basis if justified by demand. Eventually, a few of the houses may have to be removed because renovation cost, even for seasonal use, cannot be justified.

An analysis of potential changes in population and housing units within the local study area is presented in subsection 4.2.10.

4.1.9.1.5 Commercial and Industrial

There are few commercial and industrial establishments within the environmental study area (Chapter 2, Section 2.10). The majority of these are service oriented. For those businesses providing services to tourist-oriented trade, the effects of construction will be positive. Automotive-related and light-construction industry should also reflect economic benefits.

Concentrations of commercial development in areas around the Project area will tend to attract additional development. Modest retail development will probably occur in response to the need for additional services. This development should be positive in terms of its effect on economic factors.

There is potential for increased commercial and industrial development in population centers within the local study area, and the impact on community sociocultural and economic conditions is discussed in subsection 4.2.10.

There are no commercial or industrial establishments within the Project boundary or immediate site area. Therefore, there will be no impacts to the land use for these categories.

4.1.9.1.6 Transportation

Highways - The Crandon Project will substantially increase annual average daily traffic along major and collector roads which provide access between employees' residential locations and the Project site. Those roads with notable traffic increases and potential substantial levels of traffic congestion are identified and discussed in subsection 4.2.10. Potential changes in noise levels from increased Project-related construction traffic on State Highway 55 are discussed in subsection 4.1.8. Sand Lake Road will be used for access during the construction phase. Project-related traffic will have a temporary effect on use of this road by existing users, especially at the end of the workday. The effect will be limited because the work force will be at a relatively low level when the permanent access road is being constructed. No major highway modifications, such as widening or relocation, are projected as a result of the proposed Project development. There will, however, be some modifications to State Highway 55 at its intersection with the proposed access road for required DOT safety purposes.

Air - Construction activities associated with the Crandon Project site are not expected to create any major impact on the Crandon Municipal Airport. However, there will likely be an increase in the use of the airport facilities.

The proposed height of the headframe is below the maximum height limitations imposed by the airport zoning. Therefore, when required safety features are provided, the headframe should not impact the operation of the airport.

Rail - The proposed Crandon Project will not increase the frequency of trains over the Soo Line Railroad. The maximum extent to which the Project will impact the rail service will be in increased average train lengths on scheduled pickup and delivery dates. The impact created by the additional railcars in these trains could result in modest increases in motorist delays at railroad crossings.

4.1.9.1.7 Public Lands

The proposed Crandon Project will create no major public land use impacts. Exxon has exercised its option to purchase the County-owned acreage through which the railroad spur is routed (i.e., approximately 356 ha (880 acres). The County has been compensated to the extent that State of Wisconsin owned lands can be purchased to replace those sold to Exxon. At the end of the mine life, most of this former country land probably will be open to the public. Therefore, any impact created by "loss" of this acreage will be relatively short in duration. During the life of the mine only 3.4 ha (8.5 acres) of the county land will actually be used for the railroad spur.

4.1.9.1.8 Special Use Areas

Within the environmental study area, the only lands designated as special use areas were those associated with valuable wildlife habitat, such as deeryards, bald eagle and osprey nest sites, and trout streams. The potential effect of construction activities on these areas is discussed in subsections 4.1.5, Aquatic Ecology and 4.1.6, Terrestrial Ecology.

4.1.9.2 Aesthetics

The Crandon Project's aesthetic impacts were evaluated by The Sanborn Group, Inc. and Schreiber/Anderson Associates. Emphasis was placed on visual effects during operation since the operational phase would represent worst-case effects. The results of the analysis describing Project visual impacts are presented in subsection 4.2.9.2.

4.1.10 Socioeconomics

The Crandon Project's socioeconomic impacts were evaluated by Research Planning Consultants, Inc. (RPC, Inc.). The results of the analysis describing Project socioeconomic impacts are presented in subsection 4.2.10.2.

4.1.11 References

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4.2 OPERATION

4.2.1 Meteorology and Air Quality

4.2.1.1 Local Meteorology

As presented in subsection 4.1.1.1, operation of Project facilities is also expected to have no discernible impact on local meteorology. The physical facilities will not alter wind patterns off-site. Under some conditions, the mine exhaust ventilation shafts will cause water vapor plumes. However, there are no consequences except for the visibility of the water vapor plumes.

4.2.1.2 Ambient Air Quality

As discussed in subsection 4.1.1.2, estimated air emissions during operation are similar to those during construction. Although construction of the mine/mill surface facilities and access corridors will be complete, the elimination of air emissions from these is offset to some extent by sources from operation of the mine and mill. Emissions from the MWDF were conservatively assumed to be continuous during construction and operation. However, emissions will occur only periodically during periods of actual construction because the tailing ponds will be built sequentially, and three of the proposed four ponds will be constructed during the Project operation.

The main sources of air emissions during the operation phase will originate from ore excavation and handling, excavation, hauling, loading and dumping, grading and exhaust from mobile equipment, primarily in use during development of the tailing ponds at the MWDF. Operation air emission sources, rates, and control efficiencies are presented in the December 1985 Revised Air Quality Permit Application Report (RAQPAR) (Exxon Minerals Company, 1985).

As in the construction phase, total suspended particulates (TSP) constitute the major portion of the air emissions during the operation phase, amounting to approximately 245 tons per year at their highest estimate when construction activities are also in progress at the MWDF (Table 4.2-1). Over 64 percent of these air emissions are fugitive particulates from development activities for the next tailing pond at the MWDF during the operation phase (Table 4.2-1). The remainder are primarily mine stack air emissions generated during ore removal and processing.

Other quantifiable emission constituents during the operation phase are SO_2 (29 tons per year), NO_x (63 tons per year), CO (130 tons per year), HC (8 tons per year) and Pb (0.18 tons per year) (see also the December 1985 RAQPAR). Most of these emissions are from drilling and blasting, facility heating and mobile equipment tailpipe exhaust.

The air quality impact analysis methods and procedures are discussed in detail in the application (December 1985) for an Air Pollution Control Permit for the Project. The results indicate that the effect of these emissions on the ambient air quality will be negligible. Air quality constituent concentrations are expected to be below the primary and secondary federal and state ambient air quality standards at the Project boundary during operation (Table 4.2-2).

The model calculations for annual mean and short-term (3-hour and 24-hour) ground level air pollutant concentrations were performed with the Industrial Source Complex (ISC) model using one year of meteorological data. These data consisted of surface observations from Eau Claire, Wisconsin (1977) and upper air data from St. Cloud, Minnesota (1977) for the TSP modelling (see the December 1985 RAQPAR).

TABLE 4.2-1

SCHEDULE ASSOCIATED WITH PROJECT ACTIVITIES DURING THE CONSTRUCTION AND OPERATION PHASES AND THE ESTIMATED TSP AIR EMISSIONS FROM THE PROPOSED SOURCES (tons/year)

	CONSTRUCTION			OPERATION																						
Project Activities	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-29
Site Preparation (trees & brush)																										
1. Mine Shafts	17.6																									
2. Mine/Mill Site	74.9																									
3. MWDF Area	36.0	36.0			114.0							54.0							144.0							
4. Access Road/Powerline	2.7	2.8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5. Railroad Spur	4.2	0.14	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6. Haul Road	6.0																									
7. Water Discharge Pipeline	10.3																									
8. In-Plant Roads	4.7	49.1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9. Concrete Batch Plant	0.4	*	*																							
Construct Mine Support Facilities																										
1. Sink Main Shaft	0.5	5.3																								
2. Construct East Exhaust Shaft		4.0																								
3. Construct West Exhaust Shaft								4.0																		
4. Power Generation	1.9	0.2	*																							
Underground Mine Development																										
1. Develop Drifts and Stopes		0.2	1.3																							
2. Mine Air Heating		0.22	*																							
3. Mine Vehicles		3.1	*																							

TABLE 4..2-1 (continued)

Project Activities	CONSTRUCTION			OPERATION																						
	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-29
Construct Major Surface Facilities																										
1. Construct Reclaim Pond - Cell A	36.0																									
2. Construct Reclaim Pond - Cell B				36.0																						
3. Mobile Sources	0.7																									
4. Construct Preproduction Ore(and Waste Rock) Storage Pad	Included in Mine Shafts																									
5. Waste Rock Handling																										
a. Loading and Dumping		0.01	0.05	0.01	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
b. Hauling	0.1	2.4	2.3			1.7	*						1.1	*						1.6	*					
Construct MWDF Facilities (Operation)																										
1. Construct Tailing Pipeline		6.0	6.0																							
2. Construct Construction Support Area	30.0																									
3. Construct Tailing Pond T1		96.8	99.2																							
4. Construct Tailing Pond T2						104.4	106.8																			
5. Reclaim Tailing Pond T1								36.0	36.0																	
6. Construct Tailing Pond T3		30.0											91.4	93.8												
7. Reclaim Tailing Pond T2							24.5								54.7											
8. Construct Tailing Pond T4													24.0							151.0	153.4					
9. Reclaim Tailing Pond T3																						33.1	33.1			
10. Mobile Sources		0.1	*	*		*	*	*	*				*	*	*					*	*	*	*			
11. Install Liner	1.3	*	*	*		*	*	*	*				*	*	*					*	*	*	*			
a. Hauling of Bentonite to MWDF		0.9	*	*		*	*	*	*				*	*	*					*	*	*	*			

TABLE 4.2-1 (continued)

Project Activities	CONSTRUCTION			OPERATION																						
	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-29
Mine Operation (Production)																										
1. Full (Total Estimated Underground Emissions																										
a. Drilling & Blasting (Rock Handling)				26.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
b. Mine Air Heating				0.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
c. Mobile Equipment				6.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mill/Concentrator Operations																										
1. Coarse Ore Transport		0.2	3.2	2.8	1.4																					
2. Concrete Batch Plant				0.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3. Concentrate Handling and Shipping				1.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4. Facility Heating				0.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5. Emergency Diesel Generators				0.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
TOTAL	227.3	239.2	170.3	128.4	202.7	195.7	222.6	129.6	125.6	87.3	87.3	141.3	206.1	184.5	144.3	87.3	87.3	87.3	231.3	242.2	244.6	122.7	122.7	87.3	87.3	87.3

* Means previous annual estimate is used for this year.

TABLE 4.2-2

COMPARISON OF STATE AND FEDERAL AMBIENT AIR QUALITY STANDARDS[a] WITH ISC MODEL PREDICTED CONCENTRATIONS FOR THE PROJECT AT THE MODELLING BOUNDARY (All Concentrations in ug/m^3)

COMPONENT	PREDICTED CONCENTRATION FROM CRANDON PROJECT	BACKGROUND CONCENTRATION	SUMMED CONCENTRATION	PRIMARY NAAQS	SECONDARY NAAQS
SULFUR DIOXIDE					
Annual	0.1[b] (2.1)[c]	25.0	25.1 (27.1)	80	--
24-Hour	1.8 (25.0)	25.0	26.8 (50.0)	365	--
3-Hour	7.1 (186.0)	25.0	32.1 (211.0)	--	1,300
PARTICULATE MATTER (TSP)					
Annual	4.3	17.9	22.2	75	60
24-Hour	28.9	77.0	105.9	260	150
NITROGEN DIOXIDE					
Annual	3.8	19.4	23.2	100	100
CARBON MONOXIDE					
8-Hour	1802.5	N/A[d]	1802.5	10,000	10,000
1-Hour	2025.3	N/A	2025.3	40,000	40,000
HYDROCARBONS (HC)					
3-Hour	47.1	N/A	47.1	160	160
LEAD (Pb)					
3-Month Average	0.01	N/A	0.01	1.5	1.5

[a]All short-term limits (24-hour and less) can be exceeded once a year.

[b]Stationary sources only (see the December 1985 RAQPAR, Appendix C - Tables C-13, C-14 and C-15 [Exxon Minerals Company, 1985]).

[c]Includes temporary mobile source emissions and are the highest, second-highest predicted concentrations (see the December 1985 RAQPAR, Appendix C - Tables C-9, C-10, and C-11 [Exxon Minerals Company, 1985]).

[d] N/A = Not applicable.

The model calculations for prediction of ambient SO_2 and NO_2 concentrations used the meteorological data for surface observations from Quinnesec, Michigan (1979) and the upper air data from Green Bay, Wisconsin (1979) (see the December 1985 RAQPAR). Both of these meteorological data sets are conservative for the site area because of stronger easterly wind direction and speed components than what were measured during the monitoring program. As a result, the predicted ambient concentrations for all the air quality parameters are higher than expected (i.e., conservative).

Air emissions of TSP leaving the modeling property boundary were estimated for an annual and 24-hour second highest occurrence. The maximum annual average TSP concentration from all sources was 4.29 ug/m^3 at receptor 80 (see the December 1985 RAQPAR). The second highest annual average TSP concentration for these days was 4.28 ug/m^3 at receptor 46. The second highest 24-hour TSP concentration predicted for the Project with the 24-hour emission rates was 22.7 ug/m^3 at receptor 46.

Air emissions of SO_2 from the Project sources were predicted for the annual, 24-hour and 3-hour second highest occurrence (Table 4.2-2). The predicted maximum SO_2 concentrations were 2.1, 25.0, and 186.0 ug/m^3 for annual, 24-hour and 3-hours, respectively, at receptor 52 (see the December 1985 RAQPAR).

The highest predicted annual NO_2 ground level concentration was 3.8 ug/m^3 (see the December 1985 RAQPAR). The primary sources of this low concentration were mobile vehicles.

Carbon monoxide (CO) concentrations were interpolated from the SO_2 modelling results. The highest estimated CO concentrations were 675.1 and 90.6 ug/m^3 for 3-hour and 24-hour calculations, respectively (see the December 1985 RAQPAR). These values converted to 2025.3 and 1802.5 ug/m^3 on a 1-hour and 8-hour basis, respectively (Table 4.2-2).

Hydrocarbon (HC) and lead (Pb) concentrations were not modelled for the Project sources, but were estimated by interpolation from the NO_x and TSP results, respectively (see the December 1985 RAQPAR). Estimated annual HC emissions are approximately 14 percent of NO_x concentrations. The calculated maximum average 3-hour HC concentration is 47.1 ug/m^3 (Table 4.2-2).

Lead emissions from the Project will be released as small particles and as a result the estimated ambient concentrations can be conservatively compared with modelled TSP quantities. Estimated Pb emissions are approximately 0.0047 percent of TSP concentrations (see the December 1985 RAQPAR). The estimated maximum 3-month average lead concentration is 0.01 ug/m^3 (Table 4.2-2).

Similarly, extremely low concentrations can be predicted for other metals which might be hypothesized as associated with the particles having an origin from Project activities. Approximately 6 percent of the estimated particles reaching a modelling boundary receptor might actually be wind-blown tailings from the disposal pond then currently in operation (see the December 1985 RAQPAR).

For the following metals, the concentrations in ppm (parts per million) estimated for the tailings are in the second column.

Parameter	Estimated Tailings Concentration (ppm)	Tailings Particle %	Estimated TSP Particle Conc. (ug/m^3)	Recommended TLV Conc. (ug/m^3)
Aluminum (Al)	45,000	4.5	0.08	10,000
Arsenic (As)	900	0.09	0.002	200
Cadmium (Cd)	16	0.0016	0.00003	50
Copper (Cu)	1,690	0.169	0.003	1,000
Mercury (Hg)	2.2	0.00022	0.000004	50
Zinc (Zn)	5,410	0.541	0.009	5,000

Column 3 represents the percent of these metals for each particle. The concentrations in ug/m^3 of these metals, which can then be conservatively (i.e., higher) predicted at the location calculated from the ISC model to have the highest 24-hour average TSP concentration (28.9 ug/m^3), are found in column 4 (e.g., Al - 28.9 x 0.045 x 0.06 = 0.08).

These concentrations can be compared with the Threshold Limit Values (TLV) recommended as guidelines for worker exposures by the American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values generally refer to airborne concentrations of substances to which "...it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect." (ACGIH, 1982). The recommended TLV concentrations for the above metals in ug/m^3 are found in column 5. As indicated by the conservatively extrapolated property boundary values and the TLV concentrations recommended for repeated exposures (i.e., not a conservatively estimated maximum single event), dispersed particles from Project facilities at the property boundary will be below the guidelines of the ACGIH for worker health (ACGIH, 1982).

The predicted ambient air quality around the Project will meet all state and federal standards. The net air quality effects predicted for the construction, operation and reclamation phases of the Project are minimal. As a result, no deleterious effects are projected to occur to either the soil, vegetation, or animals. Because state and federal standards will be attained, the Project will maintain the air quality for the area. Therefore, Project operations are expected to have no deleterious effect on the environment and will not create a risk to public health and safety.

Mitigative measures will also be implemented during the operation phase to minimize any potential air quality impacts. The control measures discussed in subsection 4.1.1 to reduce air emissions from mobile equipment will also be used during the operation phase. Additional controls will be used to minimize air emissions from ore removal and processing operations (see the December 1985 RAQPAR). Specific controls and control efficiencies to be implemented are summarized below.

During operation of the mine, generation of dust from drilling will be essentially 100 percent controlled with water injection to the drill bit. Dust from blasting will be controlled to a minimum of 95 percent because of gravity settling of particles from the low air velocities and humid underground areas of the mine, and water sprays, if necessary.

Insertable dust collectors and baghouses will be used to control emissions from the mill and other surface operations. The use of these controls was based upon the physical characteristics of the particulates. Insertable collectors will generally be used where the captured material is fine and can be returned directly to the process. The insertable collectors will vent inside the buildings.

Ore handling, vehicle travel, and fuel transfer and storage constitute the other major emission sources from surface facility operations. Other air emissions will originate from reagent and concentrate handling. All air emission sources will have reliable and effective controls.

A vapor balance system will be used during storage tank loading to minimize hydrocarbon emissions. This will consist of a product line and ventilation line connected between tank car or tank truck and the storage tanks. The ventilation lines will exhaust the hydrocarbon vapors from the tank vents to the tank car or tank truck.

Two programs will be conducted during these phases to assure protection and maintenance of all ambient state and federal air quality standards. These programs are for air quality monitoring and pollution equipment operation and maintenance and they will ultimately be part of the Mine Permit (NR 132) - Monitoring and Quality Assurance Plan, and the Air Permit (NR 154) - Malfunction Prevention and Abatement Plan. The Malfunction Prevention and Abatement Plan will also include programs to assure consistency with federal regulations such as the NSPS for metallic mineral processing plants. Final design of the programs will be reviewed with the DNR before their initiation.

4.2.2 Geology and Topography

4.2.2.1 Soils

Mitigation measures initiated during the construction phase, such as reseeding and landscaping, will minimize potential erosion impacts in areas of previously disturbed soil. Sequential expansion of facilities, such as proposed for the MWDF area, is planned so as to reduce the total area disturbed at any time. No long-term irreversible impacts to site area soils are projected to occur as a result of operation activities.

4.2.2.2 Landscape

Operation and filling of the MWDF and the MRDF will produce new landforms that presently do not exist in the site area. The tailing pond embankments will reach a maximum height of approximately 30 m (98 feet) above the existing ground surface. The construction of this landform followed by the filling of the ponds from the disposal operations will be a long-term impact that will be mitigated by post-operation reclamation activities, described in the Reclamation Plan.

If the contingency borrow area is required during operations, it would also alter the landscape by eliminating an existing topographical high area.

4.2.2.3 Minerals

A direct and irreversible impact of the mining operation will be depletion of the known mineral resources contained within the mined area. All economically recoverable metals of importance will be extracted from the orebody. These include: zinc, copper, lead, silver, and gold.

Two minerals produced in the water treatment process will be calcium carbonate ($CaCO_3$) and sodium sulfate (Na_2SO_4). Calcium carbonate will be used as a buffering agent in the tailings. There is a market for sodium sulfate as a reagent in the paper industry and this mineral will be recovered and marketed, if possible. This may be an economic benefit to the Project.

4.2.3 Ground Water

Lowering of the ground water potentiometric surface will begin during the operation of the mine and continue through the operating period. Most of the lowering of the water table will occur in Project Years 6-8 following the development of the expected steady state mine inflow of approximately 0.08 m^3/s (1,270 gallons per minute). The hydrologic analyses of mine dewatering and subsequent ground water drawdown indicate that no permanent, detrimental effects to the ground water regime will occur (see Appendix 4.1A; Prickett & Associates, 1984). Mitigative measures proposed to assure a water supply to local users of ground water will be in effect throughout the operation of the mine.

During the operation phase, chemical constituents in the MWDF seepage are expected to be attenuated within the unsaturated till beneath the MWDF and the influence of the tailing ponds seepage on ground water quality will not be measurable. The MRDF and other Project facilities are designed so that ground water quality will not be affected during the operations phase.

4.2.3.1 Ground Water Hydraulics

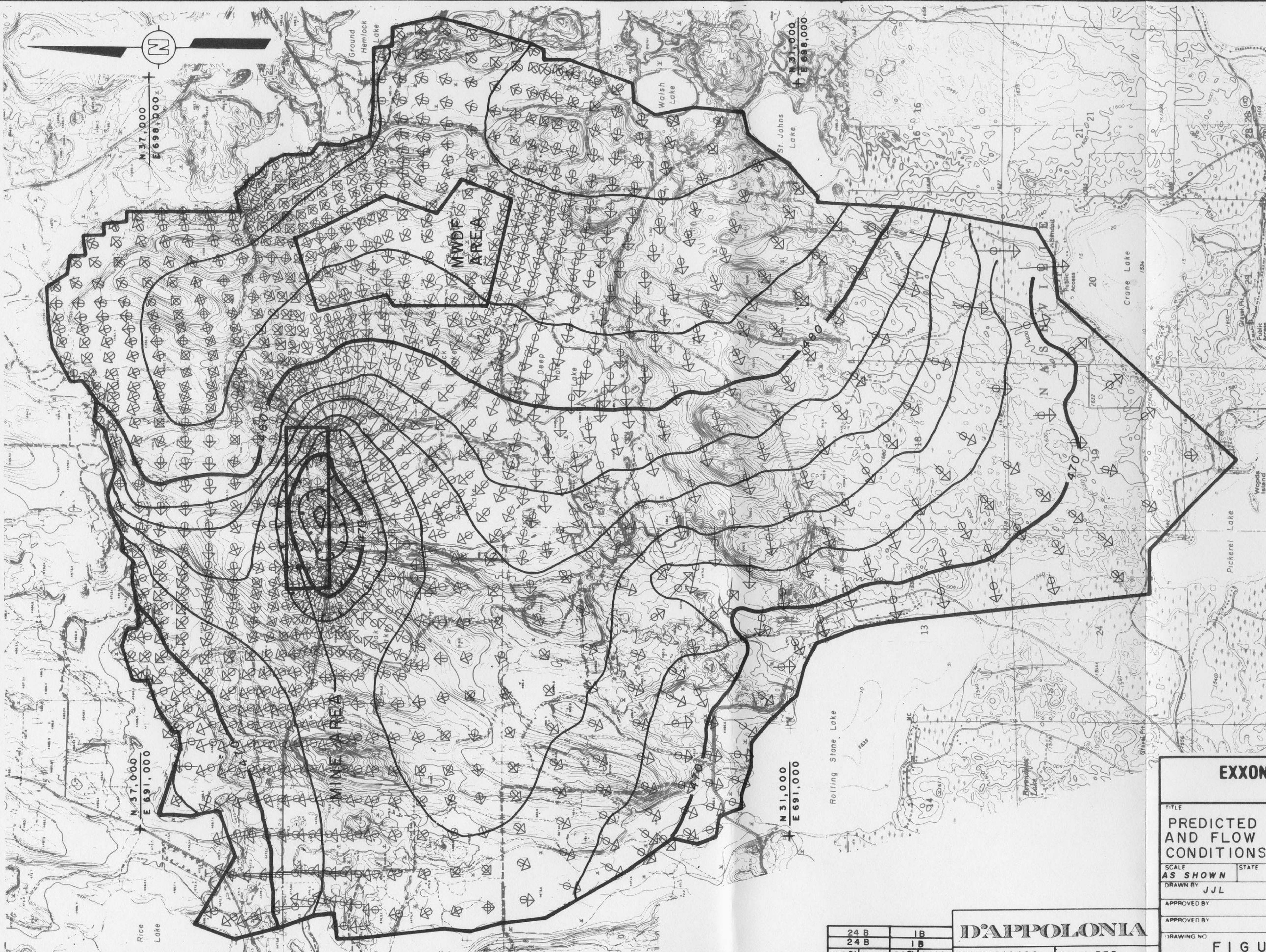
The site area hydrogeologic conditions and ground water flow are discussed in subsection 4.1.3.1. The estimated potentiometric surface at the start of operations is the same as the preconstruction potentiometric surface as shown on Figure 4.1-2 (also see Appendix 4.1A). Most of the increase in mine inflow will occur during the initial years of the operation phase.

The High Capacity Well Approval provides additional detail for the increase of mine inflow and Appendix 4.1A includes an impact analysis for an interim point after the majority of the mine inflow has developed.

Figure 4.2-1 presents the estimated potentiometric surface at the end of operations for the middle recharge mine inflow case. Figure 4.2-2 presents the model predicted drawdown contours of the water table for the same year. The estimates were made using the same computer model discussed in subsection 4.1.3.1 and presented in Appendix 4.1A. The middle recharge rate (216 mm/y [8.5 inches per year]) has been taken as the most likely case and the discussion that follows is based on this recharge rate.

The maximum drawdown over the mine area is estimated to be 17 m (58 feet) (see Appendix 4.1A). The cone of depression defines the area outside which the mine dewatering will not cause any measurable decline in the potentiometric surface. The limit of the cone of depression was defined as a maximum drawdown of 1 m (3.3 feet) because the seasonal ground water fluctuation within the site area is approximately this value. These same criteria that are used to determine the cone of depression are applied later to the assessment of the consequences of dewatering the main aquifer on surface waters.

The area defined by the cone of depression is roughly circular in shape and is elongated toward the south. The shape is primarily caused by differences in the hydrologic parameters of the glacial deposits. In the northern portion of the site area, the main aquifer consists primarily of low permeabilty till material. In the southwest, the most permeable glacial unit, stratified drift, constitutes the



SCALE

0 1000 2000 meters

NOTE:
LENGTH OF VECTOR IS PROPORTIONAL TO THE MAGNITUDE OF FLOW. EACH cm IS APPROXIMATELY EQUAL TO 787.4 m^3/y PER HORIZONTAL UNIT WIDTH IN METERS.

LEGEND

470 — PREDICTED POTENTIOMETRIC SURFACE IN METERS ABOVE MSL

PREDICTED FLOW VECTOR

24 B	1 B
24 B	1 B
100% BLUE	50% BLACK

D'APPOLONIA

PROJ NO 846498 | DWG NO B35

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

PREDICTED POTENTIOMETRIC SURFACE AND FLOW VECTORS AT STEADY STATE CONDITIONS FOR MIDDLE RECHARGE CASE

SCALE	STATE	COUNTY	
AS SHOWN			
DRAWN BY JJL	DATE 9-26-84	CHECKED BY MMR	DATE 12/10/85
APPROVED BY	DATE	APPROVED BY SHD	DATE 12/10/85
APPROVED BY	DATE	EXXON	DATE
DRAWING NO	FIGURE 4.2-1	SHEET ___ OF ___	REVISION NO.

NOTE:

LIMIT OF ZONE OF INFLUENCE IS SET AT A MAXIMUM DRAWDOWN OF 1.0m (3.3 FEET)

LEGEND

—2— PREDICTED POTENTIOMETRIC DRAWDOWN IN METERS

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

PREDICTED POTENTIOMETRIC DRAWDOWN UNDER STEADY STATE CONDITIONS FOR MIDDLE RECHARGE CASE

SCALE	STATE		COUNTY	
AS SHOWN				
DRAWN BY RW	DATE 9-26-84	CHECKED BY MMR		DATE 12/10/85
APPROVED BY	DATE	APPROVED BY SHD		DATE 12/10/85
APPROVED BY	DATE	EXXON		DATE
DRAWING NO	FIGURE 4.2-2		SHEET ___ OF ___	REVISION NO

D'APPOLONIA

1B		
1B		
50% BLACK	PROJ NO 846498	DWG NO B57

primary portion of the aquifer. The lower permeability glacial materials to the north of the mine area will act as a barrier to reduce the effects of mine dewatering on ground water discharge to Swamp Creek. To the south the cone of depression is more widespread, but the gradients associated with this zone are lower, thereby reducing the overall effect of the mine construction dewatering on ground water users in the site area.

Ground water recharge will be altered around the MWDF, reclaim pond, MRDF, and mine/mill site. Surface water runoff from the mine/mill area will be contained and recharged to ground water via peripheral surface water collection ditches and retention basins. These changes in recharge conditions have been incorporated in the evaluation of ground water effects. Reclamation of the tailing ponds, starting during the operation phase, will result in routing of surface infiltration through the tailing pond reclamation cap overdrain to the embankments and as surface water runoff to the MWDF periphery. From these two locations the water can then enter into the ground water system.

4.2.3.2 Ground Water Quality

Seepage from the MWDF will move basically downward toward the ground water. The chemistry of the pond seepage will be different from the ground water. The potential for and degree of any influence was assessed by laboratory testing and computer modeling of the movement of the estimated chemical constituents in the tailing seepage water into and through the underlying glacial deposits. The details of the assessment are presented in Appendix 4.1A.

Four tailing ponds (T1 through T4) will contribute seepage at varying rates and through different time periods during the operation

TABLE 4.2-3

PROJECTED SEEPAGE RATE OF MWDF[a,b,c]

	SURFACE AREA		OPERATION SEEPAGE RATE[d]				MAXIMUM POST-OPERATION SEEPAGE RATE[d]				POST-OPERATION STEADY-STATE CONDITION SEEPAGE RATE[d]			
			POND		PER UNIT AREA		POND		PER UNIT AREA		POND		PER UNIT AREA	
POND NO.	ha	acre	m^3/s	gpm	mm/y	in/y	m^3/s	gpm	mm/y	in/y	m^3/s	gpm	mm/y	in/y
T1	33.08	81.7	0.00018	2.9	17.3	0.68	0.00018	2.9	17.3	0.68	0.000018	0.29	1.68	0.066
T2	43.86	108.4	0.00024	3.8	17.3	0.68	0.00024	3.8	17.3	0.68	0.000023	0.37	1.68	0.066
T3	40.29	99.6	0.00022	3.5	17.3	0.68	0.00022	3.5	17.3	0.68	0.000021	0.34	1.68	0.066
T4	39.98	98.8	0.00022	3.5	17.3	0.68	0.00041	6.5	32.3	1.27	0.000021	0.34	1.68	0.066
TOTAL	157.21	388.5	-[e]	-	-	-	-	-	-	-	0.000083	1.33	1.68	0.066

[a]Data in this table follow the results presented in Appendix 4.1A. The Project plan, as presented in Chapter 1, includes smaller tailing ponds which would have reduced seepage (per unit area seepage rates remain the same).

[b]Source: Exxon Minerals Company (1984).

[c]Refer to Appendix 4.1A, Figure A-2 for location of ponds and Appendix 4.1A, Figure A-3b for seepage rate distribution.

[d]Refer to Appendix 4.1A, Figure A-3b for period of each rate.

[e]Operational seepage rates are not cumulative because of tailing ponds operation schedule (Appendix 4.1A, Figure A-3b).

phase. Table 4.2-3 presents the estimated seepage rates and schedules. Table 4.2-4 presents the projected chemistry of the tailing pond seepage. The seepage chemistry is expected to be approximately the same for all four ponds. Although the tailings for the first 15 years are from massive ore and the last 14 years from stringer ore, leachate quality is primarily controlled by excess alkalinity and saturated conditions in the MWDF operation. These factors lead to the similiarity in leachate chemistry. The MWDF Feasibility Report includes additional information on tailings and leachate characteristics.

Seepage will have to pass through the bentonite modified soil tailing pond liner and then through approximately 12 m (40 feet) of unsaturated till and drift before encountering the ground water. Before reaching the main aquifer, the seepage must pass through an additional 20 m (65 feet) of saturated till. Geochemical analyses of the till materials indicate that many of the potential chemical constituents in the seepage will be attenuated in the till (D'Appolonia, 1982). The thickness of the stratified drift beneath the ponds varies from approximately 15 to 40 m (50 to 130 feet). Any seepage mixing with and diluted by the ground water in the drift will move mainly horizontally in the direction of the ground water movement.

To assess the rate of movement of chemical constituents through the partially saturated till, a one-dimensional vertical columnar computer model was used. The chemical constituents were expressed in terms of a normalized concentration; that is the concentration (C) at the point of interest divided by the concentration (C_o) in tailing ponds or at the source of seepage. Figure 4.2-3

TABLE 4.2-4

PROJECTED MWDF TAILING PONDS SEEPAGE CHEMISTRY

PARAMETER	UNITS	YEARS 5 THROUGH 79		YEAR 80 AND BEYOND		U.S. EPA PRIMARY DRINKING WATER STANDARDS[c]	U.S. EPA SECONDARY DRINKING WATER STANDARDS[d]
		C_o[a]	C_o/DW[b]	C_o[a]	C_o/DW[b]		
pH	pH units	7	--	7-8	--	--	6.5-8.5
Filterable Residue (TDS)	mg/l[e]	3,000	6	3,000	6	--	500
Sulfate	mg/l	2,000	8	2,000	8	--	250
Arsenic	mg/l	0.50	10	0.03	<1	0.05	--
Barium	mg/l	0.03	0.03	0.1	<1	1.0	--
Cadmium	mg/l	0.50	50	<0.001	<0.1	0.01	--
Chromium	mg/l	0.06	1.2	0.001	<0.1	0.05	--
Copper	mg/l	0.10	0.1	<0.01	<0.01	--	1.0
Iron	mg/l	30	100	0.02	<0.1	--	0.3
Lead	mg/l	0.04	0.8	0.01	<1	0.05	--
Manganese	mg/l	20	400	0.02	<1	--	0.05
Mercury	mg/l	0.01	5	<0.001	<1	0.002	--
Selenium	mg/l	0.10	10	<0.001	<0.1	0.01	--
Silver	mg/l	0.03	0.6	<0.001	<0.1	0.5	--
Zinc	mg/l	10	2	0.2	<0.1	--	5.0

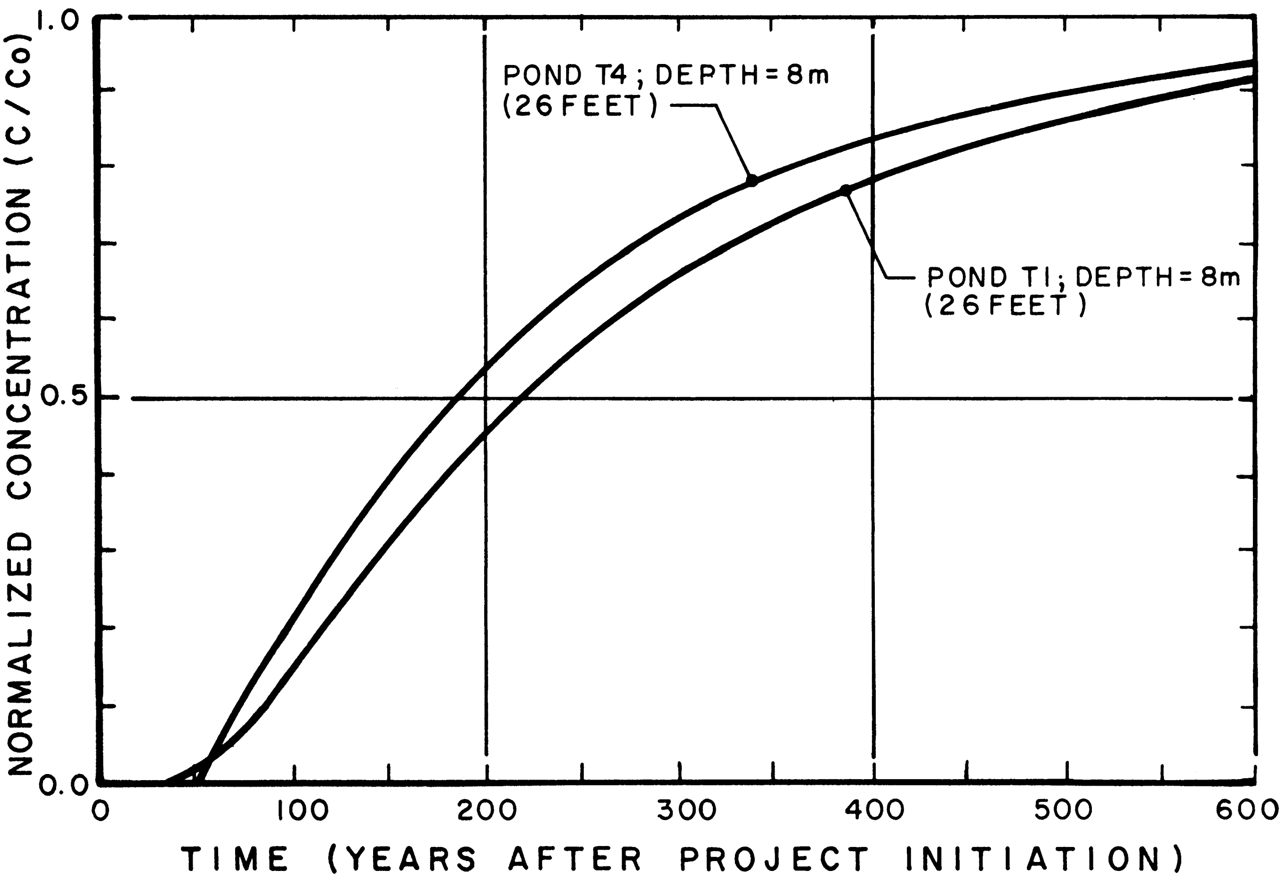
[a] Projected tailing ponds seepage concentration (Exxon Minerals Company, 1982).

[b] Projected tailing ponds seepage concentration (c) divided by the U.S. EPA Drinking Water Standard (DW); dilution ratio required to reach drinking water standard (values less than one indicate no dilution required).

[c] U.S. EPA (1975), 40 CFR, Part 141.

[d] U.S. EPA (1979), 40 CFR, Part 143.

[e] mg/l = parts per million.



NOTES:

1. SOURCE: APPENDIX 4.1A

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

COMPUTED NORMALIZED CONCENTRATIONS IN PARTIALLY SATURATED TILL BENEATH MWDF

SCALE AS SHOWN	STATE	COUNTY	
DRAWN BY J J L	DATE 9·26·84	CHECKED BY MMR	DATE 12/10/85
APPROVED BY	DATE	APPROVED BY SHD	DATE 12/10/85
APPROVED BY	DATE	EXXON	DATE
DRAWING NO FIGURE 4.2-3		SHEET ___ OF ___	REVISION NO.

D'APPOLONIA

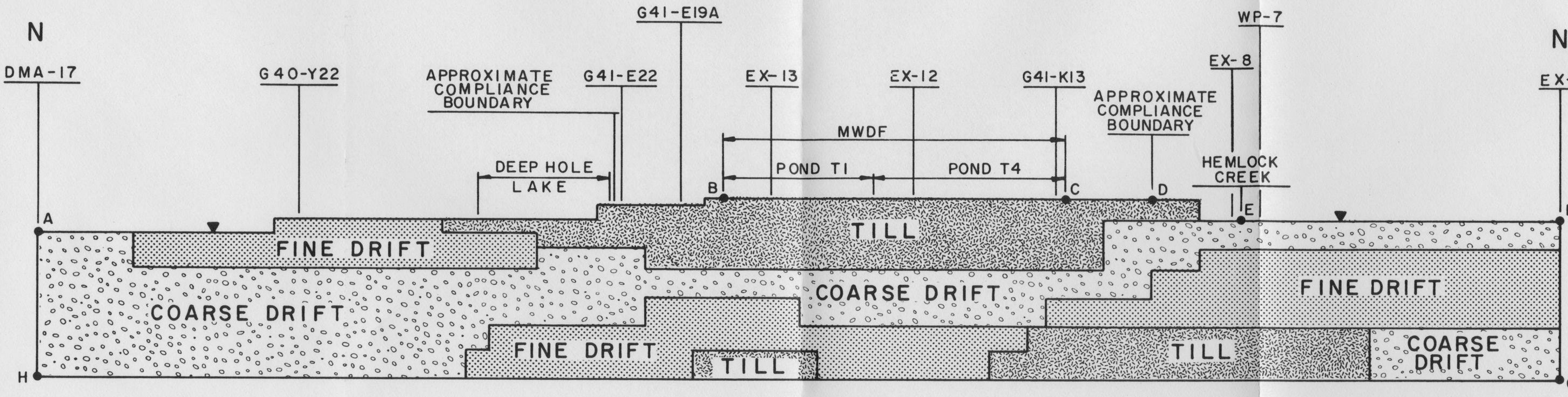
PROJ NO 846498 DWG NO A9

presents the normalized concentration (C/C_o), i.e., actual concentration at any point compared to concentration directly from MWDF, for a chemical constituent with a retardation factor of one (i.e., the constituent moves with the velocity of the water) at a depth of 8 m (26 feet) in the partially saturated till beneath the tailing ponds. As shown on Figure 4.2-3, the chemical constituents studied will not reach the 8-m (26-foot) level beneath the ponds at a normalized concentration of 0.1 by the end of the operation phase.

To assess the rate of chemical constituent movement through the saturated till and into the stratified drift, a two-dimensional vertical cross-sectional computer model was used. The geologic cross-section used in the model is shown on Figure 4.2-4. Figure 4.2-5 shows the results of the modeling for 800 years after mine construction begins for the middle recharge case in terms of normalized concentrations in the saturated till. Chemical constituents with a retardation coefficient (R_d) of 1.0 did not exceed a C/C_o value greater than 0.4 at year 800. These constituents remained in the till and did not enter the stratified drift during the operation phase.

The rates of movement predicted by the modeling were consistent with the rates observed in column tests of till samples conducted in the laboratory. A comparison of the results of laboratory testing and modeling is presented in Appendix 4.1A, Section 6.0.

The rates of movement discussed above are applicable only to very mobile chemical constituents which exhibit retardation factors near 1.0. For other chemical constituents such as heavy metals which characteristically have retardation factors substantially greater than



LEGEND:

- ● A POINTS REFERRED TO IN TEXT
- ▼ WATER TABLE (RECHARGE BOUNDARY)

HORIZONTAL SCALE: 0 300 600 900 meters

VERTICAL SCALE: 0 20 40 60 meters

NOTES:

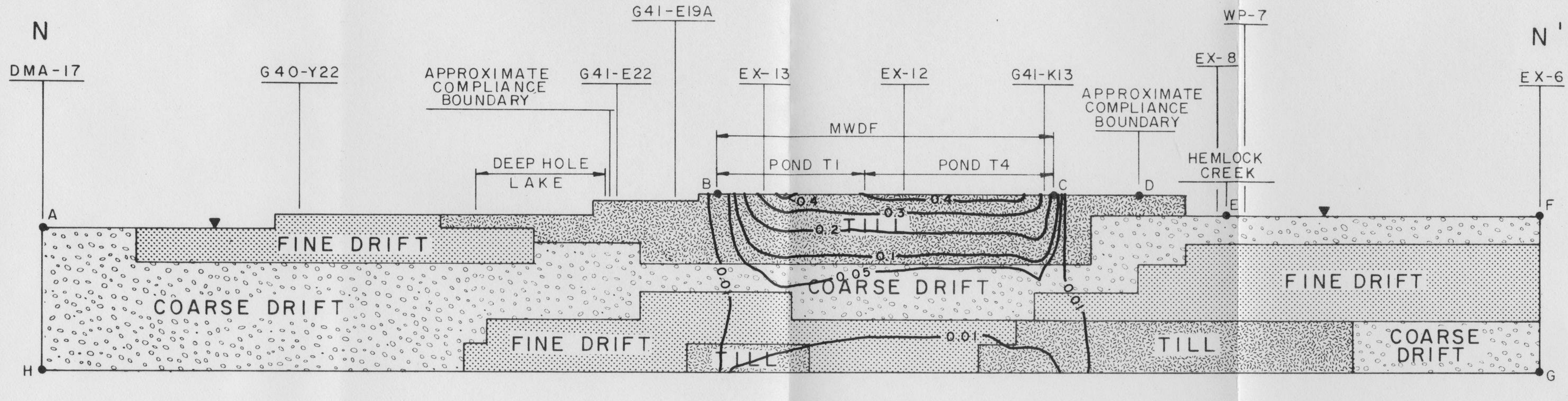
1. SOURCE: APPENDIX 4.1A
2. VERTICAL EXAGGERATION 15X

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: IDEALIZED SATURATED HYDROGEOLOGIC CONDITIONS IN VERTICAL GEOLOGIC SECTION N-N'

SCALE: AS SHOWN | STATE | COUNTY
DRAWN BY: D. Weick | DATE: 10-12-84 | CHECKED BY: MMR | DATE: 12/10/85
APPROVED BY | DATE | APPROVED BY: SHD | DATE: 12/10/85
APPROVED BY | DATE | EXXON | DATE
DRAWING NO: FIGURE 4.2-4 | SHEET ___ OF ___ | REVISION NO.

D'APPOLONIA
13B
13B
50% BLK. PROJ NO 846498 DWG NO B21



NOTES:

1. SOURCE: APPENDIX 4.1A
2. VERTICAL EXAGGERATION 15X

LEGEND:

A ● POINTS REFERRED TO IN TEXT

—0.1— NORMALIZED CONCENTRATION CONTOUR

▼ WATER TABLE (RECHARGE BOUNDARY)

HORIZONTAL SCALE

0 300 600 900 meters

VERTICAL SCALE

0 20 40 60 meters

FIGURE 4.2-5

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE: PREDICTED NORMALIZED CONCENTRATIONS AT YEAR 800 FOR SECTION N-N' FOR MIDDLE RECHARGE CASE

SCALE: AS SHOWN	STATE		COUNTY		
DRAWN BY: D. Weick	DATE: 10-12-84	CHECKED BY: MMR		DATE: 12/10/85	
APPROVED BY	DATE	APPROVED BY: SHD		DATE: 12/10/85	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO: FIGURE 4.2-5		SHEET	OF	REVISION NO	

28B
28B
50% BLK.

D'APPOLONIA

PROJ NO 846498 DWG NO B44

1.0, the rate of movement, based on laboratory analyses, is proportionally slower than those constituents with a retardation factor of 1.0.

During the operation phase of the mine, concentrations of seepage from the MWDF area are expected to remain nearly constant.

4.2.3.3 Local Ground Water Use

During mine operation the lowering of the potentiometric surface may affect some domestic water wells to the south of the mine, in the area of Little Sand Lake and Oak Lake (Section 2.3, Appendix 2.3G). Water levels in these wells may be lowered by as much as 10 m (33 feet) for the middle recharge mine inflow case (see Appendix 4.1A). Some of these wells may be rendered unuseable at their present depth.

Exxon will undertake mitigative measures to provide a reliable water supply to affected ground water users. In those wells where a reliable water supply is necessary during mine operation, three possible actions can be taken to provide this supply. One measure is to lower the pump in the existing well to a depth that will allow continuous use of the well. If this measure is not practical, then the well may be deepened or a new water well will be constructed to a depth that will provide a reliable supply of ground water.

4.2.4 Surface Water

Project operations have the potential to effect surface waters in the Project area through two mechanisms. The primary mechanism is through the inflow of ground water to the mine and its subsequent removal. This basic mechanism lowers the ground water table and reduces ground water flows which cause associated effects to surface waters through reduced ground water discharges and can potentially affect perched surface water systems by increasing seepage from them to the lowered ground water table.

The second mechanism is the discharge of the treated excess water into Swamp Creek below Rice Lake. The excess water is a result of the mine inflow and its placement back into Swamp Creek more than offsets the reductions of flow in the creek from mine inflow. These effects are discussed separately and in more detail in the following sections.

During operation of the mine, the build-up of mine inflow is projected to have an effect on the base flow rate to the streams and lakes in the site area. Appendix 4.1A provides additional detail for the build-up of mine inflow and the accompanying surface water effects. An interim condition, representative of conditions expected after Project Years 6-8, is presented, along with the slightly increased steady-state effects which will be experienced throughout the remaining operations period. Most of the effect will begin to occur in Project Years 6-8 following the development of the expected steady-state mine inflow of approximately 0.08 m^3/s (1,270 gallons per minute) (Prickett & Associates, 1984). Based upon the hydrologic analyses of the site area (Appendix 4.1A), the reduced base flow at the steady-state mine inflow condition will not adversely affect the hydrology of site area streams or discharge lakes during average climatic conditions.

For the site area springs and their associated streams, which mainly reflect ground water discharge flow, and for the site area streams and lakes during dry climatic conditions, a Hydrologic Impact Contingency Plan to mitigate any impacts from low flows or low water levels has also been provided. However, during these dry conditions, mine inflow itself would be lower, which would lower the ground water discharge reduction to the stream.

Estimate of reductions in base flow were made using the computer model discussed in subsection 4.1.3.1 and presented in Appendix 4.1A.

The hydrological impact studies were conducted considering a range of precipitation infiltration (152-279 mm/y [6.0-11.0 inches per year]) which resulted in a range of corresponding mine inflow (0.059-0.100 m^3/s [933-1,592 gallons per minute]). The middle recharge rate (216 mm/y [8.5 inches per year]) has been taken as the most likely case and the discussion that follows is based on this recharge rate. The actual recharge rate for the Project site area is probably between the low and middle recharge rate modeled. Therefore, the middle recharge rate evaluation is conservative because its impacts would be greater.

4.2.4.1 Surface Water Quantity

4.2.4.1.1 Streams

Mine Inflow

Surface water impacts which may be attributable to mine dewatering were evaluated in two ways. First, an analysis was made of changes in base flow and average flow conditions as determined in the baseline studies. At the request of DNR, an analysis was also made of the changes in $Q_{7,2}$ and $Q_{7,10}$ flows as determined by the USGS. The $Q_{7,2}$ flow defines the average low flow over a 7-day period expected once every 2 years. For $Q_{7,10}$ flow the reoccurrence period is extended to 10 years, resulting in a lower flow rate. The results are discussed in the following subsections.

Table 4.2-5 shows the predicted changes in the ground water discharges to surrounding surface waters at steady-state inflow conditions. Figure 4.2-6 indicates the stream segments that have been analyzed.

The maximum operations period reduction in ground water discharged from the site area to Swamp Creek and Hemlock Creek is approximately 0.043 m^3/s (1.49 cubic feet per second). All other streams in Table 4.2-5 are expected to be reduced to a lesser degree.

Table 4.2-6 presents estimated average annual base flow and average annual total flow for the streams adjacent to the site area. The estimated stream flow reduction at steady-state mine inflow is also presented in the table.

The estimated reduction in average annual stream base flow for Swamp Creek and Hemlock Creek adjacent to the site is 0.043 m^3/s (1.49 cubic feet per second) at steady-state (same as the reduction in ground water discharge to the streams). This is, approximately 7.8 percent of the average annual base flow. The average total flow reduction is 3.2 percent.

TABLE 4.2-5

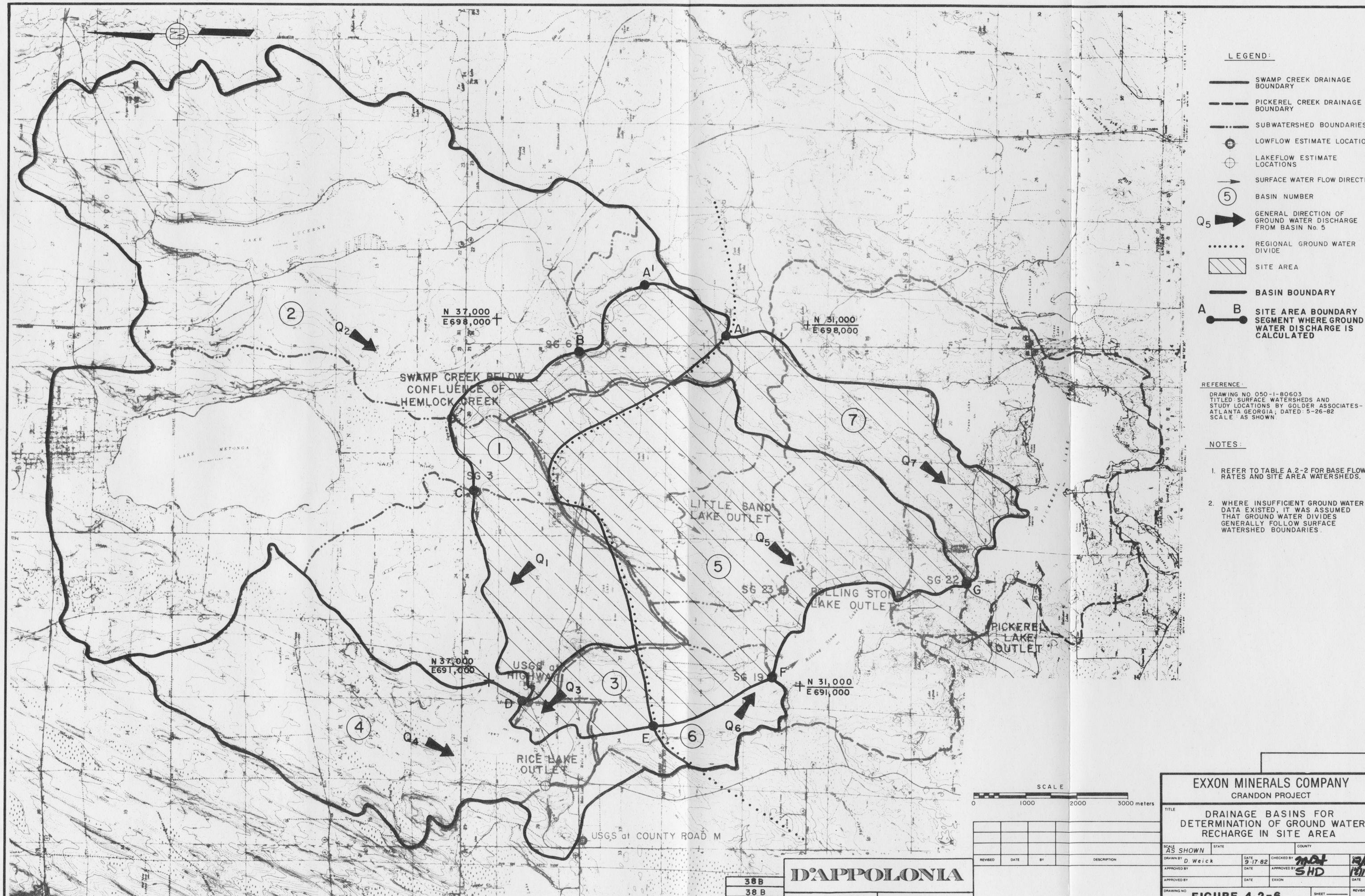
ESTIMATED GROUND WATER DISCHARGE FROM SITE AREA
AT STEADY-STATE[a] MINE INFLOW FOR THE MIDDLE RECHARGE CASE

SEGMENT DESCRIPTION	SEGMENT[b]	PRECONSTRUCTION DISCHARGE RATE m^3/s	PRECONSTRUCTION DISCHARGE RATE cfs	STEADY-STATE[a] DISCHARGE RATE m^3/s	STEADY-STATE[a] DISCHARGE RATE cfs	DIFFERENCE[c] m^3/s	DIFFERENCE[c] cfs
Upper Hemlock Creek	AB	0.026	0.93	0.014	0.51	0.012	0.42
Lower Hemlock Creek and Swamp Creek Below Hemlock Creek Confluence	BC	0.039	1.39	0.024	0.86	0.015	0.53
Swamp Creek Above Rice Lake	CD	0.062	2.18	0.046	1.64	0.016	0.54
Hemlock and Swamp Creeks	ABCD	0.127	4.50	0.084	3.01	0.043	1.49
Rice and Mole Lakes	DE	0.022	0.78	0.014	0.52	0.008	0.26
Pickerel Creek, Upstream of Rolling Stone Lake	EF	0.027	0.94	0.020	0.71	0.007	0.23
Rolling Stone Lake and Lower Portion of Pickerel Creek	FG	0.068	2.40	0.066	2.34	0.002	0.06
Rolling Stone Lake and Pickerel Creek	EFG	0.095	3.34	0.860	3.05	0.009	0.29
Pickerel Creek to Ground Hemlock Lake	GA	0.064	2.27	0.055	1.93	0.009	0.34

[a]Steady-state conditions determined from GEOFLOW ground water impact model.

[b]Refer to Figure 4.2-6 for segment locations.

[c]The difference is calculated by subtracting the steady-state discharge rate from the preconstruction value.



REFERENCE:
DRAWING NO. 050-1-80603
TITLED: SURFACE WATERSHEDS AND STUDY LOCATIONS BY GOLDER ASSOCIATES- ATLANTA GEORGIA; DATED 5-26-82
SCALE: AS SHOWN

NOTES:

1. REFER TO TABLE A.2-2 FOR BASE FLOW RATES AND SITE AREA WATERSHEDS.
2. WHERE INSUFFICIENT GROUND WATER DATA EXISTED, IT WAS ASSUMED THAT GROUND WATER DIVIDES GENERALLY FOLLOW SURFACE WATERSHED BOUNDARIES.

REVISED	DATE	BY	DESCRIPTION

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: DRAINAGE BASINS FOR DETERMINATION OF GROUND WATER RECHARGE IN SITE AREA

SCALE: AS SHOWN | STATE | COUNTY
DRAWN BY: D. Weick | DATE: 9-17-82 | CHECKED BY: MDH | DATE: 12/10/85
APPROVED BY | DATE | APPROVED BY: SHD | DATE: 12/10/85
APPROVED BY | DATE | EXXON | DATE
DRAWING NO: FIGURE 4.2-6 | SHEET ___ OF ___ | REVISION NO.

D'APPOLONIA

PROJ. NO. 846498 | DWG. NO. B47

38B
38 B
50% BLK.

GBB 5/1961

TABLE 4.2-6

STREAM FLOW RATES - STEADY-STATE[a] MINE INFLOW FOR MIDDLE RECHARGE CASE

				Calculated Average Annual Total Flow Rate					Average Annual Base Flow Rate				
SEGMENT DESCRIPTION	SEGMENT[b]	REDUCTION OF FLOW RATE[c] m³/s	REDUCTION OF FLOW RATE[c] cfs	PRECONSTRUCTION m³/s	PRECONSTRUCTION cfs	STEADY-STATE[a] m³/s	STEADY-STATE[a] cfs	PERCENT REDUCTION	PRECONSTRUCTION m³/s	PRECONSTRUCTION cfs	STEADY-STATE[a] m³/s	STEADY-STATE[a] cfs	PERCENT REDUCTION
Upper Hemlock Creek	AB	0.012	0.42	--[d]	--[d]	--[d]	--[d]	--[d]	0.113	4.0	0.101	3.58	10.5
Lower Hemlock Creek and Swamp Creek Below Hemlock Creek Confluence	BC	0.015	0.53	1.034	36.5	1.019[e]	35.97[e]	1.4[e]	0.652	23.0	0.637[e]	22.47[e]	2.3[e]
Swamp Creek Above Rice Lake	CD	0.016	0.54	1.308	46.2	1.292[e]	45.66[e]	1.2[e]	0.538	19.0	0.522[e]	18.46[e]	2.8[e]
Hemlock and Swamp Creeks	ABCD	0.043	1.49	1.308	46.2	1.265	44.71	3.2	0.538	19.0	0.495	17.51	7.8
Pickerel Creek, Upstream of Rolling Stone Lake	EF	0.007	0.23	--[d]	--[d]	--[d]	--[d]	--[d]	0.113	4.0	0.106	3.77	5.8
Rolling Stone Lake and Lower Portion of Pickerel Creek	FG	0.002	0.06	0.399	14.1	0.397[e]	14.04[e]	0.4[e]	0.198	7.0	0.196[e]	6.94[e]	0.9[e]
Rolling Stone Lake and Pickerel Creek	EFG	0.009	0.29	0.399	14.1	0.390	13.81	2.1	0.198	7.0	0.189	6.71	4.1
Creek 12-9	--	0.016	0.56	0.133[f]	4.70[f]	0.117[f]	4.14[f]	11.9[f]	0.071[g]	2.52[g]	0.056[g]	1.96[g]	22.2[g]
Creek 11-4 (Martin Spring)	--	0.002	0.08	0.016[f]	0.58[f]	0.014[f]	0.50[f]	13.8[f]	0.015[g]	0.53[g]	0.013[g]	0.45[g]	15.1[g]

[a]Steady-state conditions determined from GEOFLOW ground water impact model.

[b]Refer to Figure 4.2-6 for segment locations.

[c]Refer to Appendix 4.1A, Table A-19. The reduction in stream flow rate is assumed to be only from changes in ground water discharge from the site area.

[d]Average annual total stream flow is not included for the upper portion of Hemlock Creek and Pickerel Creek upstream of Rolling Stone Lake because the method of calculation is not applicable to these small watersheds.

[e]The actual total reduction in this segment will be greater, resulting from reduction in the upstream segment.

[f]Average annual total flows calculated by ratio comparison with Swamp Creek flows.

[g]GEOFLOW nodal flows for middle recharge case used as an approximation of average annual base flow.

Estimates indicate that the base flow to Hemlock Creek along Segment AB may be reduced by 10.5 percent. The percentage reduction to a larger average flow would be less. Along other reaches of Swamp Creek and Hemlock Creek, mine dewatering and other operation period activities will have no measurable effect on ground water discharge into the streams because these areas are outside the zone-of-influence of mine dewatering.

The influence on base flow for the total length of Pickerel Creek is a reduction of 0.007 m^3/s (0.23 cubic feet per second). This represents a reduction in average annual base flow of 5.8 percent. The percentage reduction to a larger average flow would be less. Flow reductions are also expected in other smaller streams within the Project area.

For Creek 11-4 and Creek 12-9, flow reductions are based on the difference between the GEOFLOW model calibrated flow for the middle recharge case and the model predicted flow at steady-state mine inflow. On this basis stream base flow reductions of approximately 15 percent for Creek 11-4 and 22 percent for Creek 12-9 were estimated. For average annual flows the flow reductions decrease to 14 percent for Creek 11-4 and 12 percent for Creek 12-9. In the case of Hoffman Spring Creek, the model predicts an average 29 percent reduction in ground water flow in the area and an approximate 0.8-m (2.6-foot) reduction in the potentiometric surface in the area of the spring. While specific impacts to the stream will depend on the exact relationship of the spring topography and hydrologic setting with respect to the actual ground water table decline, the predicted reduction in ground water flow and water table elevation indicates that Hoffman Spring and Creek may experience some reduction of flow. However, a mitigative supplement will be provided to offset this flow reduction.

In addition to the stream flow reductions for annual average flow and annual average base flow, presented in Table 4.2-6, the same volumetric flow reductions were applied to the $Q_{7,2}$ and $Q_{7,10}$ flow estimates (Table 4.2-7). This comparison reflects a conservative condition because lower than average recharge rates probably occur when $Q_{7,2}$ and $Q_{7,10}$ flow conditions are evident. The modeling results indicate that mine inflow will be reduced with a lower recharge rate, and lower mine inflow will result in a lower reduction of stream flow. Therefore, the reduction in flow for the $Q_{7,2}$ and $Q_{7,10}$ conditions would be less than that presented in the table.

Using the same volumetric flow reduction (0.043 m^3/s [1.49 cubic feet per second]) in Swamp Creek that was associated with the middle recharge rate results in a 13.5 percent reduction in the $Q_{7,2}$ flow of 0.311 m^3/s (11.0 cubic feet per second) at the USGS State Highway 55 measuring location.

In Hemlock Creek the 10.5 percent reduction in base flow described above increases to a 21.0 percent reduction when the same volumetric decrease is applied to the lower $Q_{7,2}$ flow of 0.057 m^3/s (2.0 cubic feet per second).

Similarly, the 5.8 percent reduction in average base flow presented above for Pickerel Creek increases to a 38.3 percent reduction in flow when the same volumetric flow reduction is applied to the much lower $Q_{7,2}$ flow of 0.017 m^3/s (0.6 cubic feet per second).

TABLE 4.2-7

$Q_{7,2}$ AND $Q_{7,10}$ STREAM BASE FLOW RATES - STEADY-STATE MINE INFLOW FOR MIDDLE RECHARGE CASE

SEGMENT DESCRIPTION	SEGMENT[b]	REDUCTION OF FLOW RATE[c] m^3/s	REDUCTION OF FLOW RATE[c] cfs	$Q_{7,2}$ FLOW RATE[a] PRECONSTRUCTION m^3/s	$Q_{7,2}$ PRECONSTRUCTION cfs	$Q_{7,2}$ STEADY-STATE m^3/s	$Q_{7,2}$ STEADY-STATE cfs	$Q_{7,2}$ PERCENT REDUCTION	$Q_{7,10}$ FLOW RATE[a] PRECONSTRUCTION m^3/s	$Q_{7,10}$ PRECONSTRUCTION cfs	$Q_{7,10}$ STEADY-STATE m^3/s	$Q_{7,10}$ STEADY-STATE cfs
Upper Hemlock Creek	AB	0.012	0.42	0.057	2.0	0.045	1.58	21.0	0.040	1.4	0.028	0.98
Lower Hemlock Creek and Swamp Creek Below Hemlock Creek Confluence	BC	0.015	0.53	0.190	6.7	0.175[d]	6.17[d]	7.9[d]	0.133	4.7	0.078[d]	2.77
Swamp Creek Above Rice Lake	CD	0.016	0.54	0.311	11.0	0.295[d]	10.46[d]	4.9[d]	0.226	8.0	0.077	2.76
Hemlock and Swamp Creeks	ABCD	0.043	1.49	0.311	11.0	0.268	9.51	13.5	0.226	8.0	0.183	6.51
Pickerel Creek, Upstream of Rolling Stone Lake	EF	0.007	0.23	0.017	0.6	0.010	0.37	38.3	0.011	0.4	0.004	0.17
Rolling Stone Lake and Lower Portion of Pickerel Creek	FG	0.002	0.06	0.184	6.5	0.182[d]	6.44[d]	0.9[d]	0.133	4.7	0.120	4.24
Rolling Stone Lake and Pickerel Creek	EFG	0.009	0.29	0.184	6.5	0.175	6.21	4.5	0.133	4.7	0.124	4.41
Creek 12-9[e]	--	0.016	0.56	0.043	1.500	0.027	0.94	37.3	0.031	1.10	0.015	0.54
Creek 11-4 (Marting Spring)[e]	--	0.002	0.08	0.008	0.300	0.006	0.22	26.7	0.006	0.20	0.003	0.12

[a] Flow rates $Q_{7,2}$ and $Q_{7,10}$ are average low flows over a 7-day period and having a 2- and 10-year recurrence period, respectively.
[b] Refer to Figure 4.2-6 for segment locations.
[c] Refer to Appendix 4.1A, Table A-19. The reduction in stream flow rate is assumed to be only from changes in ground water discharge from the site area.
[d] The actual total reduction in this segment will be greater, resulting from reduction in the upstream segment.
[e] Source: DNR letter from B. Baker/R. Roden to B. Hansen dated October [illegible] 1985.

Similarly to the previous discussion for average base flow, the lower $Q_{7,2}$ base flow in Hoffman Creek, which originates at Hoffman Spring, may be reduced because of the overall reduction in ground water flow and the decline of the potentiometric surface in the area of the spring. While the exact effects will be dependent on topography in the vicinity of the spring, the model results indicate that Hoffman Spring and Creek may experience some reduction of flow.

Creek 12-9 originates at the surface outflow of Little Sand Lake and flows southwest to Rolling Stone Lake picking up a ground water discharge component downstream. The ground water modeling results indicate an approximate 22 percent reduction in ground water discharge into Creek 12-9 as indicated above for the average base flow. When this same volumetric flow reduction is applied to an estimated $Q_{7,2}$ flow of 0.04 m^3/s (1.5 cubic feet per second) for the creek, the reduced flow would be approximately 0.027 m^3/s (0.94 cubic feet per second) indicating an approximate 37 percent flow reduction.

Creek 11-4 originates at Martin Spring and has an estimated $Q_{7,2}$ flow of 0.009 m^3/s (0.3 cubic feet per second). Ground water flow in this area is expected to be reduced by about 15 percent as indicated by the base flow reduction shown in Table 4.2-6; under $Q_{7,2}$ flow conditions this same volumetric flow reduction would result in a reduced stream flow of approximately 0.006 m^3/s (0.22 cubic feet per second), a flow reduction of approximately 27 percent.

For all of the above streams, projections of flow changes at the lower $Q_{7,10}$ flow rates have also been included in Table 4.2-7. For the reduced flows the same volumetric flow changes have also been applied to the $Q_{7,10}$ flows. As explained above this conservative approach probably overestimates the percentage changes, because the volumetric flow reductions would likely also decrease during low flow conditions. In any event, a Hydrologic Impact Contingency Plan is provided to mitigate effects for these low flow conditions with a ground water supplement equal to the full value of the projected volumetric flow reduction.

Excess Water Discharge

The discharge of treated excess water into Swamp Creek below Rice Lake was evaluated to determine the potential for increased downstream flooding and alteration of channel morphology (USGS, 1984). The flood potential for Swamp Creek below the treated water outfall will not increase as a result of the discharge. An outfall discharge of 0.126 m^3/s (2,000 gallons per minute), which is approximately 2 percent of the highest recorded flow was considered for analysis of impacts. Actual discharges are expected to be lower, approximating the 0.08 m^3/s (1,270 gallons per minute) steady-state mine inflow.

The USGS (1984) has indicated that given the natural variability of width and depth of Swamp Creek, the predicted small increases in channel bankfull depth and width from the discharge will be negligible.

4.2.4.1.2 Lakes

The primary source of inflow for all Project site area lakes is direct precipitation and surface water runoff. Because the lakes receive direct surface runoff resulting from precipitation and some receive ground water and/or stream inflow, the projected average effects on lake water levels will be small. The effects due to drawdown during operations will begin to be experienced after Project Years 6-8 following the development of the expected steady-state mine inflow.

For Deep Hole, Duck, Little Sand, and Skunk lakes the elevation of the potentiometric surface is the controlling factor in lake seepage. Lowering the potentiometric surface will increase the hydraulic gradient across the lake bottom and will increase ground water recharge (seepage) from the lake. Table 4.2-8 presents the difference in recharge rate and the estimated average water level declines due to the increased seepage from these lakes at steady-state mine inflow for the middle recharge case and average climatic conditions.

Table 4.2-8 also includes the overall (mine and climate related) lake level decline projected during two consective dry years. This overall change includes the normal decline from reduced precipitation combined with the decline related to increased seepage from mine inflow and ground water table decline. Figure 4.2-7 presents these results graphically for each Project area lake and shows the representative seasonal fluctuations the lakes will experience with and without the additional influence of increased seepage from ground water table decline. The analysis includes a year of average climatic conditions followed by 2 years of dry climatic conditions and a return to average climatic conditions. Because of the hydrologic conditions at Skunk Lake, only 1 year of dry climatic conditions was analyzed.

The lake graphs show changes for average climatic conditions are minimal. For dry conditions, while the changes are greater, they

TABLE 4.2-8

PREDICTED RECHARGE RATE FROM LAKES WITHIN THE SITE AREA[a]

LAKE	PRECONSTRUCTION PHASE RECHARGE RATE[b] (per unit area)		OPERATION PHASE RECHARGE RATE[c] (per unit area)		DIFFERENCE		ESTIMATED AVERAGE LAKE LEVEL DECLINE[d] (average climatic conditions)		ESTIMATED AVERAGE LAKE LEVEL DECLINE (dry climatic conditions)	
	mm/y	in/y	mm/y	in/y	mm/y	in/y	m	ft	m	ft
Deep Hole	203	8.00	274	10.80	71	2.80	0.01	0.04	0.1	0.3
Duck	541	21.30	585	23.02	44	1.72	0.06	0.21	0.6	2.0
Skunk	1011	39.80	1611	63.44	600	23.64	0.18	0.58	0.3[e]	1.0[e]
Little Sand	203	8.00	573	22.54	370	14.54	0.07	0.23	0.2	0.7
Oak[f]	231	9.10	232	9.12	1	0.02	0.00	0.00	0.0	0.1

[a]Lake recharge rates and levels are maximum seepage values for the potentiometric surface for steady-state mine inflow. Procedures are presented in Appendix 4.1A, Attachment A.10.

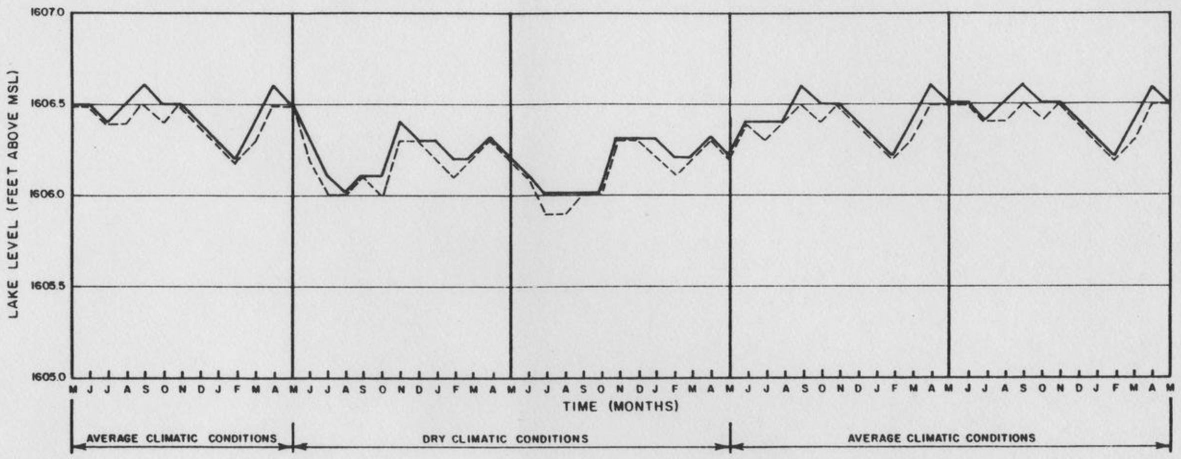
[b]Source: Dames and Moore (1985).

[c]Recharge rates presented are calculated assuming uniform lake bed sediment permeabilities for each lake; see Appendix 4.1A, Attachment A.10.

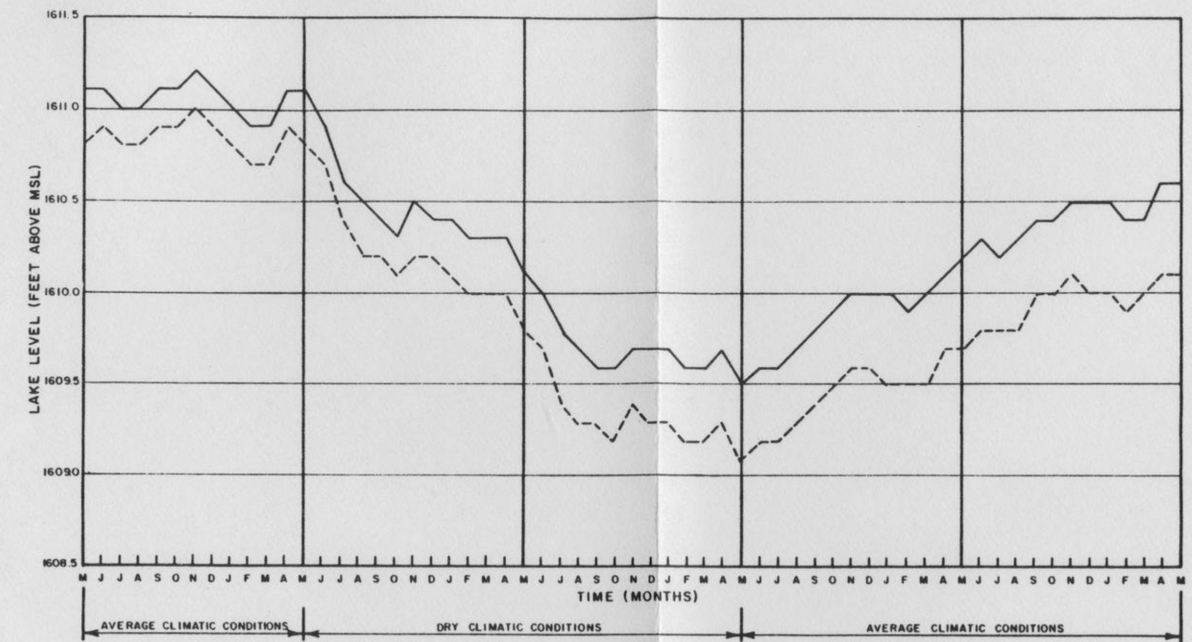
[d]Average decline is the mean value of the monthly differences between computed preconstruction and operation phase lake levels (see Appendix 4.1A, Attachment A.10).

[e]Dry climatic conditions at the end of one dry year.

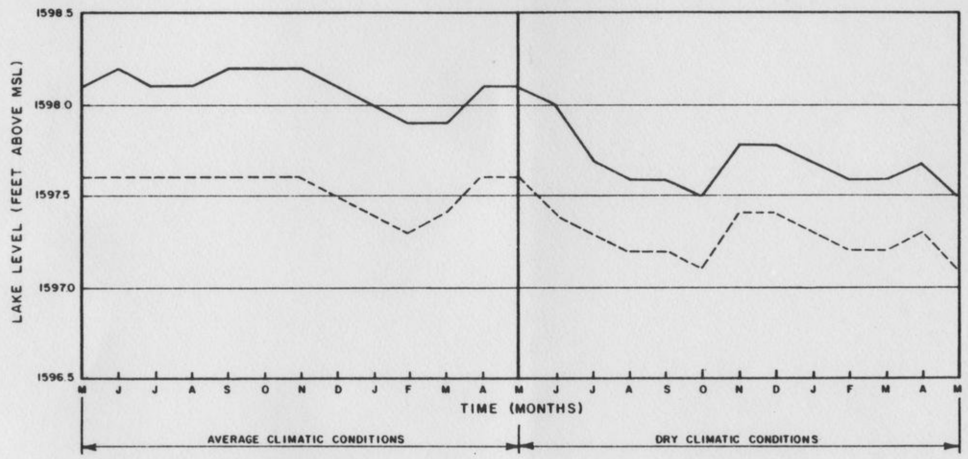
[f]Oak Lake is perched and is not in direct contact with the potentiometric surface; differences in seepage rates result solely from different calculation methods.



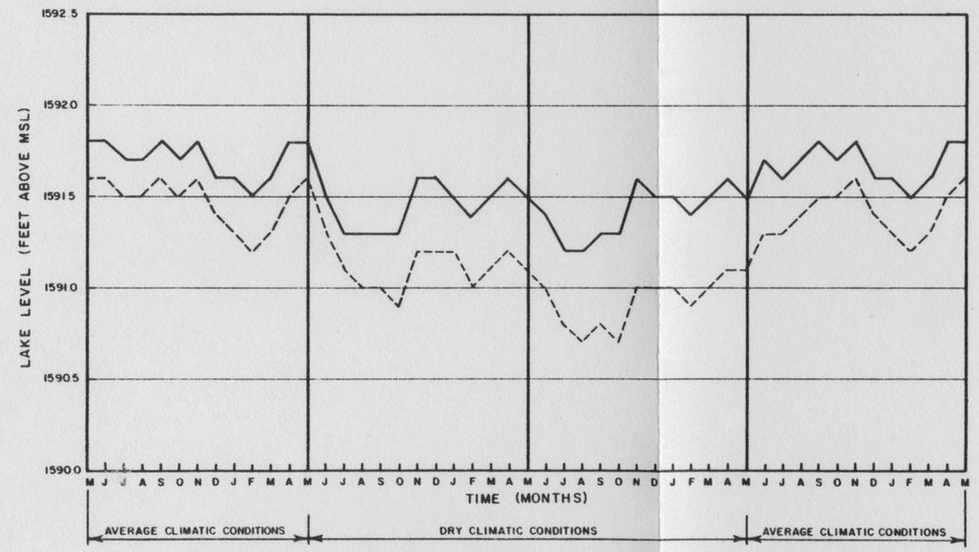
DEEP HOLE LAKE (2)



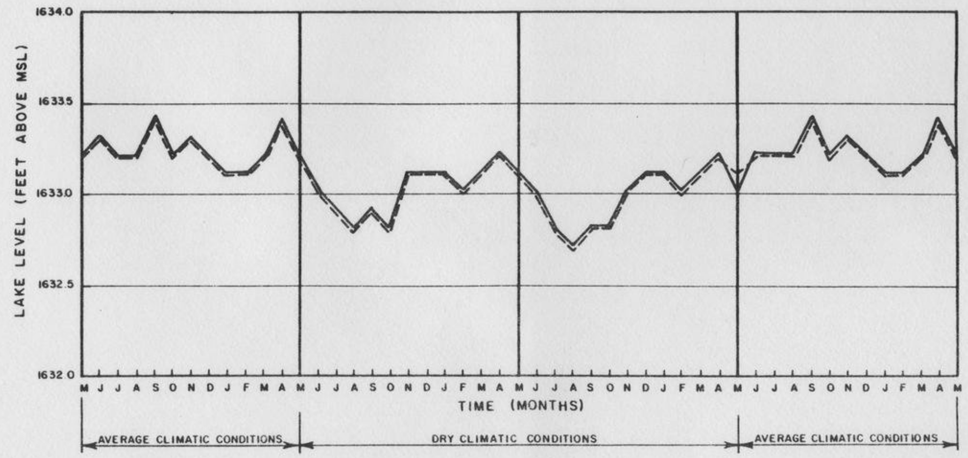
DUCK LAKE (3)



SKUNK LAKE (3)



LITTLE SAND LAKE (2)



OAK LAKE (1)(2)

LEGEND

——— ESTIMATED LAKE LEVEL DURING PRECONSTRUCTION PHASE

– – – – PREDICTED LAKE LEVEL DURING STEADY-STATE MINE INFLOW

NOTES

(1) PREDICTED LAKE LEVELS DURING OPERATION PHASE EQUAL PRECONSTRUCTION LAKE LEVELS BECAUSE PRECONSTRUCTION GROUND WATER LEVELS ARE BELOW BOTTOM OF LACUSTRINE SEDIMENTS.

(2) PRECONSTRUCTION LAKE LEVEL ANALYSIS PERFORMED USING CONSTANT LAKE SEEPAGE RATE AND AREA.

(3) PRECONSTRUCTION LAKE LEVEL ANALYSIS PERFORMED USING LAKE SEEPAGE RATES AND AREAS DETERMINED FROM LAKE LEVELS.

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE **PROJECTED LAKE LEVEL CHANGES VERSUS TIME FOR AVERAGE & DRY CLIMATIC CONDITIONS**

SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY DRS	DATE 1/86	CHECKED BY		DATE
APPROVED BY	DATE	APPROVED BY		DATE
APPROVED BY	DATE	EXXON		DATE
DRAWING NO **FIGURE 4.2-7**			SHEET ____ OF ____	REVISION NO

are primarily related to the dry climatic conditions. The graphs also show that when average climatic conditions resume the lake levels recover from the declines they experience during dry conditions.

Based on the lakes proximity to the mine and their specific hydrologic condition, each lake responds differently to the hydrologic changes from mine inflow and also to the normal varying climatic conditions.

For average climatic conditions the recharge from Deep Hole Lake will increase approximately 71 mm/y (2.8 inches per year). This increase in seepage is not expected to have a noticeable effect on the water level of the lake.

Skunk Lake will have an increase in recharge rate from 1,011 to 1,611 mm/y (39.8 to 63.4 inches per year). This results in an increase in seepage of 600 mm (23.6 inches) per year. For average climatic conditions this increased seepage is expected to cause an average water level decline of 178 mm (7 inches). This could result in a reduction of lake area of 2.4-4.0 ha (6-10 acres) (35-60 percent) primarily affecting the associated lakeside wetland area. A water supplement to mitigate these impacts is proposed for Skunk lake.

Little Sand Lake will also experience an increase in ground water recharge from 203 mm (8.0 inches) per year for computed natural conditions to 573 mm (22.5 inches) per year for steady-state mine inflow. This increase in seepage is expected to cause an average lake level decline of approximately 76 mm (3 inches) for average climatic conditions. This corresponds to a reduction of lake area of approximately 1.6 ha (4 acres) (1.6 percent).

Duck Lake will experience an increase in seepage from its baseline value of 541 mm (21.3 inches) to approximately 585 mm (23.0 inches). This increased seepage is expected to cause an average lake decline of approximately 76 mm (3 inches) during average climatic conditions. This water level decline would not cause a noticeable difference in the lake and associated lakeside wetland area.

The lacustrine sediments in Oak Lake are above the potentiometric surface (STS Consultants, Ltd., 1984). No changes in the ground water recharge rate from Oak Lake will occur as a result of lowering the potentiometric surface.

The declines predicted for the lakes for average climatic conditions are not cumulative. They represent the total change the lakes will experience for continuing average climatic conditions as a result of increased seepage from mine inflow. For the lakes with outflows (Deep Hole, Little Sand and Duck), reduction of outflow accompanies the decline. Detail of the outflow changes is included in Appendix 4.1A, Attachment A.10.

For dry climatic conditions, the computed decline for Deep Hole Lake is only approximately 0.1 m (0.3 foot). As Figure 4.2-7 indicates, this change is related almost totally to the dry climatic condition.

Skunk Lake was only analyzed through one dry year. The hydrologic conditions for Skunk Lake are not reliable beyond that time due to the shallow depth and extent of wetlands surrounding the lake. An overall 0.3 m (1.0 foot) decline was predicted for Skunk Lake, with most of the decline in lake level being attributable to the dry climatic condition.

Little Sand Lake is predicted to undergo an overall decline of approximately 0.2 m (0.7 foot) during dry climatic conditions. For Little Sand Lake, most of this projected change is related to the influence of mine inflow (Figure 4.2-7).

Duck Lake is expected to undergo an overall 0.6-m (2.0-foot) decline during dry climatic conditions. However, as indicated in Figure 4.2-7, approximately three-fourths of this decline is in response to the climatic change and not the result of mine operations.

Oak Lake shows declines in level for the dry climatic condition and, as noted earlier, it is all attributable to the climatic change.

Additional detail for the lake impacts including annual fluctuations and impacts for dry climatic conditions are included in Appendix 4.1A, Attachment A.10.

Lakes on the boundary of the study area (Crane, Ground Hemlock, Pickerel, Rice, and Rolling Stone) are connected hydraulically with the ground water potentiometric surface. Mine dewatering will not alter the potentiometric surface at these lakes or the lake level. Rolling Stone, Pickerel, and Rice lakes are discharge lakes dependent upon inflowing streams; however, the minor reductions in stream flow rates from Project operations are expected to have a negligible effect on these lake levels.

The reduction of ground water discharge to stream flow entering Rolling Stone Lake for steady-state mine inflow conditions is presented in Tables 4.2-5 and 4.2-6. The percent reduction of stream discharge (average annual base flow) to Rolling Stone Lake is less than

4.1 percent for the middle recharge case. Based on the discharge stream elevation relationship for stream gage SG 22, downstream of Rolling Stone Lake, flow reductions of this amount would be accompanied by a negligible water level decline, and the effect on the lake level attributable to Project operations is predicted to be unnoticeable.

Pickerel Lake receives direct ground water discharge from basin No. 7 as shown on Figure 4.2-6. In addition, Pickerel Lake receives the flow of Pickerel Creek flowing from Rolling Stone Lake. Basins 5, 6 and 7 provide the base flow to Pickerel Creek and direct discharge to Pickerel Lake. The reduction of average annual stream base flow from basin Nos. 5 and 6 is estimated to be 4.1 percent for the middle recharge case at steady-state mine inflow. Other inflows to Pickerel Lake would be reduced less, indicating the overall flow reduction to Pickerel Lake would be less than 4.1 percent. An average flow reduction of less than 4.1 percent will not cause a noticeable change in lake level.

For steady-state mine inflow conditions a reduction of surface water inflow to Rice Lake is predicted. Rice Lake receives an average annual stream base flow of 0.54 m^3/s (19.0 cubic feet per second) from Swamp Creek and additional inflow from Basins No. 3 and 4 (Appendix 4.1A). Omitting the base flow contributions for these two basins, the reduction in annual stream base flow from Swamp Creek will be 7.8 percent for steady-state mine inflow. This is equivalent to a 3.2 percent reduction in the average annual flow for Swamp Creek above Rice Lake. Since Basin No. 4 contributes a significant base flow to Rice Lake and its base flow will not be affected, the overall percentage reduction in base flow to Rice Lake will be substantially less than the above numbers. Therefore, the reduction in lake level will be negligible.

4.2.4.1.3 Springs

The elevation of Hoffman Spring is at the preconstruction potentiometric ground water surface. During operation, mine dewatering activities will lower the potentiometric surface slightly at Hoffman Spring, which is near the edge of the zone of influence created by mine dewatering. Evaluation of the impact of this lowering of the potentiometric surface for steady-state mine inflow, using the middle recharge case, indicated a reduction of approximately 0.8 m (2.6 feet) in the area of the spring. A review of the ground water flow vectors indicates the ground water flow rate in the vicinity of the spring could be reduced by approximately 30 percent. This reduction in ground water flow and water table elevation indicates that Hoffman Spring may experience some reduction of flow. The specific impact to the spring depends on the exact relationship of the topography and hydrologic setting in the area of the spring. However, a mitigative supplement is proposed for Hoffman Spring to replace any flow reduction in the spring related to the mine.

Although the predicted ground water table decline at Martin Spring is expected to be negligible, model calibrated ground water discharge in the area of the spring will be reduced by an estimated 15 percent. Applying this same volumetric flow reduction to the estimated $Q_{7,2}$ of 0.008 m^3/s (0.3 cubic feet per second) in Creek 11-4 (originating at Martin Spring), the flow would reduce to 0.006 m^3/s (0.22 cubic feet per second) indicating an approximate 27 percent reduction in flow.

These spring impacts are the same as the impacts predicted for their associated streams as described in subsection 4.2.4.1.1. Additional detail of the impacts is also included in Appendix 4.1A.

4.2.4.1.4 Hydrologic Impact Contingency Plan

As described in Exxon's Hydrologic Impact Contingency Plan, actions will be taken during operation to ensure that impacts to surface waters are minimized. The mitigation actions for streams and springs consist of supplementing the flow with ground water from nearby wells. The plan for lakes includes installation of lake level control structures for Little Sand and Duck lakes and a water supplement to Skunk Lake. These actions will ensure that impacts to streams, springs and lakes will be minimized. More detailed information on these actions is presented in the Hydrologic Impact Contingency Plan in the High Capacity Well Approval.

4.2.4.1.5 Wetlands Hydrology

Hydrologic impacts to wetlands during the operation phase can be divided into two categories: (1) those associated with mine dewatering, primarily the impacts caused from changes in the potentiometric surface, and (2) those associated with changes in drainage patterns, vegetative cover type, and surface water infiltration and runoff as a result of completed Project surface facilities.

Alterations in wetland water balances may result in changes in wetland functions. These alterations may mean more water or less water flowing through a wetland, and possibly a change in vegetative community types. Two different wetland hydrological types (perched wetlands and water table wetlands) were identified during the 1981 wetlands assessment (NAI and IEP, Inc., 1982).

Perched Wetlands

Haul Road/Tailings Transport Pipeline Corridor - Construction and use of the haul road and tailings transport pipeline through the watersheds of various wetlands will not measurably change the hydrology of the wetlands. The pipeline and road will be constructed through wetland F11 (Figure 4.1-4). Ditches along the sides of the road will convey water into the watershed of wetland F11. There may be a slight increase in runoff generated by the change in cover type created by the gravel roadway surface, but the amount would not be sufficient to cause wetter conditions in wetland F11. There will not be a decrease in surface water runoff to the wetland.

Mine Waste Disposal Facility - Changes in wetland water balances among MWDF development phases, when compared to existing hydrological conditions, were considered minor for the previous MWDF design and no major hydrologic impacts were evident (IEP, Inc., 1982). Therefore, the changes in wetland inflow or outflow described in IEP, Inc. (1982) for MWDF development phases 2 through 5 are considered representative, although greater in magnitude, for the current downsized MWDF design. During development of the MWDF, the following perched wetlands will be entirely removed and filled: F27, F30, F31, F32, F64, F65, F66, and F81 (Figure 4.1-8). Wetlands F15, F25, F29, F63 and M3 will be partially affected during the development of the MWDF.

Mine/Mill Site - The mine/mill site will encompass approximately 46.6 ha (115 acres) of existing upland forest. No wetlands will be removed because of construction. The watersheds of perched wetlands F11, 01, 03 and P2 will be altered.

The hydrologic alterations (unmitigated) would include the changing of drainage patterns (and hence watersheds), replacement of upland vegetative cover with nearly impervious surfaces of buildings and pavement, and the diversion of surface water drainage from potentially contaminated areas to a water treatment facility. As proposed, the total impervious surface will be approximately 26 ha (65 acres). Uncontrolled, increased runoff from this surface would increase discharge rates from the above mentioned wetlands.

Drainage basins are planned at the northern and southern perimeter regions of the mine/mill site to control surface water runoff from the impervious surfaces to wetland watersheds F11 and P2 (Chapter 1, Section 1.3). The outlet from drainage basin No. 1 will consist of a culvert which controls the rate of runoff and provides water storage in the basin. It will be designed to assure that existing peak runoff to wetland F11 will not be exceeded by that from the developed mine/mill site. Drainage basins No. 2 and 3 will be designed to contain all runoff and will have no discharge to the environment. As a result, no change in wetland discharge rates will occur.

Railroad Spur - The proposed railroad spur will cross the watersheds of perched wetlands F116, F12, F13, F114, and 01 (Figure

4.1-7). Part of the route generally will follow the watershed divide between the watersheds of the F and O wetlands and no wetlands will be crossed along this segment. Grass covered drainage ditches, which retard water flow, and culverts, which allow flow through the railroad bed, will be designed so that the watersheds of the perched wetlands will not be altered.

Access Road - The proposed mine/mill site access road will cross the wetland watersheds of perched wetlands R8 and P2 (Figure 4.1-6). It will begin at the mine/mill site and follow approximately the divide between P2 and R8, then along the P2/U wetlands watershed divide and through the W watershed where there are no wetlands. Because of the location of the access road along surface water divides, there will be no change in wetland watershed areas. Grass covered roadside drainage ditches and culverts will be designed to maintain existing watershed areas and drainage patterns.

Discharge Water Pipeline - The proposed discharge water pipeline corridor will extend from the mine/mill site west to Swamp Creek downstream from County Trunk Highway M (Figure 4.1-5). This corridor will pass through perched wetlands R3 and Z20. It also will pass, from east to west, through the watersheds of perched wetlands R8, R7A, R7, and R5 (Figure 4.1-5).

The pipeline will be buried and the land surface regraded to original contours; disturbed areas will be seeded and existing vegetation will be allowed to recolonize. As a result, there will be no change in watershed areas or vegetative cover types, and there will be no impacts to the water balance of the listed perched wetlands.

Water Table Wetlands

Changes in vegetative cover type and wetland watershed area are the major factors associated with site activities which may cause hydrologic impacts. Potential impacts of the various activities which affect water table wetlands or their wastersheds are presented below.

Access Road - The proposed access road is 4.8 km (3.0 miles) long and will require the filling of 1.3 ha (3.2 acres) of wetlands (Figure 4.1-6), assuming a conservatively large width of 30 m (100 feet) for the construction corridor. For the purpose of these hydrological analyses, the width of pavement was assumed to be 15.2 m (50 feet) and the effects of proposed mitigative measures such as grass covered drainage channels were not considered. The watersheds of water table wetlands W1, W2, Z1, Z2, Z9, Z6, and Z7 will be affected by the proposed access road.

The Swamp Creek watershed upstream from State Highway 55 totals approximately 119.7 km^2 (46.2 square miles). The amount of area changed to paved road surface will be 0.168 km^2 (0.65 square mile) or 0.14 percent of the watershed area. Changes of this dimension in the watershed will result in imperceptible changes in the Swamp Creek discharge.

Grass covered roadside drainage ditches will be designed to ensure minimal change in the water balances of isolated wetlands Z1 and Z2 (having watersheds through which the road would pass). The proposed road generally follows the drainage divide between the wetlands, and the watershed areas of these wetlands will be maintained. No other means to mitigate impacts are necessary.

Railroad Spur - The portion of the proposed railroad spur which includes the Swamp Creek region and the area to the north of Swamp Creek to the Soo Line Railroad will affect water table wetlands T1, T2 and T4.

The railroad bed will require areas of fill and a bridge to cross Swamp Creek. Wetland T4 is a streamside wetland bordering Swamp Creek in the area of the bridge crossing. Kettlehole wetlands T1 and T2 will be filled (Figure 4.1-7). The railroad will be constructed of permeable fill and the road bed will consist of crushed rock ballast, ties, and rails. Side slopes will be grass covered and invasion of shrubs will be allowed. Ditches, culverts, the bridge, and cut and fills will be constructed using conventional engineering methods and practices for railroad construction, so that existing drainage patterns and watershed areas will be preserved in wetland T4.

Discharge Water Pipeline - Water table wetlands Z23, Z25, Z28, Z30, and Z31 will be crossed by the pipeline (Figure 4.1-5). These wetlands have large water balances, are not hydrologically sensitive, and are above average for their hydrological function (IEP, Inc., 1983).

The discharge water pipeline will have no long-term effects on the hydrology of these wetlands. The buried pipeline will primarily be located in upland areas. Approximately 2.8 ha (6.8 acres) of wetland vegetation will be temporarily disturbed during construction (Table 4.1-3). No changes in the contour of the land surface will occur in either upland or wetland areas and thus no watershed areas will be altered. The pipeline will be installed using standard construction techniques and will progress as quickly as possible, thereby limiting the area disturbed at any one time.

Underground Mine - Dewatering of the mine will affect the water balance of water table wetlands which occur within the zone-of-influence of the mine dewatering and associated potentiometric water table reduction (see Figure 4.2-2). In addition, lakeside wetlands will be affected by changes in the lake levels. Water table wetlands and lakeside perched wetlands are discussed under this heading because both types of wetlands will be affected by mine dewatering.

The water table wetlands impacted by the mine drawdown include Z17, Z18, Z19, W1 and an unassessed conifer swamp north of and connecting with Rolling Stone Lake, Z23, Z24 and an unassessed conifer swamp north of Z24 and east of Mole Lake.

The following assumptions were used in this assessment:

1) Ground water discharge is the dominant input to the inflow portion of the water balance of water table wetlands;

2) The projected zone-of-influence will result in a lowering of the water levels in the water table wetlands to equal that of the projected drawdown water table in the adjacent aquifer (middle recharge case);

3) The organic wetland soils will become dewatered; and

4) There are no impermeable layers separatng the wetlands from the aquifer and the two are hydrologically connected.

The impact of mine dewatering to the hydrologic balance of these wetlands would be a reduction of the ground water inflow portion of their water balance and they could become drier during late summer and winter. The impacts to these water table wetlands are summarized below.

In wetland Z17 (shallow marsh), a slight decrease in ground water discharge and subsequent lowering of the potentiometric surface is projected; however, these slight changes will not alter the vegetative community.

In wetland Z18 (deciduous swamp), which borders Hoffman Spring, the decrease in the amount of discharge is not expected to alter the water balance sufficiently to impact the existing vegetative community.

The overall impact to the water balance of wetland Z19 (conifer swamp), bordering Hoffman Creek, will be negligible and no impact to the vegetative community is expected.

Negligible hydrologic impacts are projected for Swamp Creek; consequently, no impact is projected for the adjacent streamside wetland W1.

Wetland Z23 (conifer swamp) forms the headwaters of upper Pickerel Creek. A 5.8 percent reduction in average annual base flow is predicted for Pickerel Creek (Table 4.2-6). A greater percentage reduction is estimated under $Q_{7,2}$ and $Q_{7,10}$ conditions. Under average annual flow conditions negligible impacts to wetland Z23 are anticipated; however, under extended $Q_{7,2}$ flow conditions the vegetative community associated with wetland Z23 could be affected.

A slight decrease in ground water discharge to wetland Z24 and the unassessed conifer swamp north of Z24 and east of Mole Lake is predicted; however, this decrease is not expected to alter the water balance of this wetland and consequently no impact to the existing vegetative community is anticipated.

The lakeside wetlands which may be affected by mine dewatering effects on lake levels (see subsection 4.2.4.1.2 and Appendix 4.1A) are associated with Skunk, Duck and Little Sand lakes. No decline in lake level as a result of dewatering is predicted for Oak Lake; therefore, no impacts will occur to the associated lakeside wetlands.

For average meteorological conditions during the operational phase, lake levels of Duck, Deep Hole, and Little Sand lakes are expected to decline between 0.01 and 0.07 m (0.04 and 0.23 foot).

In analyzing the impact of declines in lake levels on lakeside wetlands, the following assumptions were made:

1) All lakeside wetlands contain organic wetland soils of low permeability;

2) The water table in the lakeside wetlands is primarily controlled by lake levels;

3) Declines in lake levels will generate similar declines in the water table levels of lakeside wetlands. Low permeability wetland soils should create slightly higher water tables in the lakeside wetlands than in the adjacent lakes following precipitation events; and

4) Equilibrium operational phase lake levels will result in the maximum impacts to wetland vegetative communities and wetland soils. Existing vegetative communities have been created in response to previous drought conditions. A 2-year drought is not considered long enough to alter existing vegetative communities.

The wetland associated with Duck Lake, lakeside wetland F28, consists of shrub swamp and wooded swamp (bogs) which have formed over thick peaty soils. Most of this wetland is a floating root mat underlain by peat. Minor lowering of the level of Duck Lake will lower the elevation of this bog but the change to the overall area of the lake-wetland system is expected to be negligible. This minor lowering may promote the growth of trees versus shrubs and herbs and expansion of the wooded swamp, particularly at the edge of the wetland.

Four lakeside wetlands, F19, F21, F23 and F37, are associated with Deep Hole Lake, which is predicted to experience a minimal decline in lake level for average conditions of approximately 0.01 m (0.04 foot). This will result in a negligible decrease in overall lake-wetland area. Wetlands F19, F23 and F37 are primarily deep and shallow fresh marsh communities, with smaller areas of shrub swamp and wooded swamp. Decreased lake levels and water table levels in the wetlands may cause slight advances of drier wetland communities into existing areas of wetter communities. For example, shrub swamp may invade into the edge of shallow marsh areas. This would be the result of more habitat availability for shallow rooted woody species as water levels decline and soil mineralization occurs.

An unknown factor which may influence lake levels in Deep Hole Lake is the presence of an active beaver population which maintains dams at both the primary and secondary outlets. The existing lake levels and adjacent wetlands are in response to this beaver activity.

The discharge from both Duck and Deep Hole lakes will be reduced, possibly altering the water balance of wetland F18, which receives surface water discharge from both lakes. In addition, seepage from F18 to the water table should be increased in a manner corresponding to that of increased seepage in Deep Hole and Little Sand lakes. Thus, a decline in the water budget of F18 is predicted, resulting in a decline in the water table of approximately 0.12 m (0.4 foot).

The impacts predicted to F18, a coniferous swamp, are a mineralization of the upper 0.12 m (0.4 foot) of soil and more favorable growing conditions for wetland tree species. Shrub density may decrease while tree density or height may increase. Observable species composition changes are not expected.

Little Sand Lake has four lakeside wetlands; F2, a deep marsh and shrub swamp, and F4, F9 and F10, conifer swamps. For average conditions, Little Sand Lake will decline in level by approximately 0.01 m (0.23 foot). Impacts of slight mineralization of the wetland soil in the conifer swamps with increased tree growth are predicted. Invasion of wetland species adapted to somewhat drier conditions may occur in F2.

Analysis of drawdown effects on Skunk Lake indicates drops of approximately 0.15 to 0.18 m (0.5 to 0.6 foot) in lake level and reduction in lakeside wetland and open water area from 6.4 ha (15.7 acres) to 2.4 to 4.0 ha (6 to 10 acres). The deciduous wooded swamp that forms the northeast portion of the Skunk Lake basin is expected to invade into the adjacent marsh areas as dewatering progresses. The marsh is expected to invade into those areas of existing open water which will be dewatered. The remaining 2.4 to 4.0 ha (6 to 10 acres) of open water may become deep marsh. Mineralization of wetland soils is expected in the existing areas of deciduous swamp and marsh.

As described in subsection 4.2.4.1.4, actions will be taken during operation to ensure that impacts to surface waters are minimized (see the Hydrologic Impact Contingency Plan in the High Capacity Well Approval).

4.2.4.2 Surface Water Quality

As discussed in subsection 4.2.3, the chemical constituents seeping from the tailing ponds will not migrate beyond the till under the MWDF during the operational period of the mine. Therefore, no effects on surface water quality are anticipated during the operation period.

The waste water discharge to Swamp Creek could degrade water quality in Swamp Creek if the water treatment system malfunctioned. Water treatment system upsets could occur as a result of numerous conditions involving equipment malfunctions. The worst-case upset condition would be if the entire treatment system is off-line. As a result, it would not be possible to treat the wastewater. However, during partial or complete shutdown of the treatment system, water not meeting effluent limits would be held within the storage capacity of the treatment system (i.e., the discharge water lagoons and the reclaim pond) and/or the operating tailing pond. There is sufficient capacity above the normal operating level in the reclaim pond alone to hold all anticipated discharge water for 26 days. This is based on using 75 percent of the total freeboard volume and an average discharge of 0.09

m^3/s (1,385 gallons per minute). Additional capacity is available in the operating tailing pond. Therefore, upset conditions are not anticipated that would result in having to discharge water not meeting WPDES permit limits.

To ensure that discharge water meets WPDES limits, an automated monitoring system will be used to continuously monitor pH, turbidity and conductivity of the treated effluent and the uncontaminated mine water. In addition, chemical analyses of samples will be performed routinely for other critical constituents. The frequency and type of chemical analyses and the exact constituents analyzed will be reviewed with the DNR Industrial Wastewater Section, Bureau of Wastewater Management, in conjuction with the development of the WPDES permit for this discharge. This monitoring system combined with sufficient storage capacity for any short-term upset will ensure that water is not discharged which would impair the integrity of Swamp Creek.

4.2.4.3 Surface Water Use

There are no known consumptive users of surface water within the potentially affected areas (Chapter 2, Section 2.4). Therefore, there will be no effect on surface water users.

4.2.5 Aquatic Ecology

During Project operation, ground water seepage into the mine will be collected, pumped to the surface, treated, and discharged to Swamp Creek downstream of Rice Lake. Inflow of ground water into the mine will result in a lowering of the ground water table in the site area. The degree to which selected streams and lakes in the area will be affected during operation is discussed in subsections 4.2.3 and 4.2.4 and in Appendix 4.1A. The methodology and background information that were used as the basis for evaluating impacts on aquatic biota are presented in Appendix 4.2A. In this subsection the potential reductions in stream flows and lake levels are discussed with regard to effects on aquatic biota (principally fish and macroinvertebrates) in site area streams and lakes.

4.2.5.1 Streams

The results of the low flow comparisons made before and after the predicted reductions in stream flow are summarized in Table 4.2-9. The percentages that $Q_{7,2}$ flows contribute to average annual flow are very similar among four of the six streams. For example, $Q_{7,2}$ percentages in these streams are between 32 and 35. In Hoffman Creek and Creek 11-4, the contribution made by the $Q_{7,2}$ flow is similar (51 versus 52 percent) but noticeably higher than in the other four streams. The $Q_{7,10}$ percentages in all streams ranged from only 23 to 25. After accounting for the predicted reductions in flow, the range is still small for all streams except Creek 11-4. These

TABLE 4.2-9

SUMMARY OF LOW FLOW COMPARISONS AMONG SIX STREAMS IN THE SITE AREA USING THE MONTANA METHOD[a]

	Q7,2		Q7,10	
STREAM	BEFORE FLOW REDUCTION (%)	AFTER FLOW REDUCTION (%)	BEFORE FLOW REDUCTION (%)	AFTER FLOW REDUCTION (%)
Swamp Creek	35[b]	30	25	21
Hemlock Creek	34	27	24	17
Hoffman Creek	51	36	25	18
Pickerel Creek	34	23	23	11
Creek 12-9	32	23	23	18
Creek 11-4	52	44	--	--

[a]Description of the Montana Method is presented in Appendix 4.2A.

[b]All data represent the percent that the indicated flow contributes to average annual flow.

observations suggest that impacts, if they occur, would probably be similar in all six streams, assuming other factors are equal.

Based on the classifications of the Montana Method (see Appendix 4.2A for a description of this method), few, if any, impacts are expected if the predicted reductions occur when flow rates are equal to or higher than $Q_{7,2}$ values. Only Pickerel Creek may experience significant impacts if the predicted reductions occurred concurrent with $Q_{7,10}$ flow rates.

All other factors are not equal when the Montana Method is applied to a stream because the method assumes that the aquatic biota of all streams responds identically to given reductions in flow. The exact manner in which the biota of any particular stream react to a given reduction in flow depends on the inherent sensitivity of the organisms present and the stream itself to reductions in flow. The information presented in Table 4.2-10 provides an indication of the relative sensitivity of each stream in the study area according to three categories: (1) the number or abundance of sensitive fish and invertebrate species, (2) morphometric and morphological factors (e.g., number of riffles, amount of undercut banks), and (3) the degree to which each stream serves as a spawning area for trout. Each category was assigned a relative rating. For example, Swamp Creek has more sensitive species and more sensitive habitats compared to the other five streams in the site area. However, there are many streams in Wisconsin that have more sensitive species and habitats than Swamp Creek. The sensitivity ratings for the Montana Method category in Table 4.2-10 are

TABLE 4.2-10

SENSITIVITY OF SIX STREAMS IN THE SITE AREA TO REDUCTIONS IN STREAMFLOW

STREAM	RELATIVE SENSITIVITY RELATED TO THREE FACTORS[a]			ABSOLUTE SENSITIVITY ACCORDING TO THE MONTANA METHOD	SENSITIVITY[b]
	NO. OR ABUNDANCE OF SENSITIVE SPECIES	STREAM MORPHOLOGY AND MORPHOMETRY	SPAWNING		
Swamp Creek	5	5	3	1	3.5
Hemlock Creek	3	1	2	2	2.0
Hoffman Creek	3	4	5	2	3.5
Pickerel Creek	1	1	1	3	1.5
Creek 12-9	2	3	3	2	2.5
Creek 11-4	1	1	1	1	1.0

[a]Numerical rating with 5 being the most sensitive and 1 the least sensitive.

[b]Value is the arithematic mean of the total for the four columns.

not relative ratings but are based on the narrative descriptions provided by the method.

Based on the stream sensitivity ratings, Swamp Creek and Hoffman Creek are the two most sensitive streams, and the other four are less sensitive. Swamp Creek has a higher sensitive rating because of the number of sensitive species and the amount of riffle habitat present. Importantly, the reduced flow rate in Swamp Creek when compared to the recommended base flow regimes in the Montana Method (Appendix 4.2A, Table A-1) indicates Swamp Creek would be least affected by the predicted flow reductions. Hoffman Creek is considered sensitive because of its extremely shallow nature and its importance as a brook trout spawning area. The likelihood that the four other streams will be significantly affected by the predicted reductions in flow seems low, either because the Montana Method indicates few effects are likely (e.g., Hemlock Creek and Creeks 12-9 and 11-4) or because the biota of the stream is not sensitive to flow reductions (e.g., Pickerel Creek). Among the four streams, Creek 12-9 is considered the most sensitive because of its shallow upper reaches and because it supports a small but self-sustaining brook trout population.

Impacts to Macroinvertebrates - Another important biological group to consider regarding their susceptibility to flow reductions is the macroinvertebrates. The data presented in Chapter 1, Section 2.5, indicate that the macroinvertebrate communities inhabiting Pickerel Creek, Creek 12-9, Creek 11-4, Hemlock Creek, and the pool habitats of Swamp Creek (such as Station E) are comprised of species that would be minimally impacted by the flow reductions described in subsection 4.2.4

and Appendix 4.1A. The above streams/stations contain typical pool habitats (and associated organisms) with depositional substrates, low current velocities and substantial stream depth. Pickerel Creek, Creek 11-4, and Hemlock Creek contain pool habitats and soft/fine substrates exclusively (see Chapter 2, Tables 2.5-8 and 2.5-24 and EA Science and Technology [1984b]). Reducing base flows would alter the pool habitats in these streams only slightly. In addition, the benthic community of these streams/stations is dominated by organisms that prefer depositional habitats. The dominant taxa at these stations (midge-fly larvae [Procladius sp. and Tanytarsus sp.], immature tubificid oligochaetes and the mayfly Caenis sp.) are commonly collected in silty slow-water habitats. A survey of an Illinois stream during drought conditions (Larimore et al., 1959) indicated that the above taxa were able to survive or quickly recover from extremely low water conditions.

Creek 12-9 also contains predominantly pool habitats and soft substrates; however, the intermittent, upstream reaches of the stream contain an area of rocky riffle habitat. Macroinvertebrates in the permanent, downstream reaches of Creek 12-9 were dominated by depositional organisms (midges and fingernail clams) that are not indicative of fast-flowing, riffle habitat.

The composition of the benthic faunas in Creeks 12-9 and 11-4 was slightly different from the other slow-moving streams near the mine site (i.e., greater densities of isopods and fingernail clams); however, the community was still representative of depositional streams and was not similar to the riffle fauna present in portions of Swamp Creek.

Hoffman Creek was not sampled for macroinvertebrates; however, the benthos can be predicted by examining the physical characteristics and other biological communities of the stream. The riffle habitats and trout redd area present in Hoffman Creek suggest that the macroinvertebrate community would be composed primarily of lotic, fast-water organisms. However, because of its extremely small flow, Hoffman Creek probably supports a community low in diversity and density.

The macroinvertebrate community inhabiting the riffles of Swamp Creek contains populations which potentially could be influenced by reduced or discontinuous flows. Because of the water depth (0.3 to 0.8 m [1.0 to 2.6 feet]) at the riffle sampled on Swamp Creek at Station D, and the predicted small flow reduction (8 percent of annual base flow), drying out or discontinuous flow is highly unlikely at this particular riffle. However, reduced flows and the attendant reduction in current velocities could potentially affect this and other riffle communities because the diverse and abundant insect fauna present at Station D (and presumably at other riffle habitats on Swamp Creek) is dependent on relatively fast current velocities. The dominant midges, Micropsectra sp. and Rheotanytarsus sp., are classified as rheobiontic, i.e., characteristic only of running water (Beck, 1977). The riffle habitat sampled on Swamp Creek yielded numerous stonefiles (e.g., Nemoura spp., Acroneuria spp., and Isoperla spp.), mayflies (especially Ephemerella spp. and Paraleptophlebia spp.) and caddisflies (e.g., Leucotrichia pictipes, Glossosoma spp., Symphitopsyche bifida and Symphitopsyche recurvata) which are generally confined to cooler, fast-flowing streams in the Midwest (Ross, 1944; Wiggins, 1977; Hilsenhoff, 1981).

Minshall and Winger (1968) found that a sudden reduction in flow caused a large increase in the percentage of drifting organisms. The relatively small (8 percent) projected decrease in Swamp Creek flow may cause an initial increase in drift during low flow conditions; however, since the current velocities will probably decrease only slightly, it is likely that the riffles will be quickly repopulated.

The results of experiments conducted by Rabeni and Minshall (1977) indicated significantly lower populations of certain riffle organisms (mayflies, stoneflies and riffle beetles) when subjected to a four-fold decrease in substrate-surface current velocities. Further reductions in densities were noted when these taxa were subjected to both reduced current and a light coating of silt. Of the organisms examined, the Chironomidae was the only taxon to show a significant increase in density because of reduced current or added silt. Although similar population changes theoretically could occur in riffle habitats in Swamp Creek, the current velocity decreases in Swamp Creek should be less than 8 percent (the amount that flows will be reduced) because the percentage reduction in velocity is typically less than that seen for flow rate (Kraft, 1972).

Fisher and LaVoy (1972) sampled the benthic fauna of a stream subjected to fluctuating water levels because of an upstream hydroelectric dam. The zone subject to greatest exposure (70 percent of the time) yielded the lowest density and diversity. Community composition shifted from chironomid-oligochaete predominance on the most exposed sites to mullusc predominance on the least exposed sites. These data suggest that periodic exposure (13 percent of the time) did not alter the community.

In summary, the projected drop in water levels in riffle habitat on Swamp Creek will result in a slight loss of available habitat; however, the relatively small decrease in flow and resulting reduced current velocity will probably affect only the strictly rheobiontic organisms. The degree of this impact will depend on the actual current velocity reduction and sedimentation increase. Drying out or discontinuous flow is not likely to occur in Swamp Creek riffle areas. Similar impacts might occur in the riffle areas of other streams, notably Hoffman Creek.

Temperature Impacts Associated with Reduced Ground Water Flows - Flow reductions could cause increased temperatures during the summer in surface water bodies receiving ground water discharge; however, a reduction in flow does not automatically cause an increase in water temperatures. Curtis (1960) found that temperatures in the Pitt River in California remained essentially the same at greatly reduced flows. Similarly, Kraft (1972) found that flow reductions up to 90 percent in a segment of a stream did not measurably increase temperatures in that segment.

It is also assumed that the trout streams whose ambient summer temperatures are highest would be those most likely to be adversely affected. The ranges of summer (July and August) water temperatures for Hemlock and Swamp creeks are 15 to 22 and 15 to 21 C, respectively (Appendix 2.4F). Temperatures in Swamp Creek approach those considered undesirable for brook trout, but considering the small reduction in base flow (8 percent) predicted during Project Year 28 for the middle recharge case, the possibility of significant impacts is slight. However, given the higher temperatures that have been reported (22 C) and the larger percentage reduction (10 percent) in base flow predicted for Hemlock Creek, adverse impacts to the brook trout population in this stream are possible. Whether any adverse impacts will actually occur in Hemlock Creek would depend on (1) the hydrologic and climatic regimes during July and August, (2) the amount of solar radiation reaching the stream surface, and (3) the actual percentage reduction in ground water inflow. Habitat for brook trout in Hemlock Creek is currently marginal (EA Science and Technology, 1984b). Although brook trout may inhabit Hemlock Creek, none were collected during the most recent survey (EA Science and Technology, 1984b).

No temperature data are available for Hoffman Creek. However, because the flow in Hoffman Creek is dominated by the discharge of ground water from Hoffman Spring it is likely that water temperatures in Hoffman Creek are low during the summer. This suggests that temperature will not become a limiting factor in Hoffman Creek.

During the winter, the inflow of warm ground water can be important in streams because it helps prevent the formation of frazil or anchor ice, provides water temperatures most conducive to overwintering salmonid eggs, and prevents shallow areas from freezing to the bottom of the stream. The percentage reduction of base flow into Swamp, Pickerel, and Hemlock creeks is small and no adverse impacts are likely. Larger percentage reductions are predicted in Hoffman Creek and Creeks 12-9 and

11-4. However, long-term flow data are lacking to allow a quantitative assessment of the impacts caused by the percentage reductions in these streams. No suitable trout spawning areas have been reported in Creek 11-4 and only one small area was found on Creek 12-9 (see Chapter 2, Section 2.5).

4.2.5.2 Lakes

An assessment of the potential impacts to each of the five site area lakes is summarized below. This assessment is based on the previously cited literature and the physical, chemical, and biological characteristics of each lake. Much of the data reported in the literature are conflicting, however, and even when consistent impacts have been demonstrated, the circumstances typically involved water level reductions much greater than those predicted to occur in the site area. Thus the resultant assessment is, of necessity, qualitative rather than quantitative and is based on professional judgement.

Oak Lake

Because Oak Lake is perched (i.e., it lies above the ground water table), no impacts from mine dewatering are expected.

Deep Hole Lake

In Deep Hole Lake, lake level reductions resulting from mine dewatering will not exceed those expected under preconstruction conditions (see Appendix 4.1A, Figure A.10-13). Therefore, no impacts are expected to occur in Deep Hole Lake.

Little Sand Lake

As a result of mine dewatering, the water level in Little Sand Lake is predicted to decline by 0.07 m (0.23 foot) under average conditions and approximately 0.2 m (0.7 foot) during dry climatic conditions (Appendix 4.1A). Based on hipsographic curves prepared by Exxon, these declines will cause a reduction in lake area of 2 percent and in volume of 4 percent under average conditions. Based on the preceding discussion of how lake level reductions affect aquatic organisms, it is unlikely that the small reductions predicted during average climatic conditions would impact the lake.

Among the fish species present in Little Sand Lake during 1977-78 (the last time period for which data are available), centrarchids (bluegill, pumpkinseed, black crappie and largemouth bass) and northern pike are the species most susceptible to reductions in water levels (Table 4.2-11). Centrarchids are vulnerable because of their nest building habits. However, a gradual decline of 0.07 m (0.23 foot) should not be harmful to the reproductive success of these species, because the sandy substrates they prefer for spawning are abundant in the lake and their nests should be beyond the depth at which dewatering will occur.

Northern pike are uncommon in Little Sand Lake (Table 4.2-11). This species requires marshes and wetlands for spawning, which are limited adjacent to Little Sand Lake. Because of a lack of suitable spawning habitat, Little Sand Lake will never support a large northern pike population without stocking. It is unlikely that a 0.07 m (0.23 foot) drop would appreciably affect pike spawning.

The small amount (0.07 m [0.23 foot]) of drawdown and the slow rate at which it will proceed suggest that impacts to aquatic macroinvertebrates and macrophytes should be negligible.

TABLE 4.2-11

ABUNDANCE OF FISH SPECIES COLLECTED IN FIVE SITE AREA LAKES, 1977 AND 1978[a]

Species	Lake				
	Oak	Little Sand	Duck	Deep Hole	Skunk
Northern pike	–[b]	2	–	–	–
Golden shiner	543	–	–	2	–
Longnose dace	1	–	–	–	–
Central mudminnow	–	P[c]	5	P	–
White sucker	P	2	–	1	–
Black bullhead	1	5	14	–	–
Yellow bullhead	1	152	–	–	–
Walleye	–	4	–	19	–
Yellow perch	1,058	457	1,198	240	–
Iowa darter	–	P	–	–	–
Bluegill	23	177	–	P	–
Pumpkinseed	31	158	–	–	–
Black crappie	–	56	–	–	–
Largemouth bass	73	39	–	–	–
Total Specimens	1,731	1,052	1,217	262	0
Total Species	9	12	3	6	0

[a]Source: Chapter 2, Section 2.5

[b]– Indicates none collected.

[c]Reported as present in DNR verification studies.

Under dry conditions, the area and volume of the lake may decrease by 3 and 9 percent, respectively. Thus, the possibility of adverse impacts increases, but only slightly. Centrarchids should be unaffected by a total decline of approximately 0.2 m (0.7 foot). Natural fluctuations of 0.65 m (2.14 feet) were recorded during the baseline monitoring period (1977-78) and the minimum lake level reported during that period (1590.82 feet) is 0.09 m (0.3 foot) lower than what is predicted under dry conditions.

A drop of approximately 0.2 m (0.7 foot) from the Ordinary High Water Mark (OHWM) would, however, be detrimental to northern pike as it would probably prevent access to the already limited wetland spawning areas. Because no stocking of northern pike has occurred in Little Sand Lake since 1978 (Lloyd Andrews, DNR, personal communication), the current status of this species in Little Sand Lake is unknown.

The magnitude of the predicted reductions under dry conditions is small and significant effects on the macroinverterate community seem unlikely. The 9 percent reduction in volume also seems unlikely to increase the likelihood of winterkills.

With the exception of northern pike, the group most likely to be affected during dry conditions is aquatic and/or wetland vegetation. Aquatic macrophytes, particularly emergents, may be affected in Little Sand Lake. However, large scale shifts in either abundance or species composition seem unlikely because of the small amount of reduction. Wetland vegetation is more likely to be affected than submerged macrophytes.

In summary, impacts to the aquatic biota of Little Sand Lake are unlikely during average climatic conditions. Under dry conditions, the possibility of impacts increases, with northern pike and wetland vegetation being the groups most likely to be affected. Major changes in the fish and benthos communities are unlikely, however, because they probably are affected more by the low pH and productivity of the lake than they are by water levels. More than half of the predicted total drop in lake level elevation during dry conditions would occur irrespective of mine operations.

Skunk Lake

Skunk Lake is the smallest and shallowest of the lakes under consideration. It is a winterkill lake which contains no fish and has a depauperate macroinvertebrate fauna (Chapter 2, Section 2.5). Water levels in Skunk Lake will decline 0.18 m (0.58 foot) as a result of mine dewatering during average climatic conditions (Appendix 4.1A). This will result in a decline in lake volume of about 20 percent and will dewater much of the adjacent wetlands (Appendix 4.1A). Although the sparse macroinvertebrate community is already composed of tolerant species, further declines are likely. Changes in macrophyte abundance and composition may occur. An additional 0.15 m (0.5 foot) decline is predicted to occur after one dry year (Appendix 4.1A), thereby further increasing the likelihood of winterkills in the lake.

Duck Lake

Duck Lake is predicted to undergo a decline of 0.06 (0.2 foot) during average climatic conditions and a total of approximately 0.6 m (2.0 feet) under dry conditions (Appendix 4.1A). Eighty percent (0.5 m

[1.6 feet]) of the predicted total decline is a result of climatic conditions and not mine operation. Based on hipsographic curves provided by Exxon, these reductions in elevation will result in a less than 2 percent reduction in lake area and a 4 to 5 percent reduction in volume under average conditions. Under dry conditions, the area will be reduced by 12 percent (compared to that at the OHWM) and the volume will decline by 38 percent (compared to that at the OHWM).

During baseline studies in 1977-78 and following verification studies by the DNR, only three species of fish--yellow perch, black bullhead, and central mudminnow--were collected from Duck Lake (Chapter 2, Section 2.5; Ramharter [1982]). Of these species, yellow perch were abundant, whereas the other two species were uncommon. The low number of species may be a result of the low average pH (5.0) in Duck Lake. Other investigators have reported that acid lakes have fewer fish species than lakes having a neutral pH (Harvey, 1980; Rahel and Magnuson, 1983; Wiener, 1983). However, other factors also may contribute to the paucity of fish species because Wiener (1983) found 5 to 11 species of fish in six naturally acidic small lakes in northern Wisconsin. Likely contributing factors are low alkalinity, orthophosphate, and dissolved oxygen values. Because of its shallow nature, Duck Lake approaches being a winterkill lake (Lloyd Andrews, DNR, personal communication) and dissolved oxygen values as low as 0.5 mg/l have been reported (Chapter 2, Section 2.4).

The predicted water level reductions under average climatic conditions should not significantly affect the aquatic biota of Duck Lake. Under dry climatic conditions, however, some dewatering of the adjacent wetlands is likely and Duck Lake will become more susceptible to winterkills. Both of these impacts could, in turn, affect the composition of the macrophyte, benthic, and fish communities. Because all three fish species in the lake have relatively unspecialized spawning requirements (Becker, 1983), each should be able to spawn under dry conditions. However, increased intra- and inter-specific competition may reduce survival and subsequent growth of larvae. The macroinvertebrate community may also be affected because of increased predation and competition. The increased likelihood of low dissolved oxygen concentrations in the winter would affect yellow perch more than they would black bullhead or central mudminnow.

Summary

The likelihood of impacts on the aquatic biological communities in the five site area lakes is summarized in Table 4.2-12. The potential for impacts ranges from none in Oak Lake to moderate in Duck and Skunk lakes. Because the existing aquatic community in Skunk Lake is extremely sparse, impacts to it will be limited. In Duck Lake, changes in species composition and abundance of wetlands are possible under dry conditions and the likelihood of winterkills of fish will increase.

TABLE 4.2-12

SUMMARY OF POTENTIAL FOR IMPACTS TO FIVE LAKES IN THE SITE AREA

Lake	Likelihood of Impacts	Reason(s) for Classification
Oak	None	Perched lake.
Deep Hole	Very low	Reductions will not exceed those that occur normally.
Little Sand	Low	Under average climatic conditions the lake level will drop only 0.07 m (0.23 foot), with another drop of approximately 0.15 m (0.5 foot) occurring under dry conditions (Appendix 4.1A).
Skunk	Moderate	Skunk Lake contains no fish. However, changes in its macrophyte community and especially in the associated wetland community are likely.
Duck	Moderate	No impacts are expected under average conditions; however, some impacts may occur under dry conditions. The most probable impacts will be dewatering of macrophytes and an increase in the likelihood of winterkills.

4.2.6 Terrestrial Ecology

4.2.6.1 Vegetation

4.2.6.1.1 Upland Communities

The only anticipated impacts of Project operation activities on vegetation will be the loss of timber production on those lands occupied by the Project facilities. This impact will be mitigated through reclamation of the disturbed areas to forestry use.

Wildlife habitats lost through clearing of vegetation during construction activities may again be provided after reclamation of the disturbed areas. Since portions of the Project facilities will be constructed and reclaimed in phases during the operational life of the mine, the potential impact on various wildlife populations will be partially mitigated prior to final reclamation.

Operation of the Project facilities will create additional open water which may attract waterfowl, marsh birds, and shore birds. The surface area of the reclaim water pond will encompass approximately 14 ha (35 acres) and rip-rap will be placed along the shoreline of each pond. Approximately 20 percent of each tailing pond will be covered by shallow pooled water. Based on the projected water quality analysis (CH2M Hill, 1982), these ponds are not anticipated to be toxic to wildlife.

4.2.6.1.2 Wetland Communities

Wetlands that will be affected by changes in surface water hydrology throughout the construction and operation phases will include only those that are down-gradient from the area designated for the reclaim pond and MWDF. The changes in surface water hydrology attributable to operation of the mine/mill and ancillary facilities are considered negligible (subsection 4.2.4). Six deciduous swamps, 4 coniferous swamps, 1 shallow marsh, 2 shrub swamps, 2 streamside wetlands, and 3 bogs, located around the perimeter of the reclaim pond/MWDF facility, will be affected by changes in surface water hydrology (Table 4.2-13). These effects will not occur simultaneously since construction and operation of the facilities in the MWDF area (two-celled reclaim pond, three-celled MRDF and four tailing ponds) will occur in stages during Project phases 1 through 4. For the previous reclaim pond/MWDF system design, each of these five developmental phases was evaluated to determine the effects of changes in surface water hydrology on wetlands. These effects are documented and discussed in IEP, Inc. (1982). Because these facilities have been downsized from the earlier design, hydrologic impacts are assumed to be similar but lesser in magnitude. Therefore, reanalysis of wetland water balances for these interim developmental phases (1-4) was not completed. Ayres Associates (1985) reevaluated the water balances of wetlands for the current MWDF design under final reclaimed conditions (phase 5). These results are presented in subsections 4.3.4 and 4.3.6.

The information used in evaluating the effects of mine dewatering and changes in surface water hydrology on wetland vegetation are presented in Appendix 4.2B.

In general, the 18 potentially affected wetlands around the perimeter of the reclaim pond/MWDF had high scores, with all but six

TABLE 4.2-13

STORM AND FLOODWATER STORAGE FUNCTION MODEL SCORES OF WETLANDS AFFECTED BY SURFACE WATER RUNOFF FROM THE RECLAIM POND AND MINE WASTE DISPOSAL FACILITY[a]

WETLAND NO.	DOMINANT WETLAND TYPE[b]	STORM AND FLOODWATER STORAGE FUNCTION MODEL SCORE[c]
F15	DS	98
F23	CS	106
F24	SS	69
F25	SM	97
F26	B	58
F28	B	103
F29	B	96
F57	DS	95
F60	CS	101
F61	DS	84
F62	DS	94
F63	CS	101
K1	SW	59
K2	DS	101
K3	CS	102
M1	SS	90
M2	SW	60
M3	DS	98

[a]Source: NAI and IEP, Inc. (1982).

[b]B = Bog; CS = Coniferous swamp; DS = Deciduous swamp; SM = Shallow marsh; SS = Shrub Swamp; SW = Streamside wetland.

[c]Model range: 31-123; model mean: 77; actual range: 56-109; actual mean: 91.9.

(F24, F26, F61, K1, M1 and M3) exceeding the actual mean for the Storm and Floodwater Storage Function Model (Table 4.2-13).

The wetland communities in the subject area include deciduous and coniferous wooded swamps, sapling, bushy and compact shrub swamps, marshes, streamside wetlands, and bogs. Coniferous forested wetland is by far the dominant class in areal extent. The range in site conditions suitable for the dominant species in the confier swamps suggests that only an extreme reduction in water level and duration of flooding would cause an appreciable change in species composition (Christensen et al., 1959; Curtis, 1959; Teskey and Hinckley, 1978). The relatively small decreases in water budget assumed for these wetlands are not expected to result in any major changes; potential benefits may include increased species diversity and a temporary increase in growth rate due to increased mineralization of the surface organic soils.

In those wetlands where an increase in water budget is forecast, the degree of change is considered too small to result in important changes to the plant communities. Because the seasonal fluctuations in water table activity are not anticipated to change in the wetlands, during most years there will be a period when the water table drops below the surface of the soil in the wetlands providing an opportunity for aeration in the root zone.

In addition to the effects caused by changes in surface water hydrology, mine dewatering will lower the water table 1 to 2 m (3.3 to 6.6 feet) under Z17, a ground water connected shallow marsh based on the expected mine inflow of 0.08 m^3/s (1,270 gallons per minute). This effect will occur throughout the Project operation phase and for a time after closure until ground water levels are reestablished, the entire period lasting approximately 35 to 40 years after mining ceases.

Wetland Z17 will be affected by lowering of the ground water table during mine dewatering. This wetland was of medium-size and contained a predominance of emergent wetland plants which are obligate hydrophytes, species which require water at or near the ground surface during their growing season (Reed, 1982). If mine dewatering activities cause the absence of water closer than a meter from the surface for up to 40 years, the result would be a gradual replacement of the obligate hydrophytes by species which are tolerant of drier soil conditions (Odum, 1961). Wetland Z17 scored 110 in the Biological Function Model, which was a high score compared to other wetlands in the region. Since the shallow marsh community was sparsely represented in the wetlands study area and in the region, the loss of the biological function associated with this wetland could be a major impact on wildlife species that utilize this type of habitat. However, for the reasons stated in subsection 4.2.4.1.4, it is unlikely that wetland Z17 will become dry enough to cause a major change in its vegetative community. In addition, the presence of the beaver dam and the dam's effect on water level in Z17 is a variable which could have a more pronounced effect on the wetland's vegetative community than the effects of mine dewatering during the operations phase.

The worst-case effects of changes in surface water hydrology (phase 5 conditions) are discussed in subsection 4.3.6 for each of the wetlands affected.

4.2.6.2 Wildlife

Changes in the wetland wildlife habitats of the study area because of plant succession typically occur over periods of several hundred years. Damage to plants will not occur and succession will not be affected by changes in surface water hydrology during Project operation because these changes will be minor (subsection 4.2.6.1.2). Subsequently there will be minimal loss of carrying capacity in the affected wetlands for the five wildlife indicator species beyond those calculated for the construction phase (subsection 4.1.6.2).

In wetland Z17, which may be affected by lowering of the water table during mine dewatering, some additional loss of carrying capacity may occur. This loss would occur gradually, over a period of approximately 35 to 40 years until ground water levels are reestablished and wetland plants recolonize this wetland. Because of the small acreage (1.5 ha [3.78 acres]) that will be affected, however, the reductions in carrying capacity for the five indicator species will be of minor consequence. Moreover, none of the indicator species are dependent upon this habitat type.

Although the reductions in carrying capacity of upland and wetland habitats during construction and operation will remain for a period of up to 40 years, habitat will be provided for some wildlife species as each of the four tailing ponds undergoes reclamation. During the four operational stages for the tailing ponds, the undisturbed forest land surrounding the Project facilities will be managed to ensure a sustained yield of pulp and sawlogs. This is a typical land use practice throughout the region that would occur regardless of the

Project. Such management will improve the carrying capacity for species such as deer and grouse beyond that which would occur under current conditions.

4.2.6.3 Threatened and Endangered Species

During operation the additional loss of wetland habitat, because of mine dewatering, should have no effect on either the bald eagle or osprey. Although both the bald eagle and osprey utilize the large open water bodies of the environmental study area for feeding, the small areal extent of water that will be lost because of mine dewatering is of little importance. The effects of Project operation on the Cooper's hawk will not increase beyond those outlined for the construction phase.

4.2.7 Cultural Resources

During operation of the Crandon Project facilities, no additional adverse effects on cultural resources are anticipated. The environmental consequences are identical to those identified during facilities construction (see subsection 4.1.7).

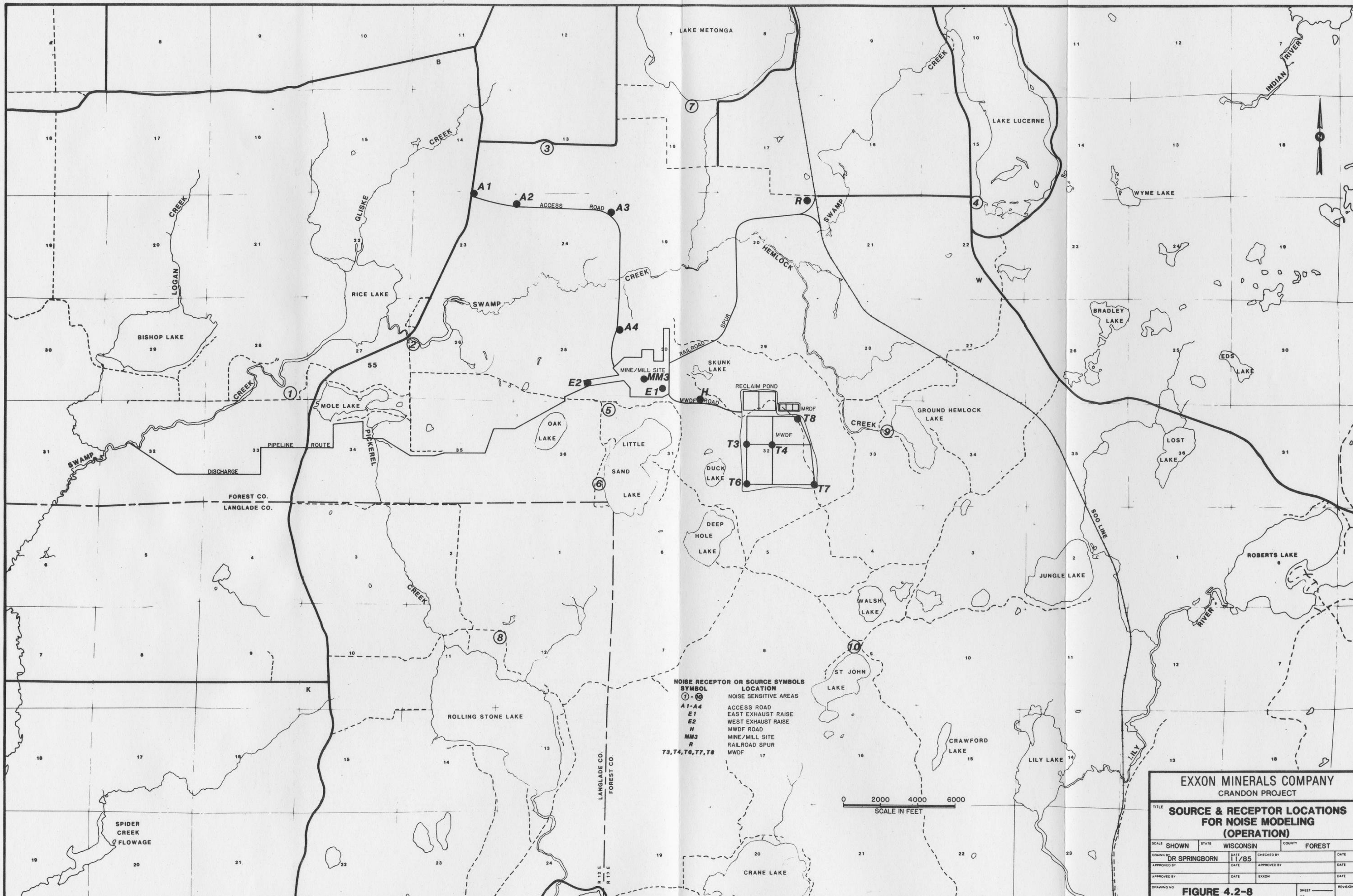
4.2.8 Noise

The methodology used to estimate site area sound during the operation phase is identical to that for construction phase noise modeling as presented in Appendix 4.1B. For a general discussion of sound levels, see Section 2.8. The noise-sensitive areas and distances to the operation phase noise sources are presented on Figure 4.2-8 and Appendix 4.1B, respectively. The major sources of noise during the Project operation phase will be associated with the following facilities:

1) Mine/Mill Site (MM3);
2) Mine Waste Disposal Facility (T3, T4, T6, T7, T8);
3) Access Road (A1, A2, A3, A4);
4) Railroad Spur (R); and
5) Haul Road (H)(Figure 4.2-8).

The operation phase noise emanations used in this assessment are "worst-case" levels (see Appendix 4.1B for additional source descriptions and sound power level data). At the mine/mill site, it was assumed that all listed noise sources would be in continuous operation, even though some may operate intermittently. At the MWDF, construction equipment was assumed to be at four periphery locations, when in actuality they will only operate there for a small fraction of the time. Further, construction activities at the MWDF are not expected to occur during the operation phase nighttime except for unusual situations. Therefore, the MWDF was not modelled as a nighttime source.

Railroad spur operations will be intermittent throughout the day. Five hours of railroad spur operation in each 24-hour day were included in the model calculations, including daytime and nighttime



LAKE METONGA
LAKE LUCERNE
INDIAN RIVER
WYME LAKE
CREEK
GLISKE
SWAMP
LOGAN
RICE LAKE
BISHOP LAKE
ACCESS ROAD
A1
A2
A3
A4
R
HEMLOCK
RAILROAD SPUR
MINE/MILL SITE
MM3
E1
E2
H
MWDF ROAD
SKUNK LAKE
RECLAIM POND
MRDF
MWDF
T3
T4
T6
T7
T8
MOLE LAKE
PICKEREL
PIPELINE ROUTE
DISCHARGE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
GROUND HEMLOCK LAKE
BRADLEY LAKE
EDS LAKE
LOST LAKE
SOO LINE
FOREST CO.
LANGLADE CO.
ROBERTS LAKE
JUNGLE LAKE
WALSH LAKE
RIVER
ST JOHN LAKE
CRAWFORD LAKE
LILY LAKE
LILY
ROLLING STONE LAKE
SPIDER CREEK FLOWAGE
CRANE LAKE
LANGLADE CO.
FOREST CO.
R 12 E
R 13 E
55
B
K
W
NOISE RECEPTOR OR SOURCE SYMBOLS
SYMBOL LOCATION
1 - 10 NOISE SENSITIVE AREAS
A1-A4 ACCESS ROAD
E1 EAST EXHAUST RAISE
E2 WEST EXHAUST RAISE
H MWDF ROAD
MM3 MINE/MILL SITE
R RAILROAD SPUR
T3,T4,T6,T7,T8 MWDF
0 2000 4000 6000
SCALE IN FEET
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE SOURCE & RECEPTOR LOCATIONS FOR NOISE MODELING (OPERATION)
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 11/85
CHECKED BY
APPROVED BY
EXXON
DRAWING NO
FIGURE 4.2-8
SHEET
OF
REVISION NO

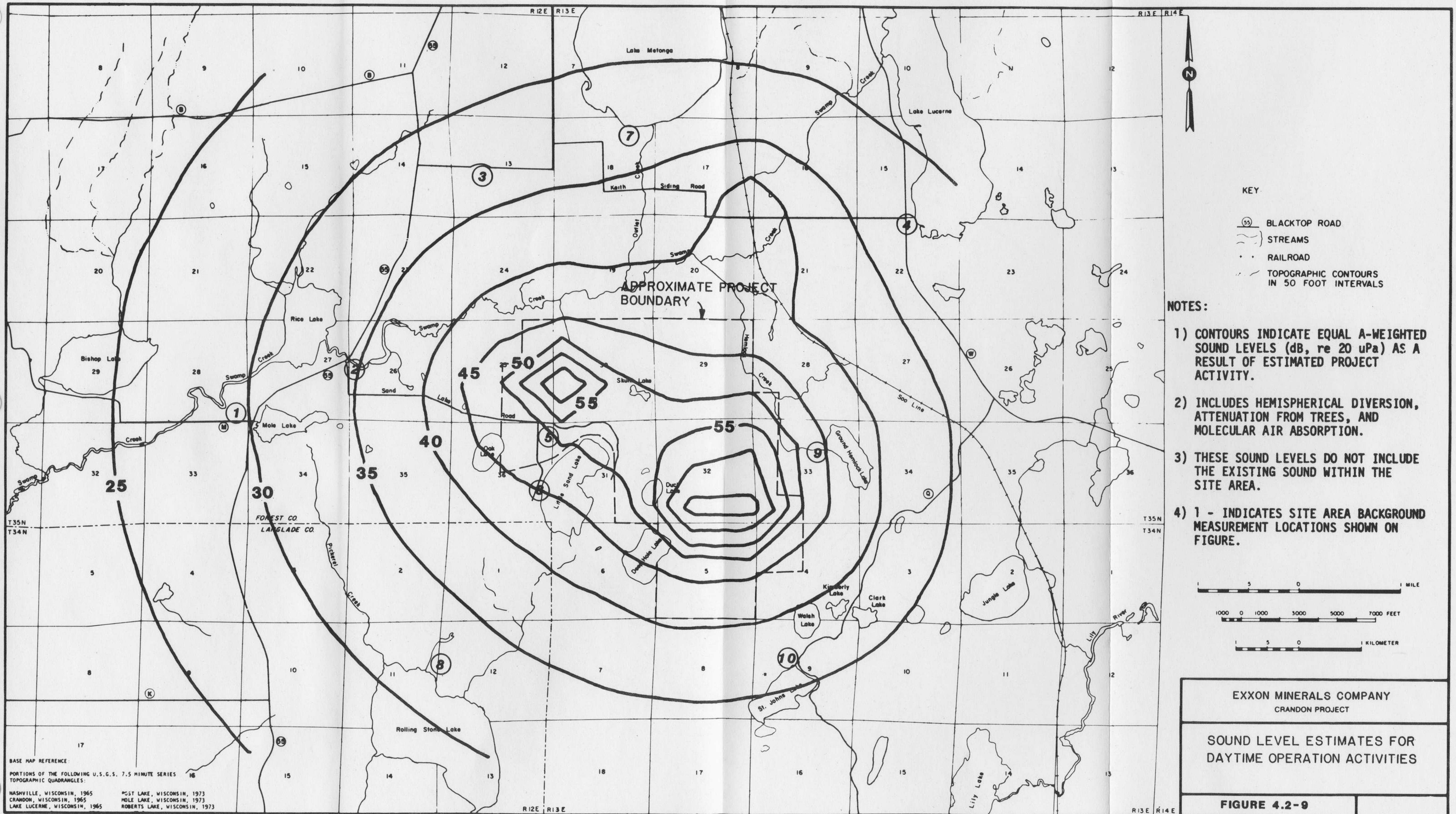
periods. However, for actual plant operations, there will only be, on the average, movement of approximately 25 railcars per day, which will take less than 1 hour to travel the length of the spur.

Access road operation phase activities were assumed to occur simultaneously at four locations, whereas these activities will actually occur for a small fraction of the time. For the mine/mill site, the mine exhaust raise fans were modeled as if five fans (i.e., 3 at the EER and 2 at the WER) were operating simultaneously. However, three fans at the EER may operate instead of two with none at the WER during the first 5 years of the operation phase, and then two fans at each exhaust raise until operations cease.

4.2.8.1 Operation Noise Impact Assessment

The data provided in Appendix 4.1B were used in a computer model (Rice, 1980) to produce contours of equi-A-weighted sound level contributions. Figures 4.2-9 and 4.2-10 provide these contours for daytime and nighttime operation phase activities, respectively. The sound levels are expected to be lower than what was modeled because of the conservative assumptions mentioned above. The effect of Project-related traffic on State Highway 55 has not been included in these contours because of the small change anticipated from highway noise (see Appendix 4.1B).

Table 4.2-14 contains a summary of the sound level contributions from these noise sources at the noise sensitive areas where the background noise was measured (Figure 4.2-8). The values in parentheses marked with the superscript "e" represent adjusted background sound levels computed from truncated measured histograms to eliminate short-term, high level intrusive sounds. The data in



NOTES:

1) CONTOURS INDICATE EQUAL A-WEIGHTED SOUND LEVELS (dB, re 20 uPa) AS A RESULT OF ESTIMATED PROJECT ACTIVITY.

2) INCLUDES HEMISPHERICAL DIVERSION, ATTENUATION FROM TREES, AND MOLECULAR AIR ABSORPTION.

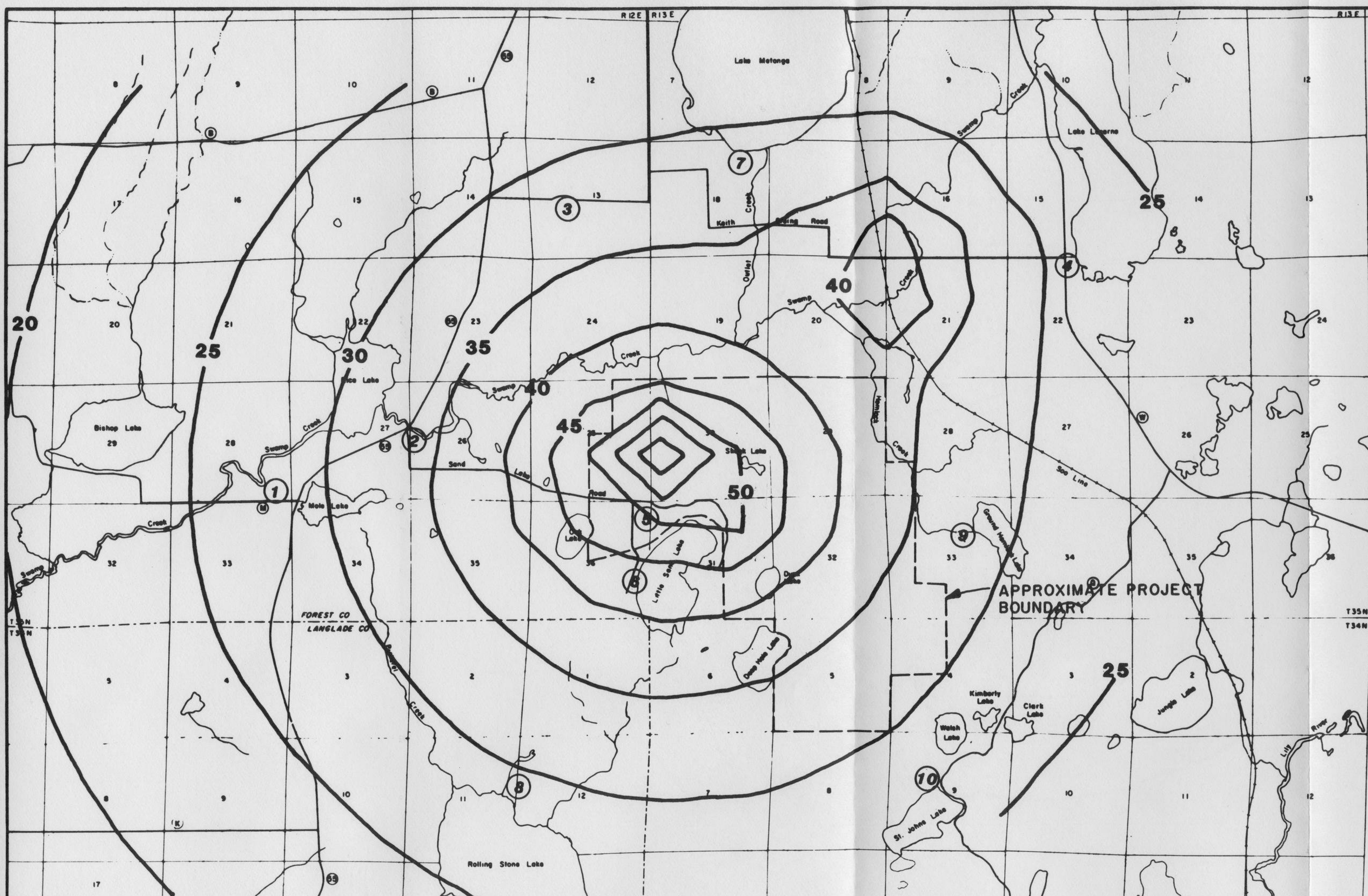
3) THESE SOUND LEVELS DO NOT INCLUDE THE EXISTING SOUND WITHIN THE SITE AREA.

4) 1 - INDICATES SITE AREA BACKGROUND MEASUREMENT LOCATIONS SHOWN ON FIGURE.

EXXON MINERALS COMPANY
CRANDON PROJECT

SOUND LEVEL ESTIMATES FOR DAYTIME OPERATION ACTIVITIES

FIGURE 4.2-9



BASE MAP REFERENCE

PORTIONS OF THE FOLLOWING U.S.G.S. 7.5 MINUTE SERIES TOPOGRAPHIC QUADRANGLES:

NASHVILLE, WISCONSIN, 1965
CRANDON, WISCONSIN, 1965
LAKE LUCERNE, WISCONSIN, 1965
POST LAKE, WISCONSIN, 1973
MOLE LAKE, WISCONSIN, 1973
ROBERTS LAKE, WISCONSIN, 1973

KEY

- BLACKTOP ROAD
- STREAMS
- RAILROAD
- TOPOGRAPHIC CONTOURS IN 50 FOOT INTERVALS

NOTES:

1) CONTOURS INDICATE EQUAL A-WEIGHTED SOUND LEVELS (dB, re 20 uPa) AS A RESULT OF ESTIMATED PROJECT ACTIVITY.

2) INCLUDES HEMISPHERICAL DIVERSION, ATTENUATION FROM TREES, AND MOLECULAR AIR ABSORPTION.

3) THESE SOUND LEVELS DO NOT INCLUDE THE EXISTING SOUND WITHIN THE SITE AREA.

4) 1 - INDICATES SITE AREA BACKGROUND MEASUREMENT LOCATIONS SHOWN ON FIGURE.

1 MILE

1000 0 1000 3000 5000 7000 FEET

1 KILOMETER

EXXON MINERALS COMPANY

CRANDON PROJECT

SOUND LEVEL ESTIMATES FOR NIGHTTIME OPERATION ACTIVITIES

FIGURE 4.2-10

TABLE 4.2-14

OPERATION PHASE EFFECT ON BACKGROUND SOUND LEVELS[a]

LOCATION	BACKGROUND L_d	BACKGROUND L_n	BACKGROUND L_{dn}	OPERATION[b] NOISE L_A DAY	OPERATION[b] NOISE L_A NIGHT[d]	TOTAL[c] NOISE DURING OPERATIONS L_d	TOTAL[c] NOISE DURING OPERATIONS L_n	TOTAL[c] NOISE DURING OPERATIONS L_{dn}	CHANGE L_d	CHANGE L_n	CHANGE L_{dn}
WINTER											
1	42.8	29.8	41.9	29.4	28.0	43.0	32.0	42.6	0.2	2.2	0.7
2	37.9	28.5	38.1	34.2	33.2	39.4	34.5	42.0	1.5	6.0	3.9
3	39.3	23.9	38.0	32.7	31.5	40.2	32.2	41.0	0.9	8.3	3.1
4	43.7 (43.4)[e]	35.1	44.3 (44.1)[e]	32.5	28.8	44.0 (43.7)[f]	36.0	44.9 (44.7)[f]	0.3 (0.3)[f]	0.9	0.6 (0.6)[f]
5	42.4	50.5 (37.7)[e]	56.4 (45.2)[e]	51.5	51.3	52.0	53.9 (51.5)[f]	60.1 (58.0)[f]	9.6	3.4 (13.8)[f]	3.8 (12.8)[f]
6	51.6 (42.1)[e]	19.0	49.6 (40.2)[e]	43.9	42.6	52.3 (46.1)[f]	42.6	52.4 (49.7)[f]	0.7 (4.0)[f]	23.6	2.8 (9.5)[f]
7	44.8	41.8	48.8	32.8	31.0	45.1	42.1	49.1	0.3	0.3	0.3
8	34.2	30.8	37.9	33.7	30.8	37.0	33.8	40.8	2.8	3.0	2.9
9	33.4	30.0	37.1	45.8	32.2	46.0	34.2	45.5	12.6	4.2	8.4
10	33.4	31.0	37.8	36.9	27.3	38.5	32.5	40.5	5.1	1.5	2.6
SUMMER											
1	46.6	42.7	49.9	29.4	28.0	46.7	42.8	50.1	0.1	0.1	0.1
2	42.1	39.7	46.5	34.2	33.2	42.8	40.6	47.4	0.7	0.9	0.8
3	47.1 (44.4)[e]	44.1	51.1 (50.6)[e]	32.7	31.5	47.3 (44.7)[f]	44.3	51.3 (50.8)[f]	0.2 (0.3)[f]	0.2	0.2 (0.2)[f]
4	63.8	47.0	62.3	32.5	28.8	63.8	47.1	62.3	0.0	0.1	0.0
5	58.6	26.5	56.6	51.5	51.3	59.4	51.3	60.2	0.8	24.8	3.6
6	38.0	38.6	44.9	43.9	42.6	44.9	44.1	50.6	6.9	5.5	5.7
7	47.5	41.3	49.3	32.8	31.0	47.6	41.7	49.6	0.1	0.4	0.3
8	40.7	39.6	46.2	33.7	30.8	41.5	40.1	46.8	0.8	0.5	0.6
9	42.7	27.4	41.4	45.8	32.2	47.5	33.4	46.4	4.8	6.0	5.0
10	38.6	28.1	38.4	36.9	27.3	40.8	30.7	40.8	2.2	2.6	2.4

[a]All sound levels are A-weighted in dB.

[b]Day and night operation phase sound levels include three mine fans in the east exhaust raise (EER) and two in the west exhaust raise (WER).

[c]Background plus operation phase noise.

[d]Night operation phase sound levels exclude MWDF activities.

[e]Measured background values were adjusted to reduce the contribution from short duration, high sound pressure level sources (Tans, 1984).

[f]Operation phase change in values based on adjusted background data.

parentheses marked with the superscript "f" represent computed total sound levels (background plus operation phase sound levels) using adjusted background data.

The A-weighted sound level contours presented on Figures 4.2-9 and 4.2-10 are based on average meteorological conditions. As described in subsection 4.1.8.1, higher or lower sound levels could occur depending upon atmospheric conditions. However, the micrometeorological conditions in the forest environment surrounding the mine/mill site would also attenuate these variations (Roth, 1983).

The following three additional noise sensitive locations were considered at the request of the DNR:

1) Location A, North Shore, Little Sand Lake;
2) Location B, East Shore, Ground Hemlock Lake; and
3) Location C, Keith Siding Road, just West of the Soo Line railroad tracks.

Ambient sound levels during the operation phase at these locations can be determined from Figures 4.2-9 and 4.2-10 and the estimated background sound levels listed below. Sound level measurements were not conducted at these locations in 1977 or 1983. These background sound levels were estimated by using measured values from other locations where land uses were similar.

ESTIMATED BACKGROUND SOUND LEVELS, dB

	WINTER			SUMMER		
Location	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}
A	52 (42)	20	49 (40)	38	39	45
B	33	30	37	43	27	41
C	43	39	46	46	43	50

Note: Values in parentheses result from adjusting the measured data by eliminating short duration, high level intrusions.

The State of Wisconsin does not have community noise control regulations or standards. The U.S. Environmental Protection Agency (U.S. EPA) has identified a day-night sound level of 55 dB as requisite for the protection of public health and welfare with a conservative margin of safety (U.S. EPA, 1974). Since community sound levels throughout the United States generally exceed this level, the agency has selected an L_{dn} of 65 dB as its short-term goal and 55 dB at its long-term goal (U.S. EPA, 1977).

During operation phase activities, the calculated sound levels at all the identified noise-sensitive receptors meet U.S. EPA's short-term goal of 65 dB with only Location 5 in winter and Locations 4 and 5 in summer exceeding their long-term goal of 55 dB (Table 4.2-14). However, the present sound levels during the summer at Locations 4 and 5 already exceed the U.S. EPA's long-term goal. Location 5 is the current Exxon field office and is not used for residential purposes. Project-related traffic on State Highway 55 during the operation phase is estimated to change ambient equivalent sound levels less than 1 dB and therefore is not a source of noise impact.

Both the Federal Highway Administration (FHWA) and the Department of Housing and Urban Development (HUD) have adopted criteria for assessing noise impact and to minimize the effect of noise on people consistent with the 55 dB L_{dn} established by EPA. These criteria from U.S. EPA, FHWA, and HUD for day-night sound level values from 55 dB and higher as coordinated by the Federal Interagency Committee (1982) are summarized in Appendix 4.1B. Based on these criteria noise levels during the Project operation phase are not anticipated to cause hearing loss, speech interference, or major annoyance. At all measurement locations the expected community reaction to day-night sound levels during the operation phase will be slight to moderate, if at all (see Appendix 4.1B).

For most locations estimated operation phase L_{dn} sound levels do not exceed 45 dB for which the background measured L_{dn} did not exceed 45 dB (Table 4.2-14). In general, the estimated changes from background are less than 5 dB. Additional discussion of the data in Table 4.2-14, including estimated L_{dn}, L_d, L_n changes compared to background sound levels, can be found in Appendix 4.1B.

Operation activities will produce some sounds that are of very short duration but not unlike sounds from any similar mining operation. These sounds may be similar to that of intermittent automobile, snowmobile, or airplane sounds already present in the site area. For example, warning horns, back-up alarms, and start-up alarms, required in accordance with Occupational Safety and Health Administration (OSHA) rules, will be used.

Underground mine development and production blasting will not be a major noise source. Blasting effects will be controlled by techniques limiting the explosive charge weight per delay. Any air blast effects, noise or concussion, will be attenuated underground within the expanse of the mine workings and shaft exits to surface.

4.2.8.2 Seismic Effects of Blasting During Mine Operation

Planned mine development and production blasting practices are designed to preclude mine/mill site damage and minimize public annoyance. Plots of peak particle velocity versus distance for a range of explosives mass per delay indicate that the seismic effects of the planned stope blasts will be less than the damage limit of 5.08 mm/s (2.0 inches per second) in the immediate mine area, and below the normal human detection limit of 5.08 mm/s (0.2 inches per second) at the 0.8-km (0.5-mile) blast monitoring boundary (see Figure 4.1-16).

There is no potential for blast-induced seismic damage to private structures adjacent to the mining site, even in the most unlikely event of accidental non-delayed detonation of an entire production blast charge. Furthermore, off-site public annoyance will be minimal, since for normal practices the seismic effects of the planned blasts will remain near or below the limit of human response for distances in excess of 0.8-km (0.5-mile) from the mine/mill site.

4.2.8.3 Effects of Noise on Wildlife and Domestic Animals

The literature prior to 1971 contains little substantive information on the effects of noise on wildlife. In 1980, the U.S. EPA published a review report (EPA 550/9-80-100) entitled "Effects of Noise on Wildlife and Other Animals - Review of Research Since 1971," which continues to be the most comprehensive review available, although limited with regard to quantitative information.

In considering a wide variety of wildlife species, the report concludes that startle or fright is the principal reaction to transient and unexpected noise. Wildlife generally flee the noise source temporarily, or for long periods if the noise persists. There is a tendency to adapt to noise that is predictable and unchanging. For example, the observed reactions of birds to high noise levels include fright reactions, altered behavior, and, in some cases, attraction to noisy areas.

Effects on domestic (farm) animals are not well documented, although there are indications that excessive noise may disrupt their behavioral activities. The major effects appear to be initial fright reactions and temporary increases in heart rate. Domestic animals are located a sufficient distance from the planned activities to be unaffected by noise.

Based on the information presented in the referenced U.S. EPA report, it is anticipated that noise impacts on wildlife will be minimal. However, little quantitative data are available to support demonstrated effects of noise on wildlife. In terms of behavioral response, some animals will tolerate increased noise levels whereas others will temporarily avoid such areas. During periods of noise generating activity in the Project area (e.g., periods of heavy equipment use during construction), wildlife may temporarily avoid the area where the activity is occurring. However, any effect should be localized around the area of activity and will decrease in magnitude with increasing distance from the noise source.

Additional discussion of the demonstrated and suspected effects of noise on mammals, birds, fish, and insects and citations to the source of the findings are presented in the above cited U.S. EPA report.

4.2.8.4 Noise Mitigative Controls

The same noise mitigation controls are planned for the operation phase as were presented for the construction phase. The following additional engineering controls are planned for the operation phase:

1) For equipment items that have been identified as potential major noise sources, purchase inquiries and requisitions will include a request of the vendors for equipment sound power level spectra.

2) All ore processing equipment will be contained within buildings or other enclosures;

3) Other major noise producing equipment, such as air compressors and emergency electric generators, may be installed in special enclosures;

4) The mine ventilation fans will be selected with emphasis placed on their low noise emission potential. Their discharge structure will be directed vertically using sound directivity to advantage; and

5) Noise from the mine air heaters will be reduced by selection of low noise units and adjusting the mixing system so that a fraction of the total air is heated to a high level and mixed with the unheated air.

4.2.9 Land Use and Aesthetics

4.2.9.1 Local Land Use

4.2.9.1.1 Forestry

Construction of surface facilities will result in partial loss of production of forest products (pulpwood and sawtimber) from approximately 284 ha (700 acres) of forest land during the construction and operation phases of the Project (32 years). The forested land that will be disturbed during construction activity consists primarily of northern hardwood and aspen-birch communities with minor components of coniferous and deciduous swamp (see Table 4.1-3). The value of forest resources in the area to be disturbed by Project facilities was estimated by Steigerwaldt (1982) at $127,000. However, since this estimate was prepared, the facilities have been downsized and less area will be required; therefore, the value of the forest resources is approximately 25 percent less than the above estimate.

Assuming a harvesting schedule of 45 to 55 years for northern hardwoods and 45 to 50 years for aspen-birch, the dominant forest types, production from these stands will be lost for approximately one rotation. The effect of this temporary loss of production is considered negligible in the regional study area. This should be considered the worst-case consequence because approximately 164 ha (405 acres) of land disturbed during construction will be managed or allowed to return to forested or shrub vegetation during the operational life of the Project (Section 1.3, Table 1.3-1). With the exception of portions of the access road and railroad spur corridors, which will be returned to agricultural uses if no alternative uses are identified, the remaining disturbed area will be reclaimed to indigenous plant species during the post-operation period.

4.2.9.1.2 Agriculture

During operation, no additional effects beyond those identified during the construction phase (subsection 4.1.9.1.1) will occur on lands classified as agricultural. Loss of production from the 6 ha (15 acres) of agricultural land disturbed during construction of the access road and railroad spur will continue through the 29-year operational life of the Project.

4.2.9.1.3 Recreation

Operation of the Project will not adversely affect recreational use of lands in the regional study area beyond those identified in subsection 4.1.9.1.3. The area within the Project boundary that is fenced will continue to be precluded from recreational use throughout the Project operation phase.

4.2.9.1.4 Residential

Operation of the Project will place no restrictions on residential use of land outside the Project site boundary. A discussion of potential changes in housing units within the local study area is presented in subsection 4.2.10, Socioeconomics.

4.2.9.1.5 Commercial/Industrial

During Project operation, there will be potential for increased retail, commercial, and industrial development in the regional study area that can be attributed to the Project. The consequence of this potential increase in business activity is discussed in subsection 4.2.10, Socioeconomics.

4.2.9.1.6 Transportation

A discussion of the potential consequences of operation of the Project on transportation systems in the local study area is presented in subsection 4.2.10, Socioeconomics.

4.2.9.1.7 Public Lands

Operation of the Project will create no additional impacts on public lands beyond those discussed in subsection 4.1.9.1.7.

4.2.9.1.8 Special Use Areas

Within the environmental study area, lands designated as special use areas included those associated with valuable wildlife habitat such as deeryards, bald eagle and osprey nest sites, and trout streams. The potential consequences of Project operation activities on these special use areas are discussed in subsections 4.2.5, Aquatic Ecology, and 4.2.6, Terrestrial Ecology.

4.2.9.1.9 Multiple Use Areas

Operation of the Project will not affect the multiple use activities associated with lands outside the Project boundary. Even though most land has multiple use potential, each land tract has a primary use. Effects of Project operation activities on these primary land uses have been discussed in previous subsections or in subsection 4.2.10, Socioeconomics.

4.2.9.2 Aesthetics

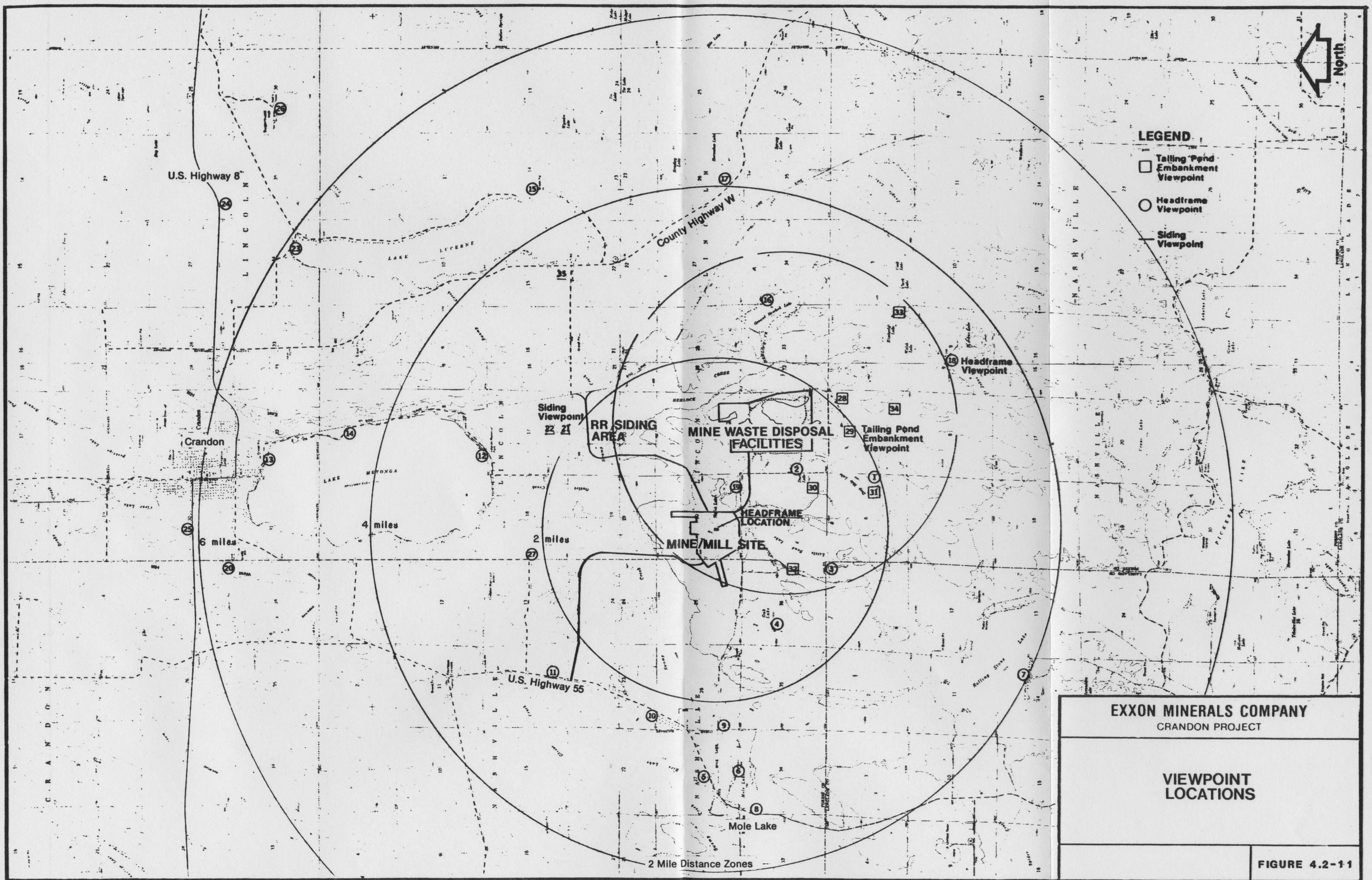
4.2.9.2.1 Visual Impacts

An inventory and assessment were performed to determine the visual presence or absence of specific surface facilities from viewpoints of sensitive or intensive land use in the locality of the Project site (The Sanborn Group, Inc., 1982). Schreiber/Anderson Associates (1985) reevaluated and updated the visual assessment to consider changes in the height and design of the headframe and changes in the layout and design of the MWDF. The methodology and results of the visual assessment are summarized below.

Key viewpoint locations were identified by the DNR, Exxon, and The Sanborn Group, Inc. and are shown on Figure 4.2-11. Land and shoreline viewpoints used in the visual impact assessment and their approximate viewing distances to major physical facilities are identified in Tables 4.2-15 through 4.2-17.

Photographic simulations were prepared which present graphic illustrations of visual consequences resulting from Project development. These simulations represent the scale of the Project features when viewed from selected viewpoints. Foliage was present when field work was conducted in August 1982. Further discussion of the methodology is presented in The Sanborn Group, Inc. (1982) and Schreiber/Anderson Associates (1985).

The photographic simulations may represent an exaggerated condition of potential visual effect. The scenes are composed in such a manner that the proposed facilities are centered in the photograph of the landscape setting. Hence, the effect may be more pronounced than if



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VIEWPOINT LOCATIONS

FIGURE 4.2-11

TABLE 4.2-15

HEADFRAME VIEWPOINT LOCATIONS

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VIEWING DISTANCE TO HEADFRAME km (miles)
1	Main Public Landing on Deep Hole Lake	3.1 (1.9)
2	Main Public Landing on Duck Lake	1.8 (1.1)
3	Southwest Shore of Little Sand Lake	2.25 (1.4)
4	Southwest Shore of Oak Lake	2.25 (1.4)
5	Sokaogon Chippewa Community Park	4.7 (2.9)
6	Mole Lake Community Park	4.7 (2.9)
7	South Shore of Rolling Stone Lake	6.4 (4)
8*	Highway 55 - South of Mole Lake	5.5 (3.4)
9*	Intersection of Sand Lake and Black Joe Roads	3.9 (2.4)
10	Highway 55 - North of Swamp Creek; North Entrance of Chief Ackley Memorial Housing Project	3.7 (2.3)
11*	Highway 55 - North of Swamp Creek	4.2 (2.6)
12	Veterans Memorial Park - Public Campground	4.7 (2.9)
13	Village of Crandon - Main Public Landing/ Swimming Beach on Lake Metonga	8.5 (5.3)
14*	Village of Crandon - East Shore of Lake Metonga	7.2 (4.5)
15	Main Public Landing on Lake Lucerne	7.2 (4.5)
16	Private Dock on East Shore of Ground Hemlock Lake	4.5 (2.8)
17	Intersection of County Highways O & W	6.6 (4.1)
18	Intersection of County Highway Q and St. John's Lane	5.5 (3.4)

Table 4.2-15 (continued)

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VIEWING DISTANCE TO HEADFRAME km (miles)
19*	Sand Lake Road East of Exxon Field Office	0.8 (0.5)
20*	Lakeview Road	9.2 (5.7)
21*	Keith Siding Road	3.4 (2.1)
22*	Keith Siding Road	3.7 (2.3)
23	North Edge of Lake Lucerne from Potawatomi Trail	9.7 (6.0)
24	Scenic Wayside on U.S. Highway 8	11.3 (7.0)
25*	U.S. Highway 8 at Western Corporate Boundary of Crandon	10.0 (6.2)
26	Sugarbush Hill Tower	11.6 (7.2)
27*	Airport Road	3.7 (2.3)

* Viewpoint located by the application of selection criteria and methods described in The Sanborn Group, Inc. (1982), and field verification.

TABLE 4.2-16

MINE WASTE DISPOSAL FACILITY VIEWPOINT LOCATIONS

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VIEWING DISTANCE TO MINE WASTE DISPOSAL FACILITY km (miles)
28	Deep Hole Lake Road East of Balloon No. 1	0.31 (0.19)
29	Deep Hole Lake Road West of Balloon No. 1	0.45 (0.28)
30	Southwest Shore of Duck Lake	0.92 (0.57)
31	Southwest Shore of Deep Hole Lake	1.53 (0.95)
32	West Shore of Little Sand Lake	2.4 (1.5)
33	County Highway Q	2.1 (1.3)
34	Sand Lake Road	0.45 (0.28)

TABLE 4.2-17

RAILROAD SIDING VIEWPOINT LOCATIONS

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VIEWING DISTANCE TO RAILROAD SIDING km (miles)
21	Keith Siding Road	0.34 (0.21)
22	Keith Siding Road	0.76 (0.47)
35	County Highway W	---

one were to perceive it in the actual setting. The photographic simulations are typical of the visual effect viewed from the general geographic area surrounding the viewpoint and do not represent an isolated instance of impact common only to a specific viewpoint.

Headframe

Visual presence or absence of the headframe from the viewpoints is denoted in Table 4.2-18. The viewpoint numbers in the table correspond to those illustrated on Figure 4.2-11.

The results of field observations suggest that three principal geographic areas, represented by clustered viewpoints, will be potentially affected by the headframe. These areas include:

1) A segment of Highway 55, about 1.0 km (0.6 mile) in length, located approximately 1.8 km (1.1 miles) south of Sherman Corners;

2) The City of Crandon represented by the north and east shores of Lake Metonga; and

3) The southwest shore of Little Sand Lake.

In addition, the headframe will be visible from the Sugarbush Hill Lookout Tower, and a portion of Sand Lake Road, approximately 91 m (300 feet) in length, located 4.3 km (2.7 miles) east of the intersection with Black Joe Road. A discussion of each geographic area is presented below.

Highway 55 Corridor - Intermittent views of the headframe will be available along a 1.0-km (0.6- mile) segment of Highway 55. A potential view was recorded at viewpoint No. 11 (Figure 4.2-12). The

TABLE 4.2-18

HEADFRAME VISIBILITY

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VISUAL PRESENCE/ABSENCE OF HEADFRAME
1	Main Public Landing On Deep Hole Lake	Absence
2	Main Public Landing On Duck Lake	Absence
3	Southwest Shore of Little Sand Lake	Presence
4	Southwest Shore of Oak Lake	Absence
5	Sokaogon Chippewa Community Park	Absence
6	Mole Lake Community Park	Absence
7	South Shore of Rolling Stone Lake	Absence
8*	Highway 55 - South of Mole Lake	Absence
9*	Intersection of Sand Lake and Black Joe Roads	Absence
10	Highway 55 - North of Swamp Creek; North Entrance of Chief Ackley Memorial Housing Project	Absence
11*	Highway 55 - North of Swamp Creek	Presence
12	Veterans Memorial Park-Public Campground	Absence
13	Village of Crandon-Main Public Landing/Swimming Beach on Lake Metonga	Presence
14*	Village of Crandon - East Shore of Lake Metonga	Presence

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VISUAL PRESENCE/ABSENCE OF HEADFRAME
15	Main Public Landing on Lake Lucerne	Absence
16	Private Dock on East Shore of Ground Hemlock Lake	Absence
17	Intersection of County Highways Q and W	Absence
18	Intersection of County Highway Q and St. John's Lane	Absence
19*	Sand Lake Road East of Exxon Field Office	Presence
20*	Lakeview Road	Absence
21*	Keith Siding Road	Absence
22*	Keith Siding Road	Absence
23	North Edge of Lake Lucerne from Potawatomi Trail	Absence
24	Scenic Wayside on U.S. Highway 8	Absence
25*	U.S. Highway 8 at Western Corporate Boundary of Crandon	Absence
26	Sugarbush Hill Tower	Presence
27*	Airport Road	Presence

*Viewpoints were located by application of selection criteria and methods, and field verification by The Sanborn Group, Inc., (1982). Remaining viewpoint locations were determined by Exxon and the DNR.

Headframe Simulation Located
at the Center of the Scene
4.2 km (2.6 mi.) viewing distance

HEADFRAME SIMULATION
U.S. HIGHWAY 55 CORRIDOR
VIEWPOINT NO. 11

FIGURE 4.2-12

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photographic simulation of the view from this viewpoint is not entirely representative of the perception of the headframe when traveling the roadway. The simulation, although accurate, offers a static view not typical of the movement and progression of views sensed from the highway (Wartofsky, 1980). The angle of view to the headframe from Highway 55 is outside the 65 degree cone of concentrated vision established for a driver traveling at a 72.4 km/h (45 miles per hour) highway speed (U.S. Department of Agriculture, Forest Service, 1973). Therefore, although visible, the headframe may not be readily perceived from an automobile traveling on Highway 55. Viewing duration will play a role in the potential visual effect sensed by the viewer from points along the highway. Viewing time can be directly related to the degree of visual impact witnessed from a given viewpoint (Bureau of Land Management, 1980). Although the headframe will be visible from Highway 55, the degree of visibility may be less than that which is imposed on a stationary land use such as a residential concentration.

City of Crandon - The headframe will be visible from several areas within the corporate boundaries of Crandon. Viewpoints No. 13 and 14 represent the visual presence of the headframe from the north and east shores of Lake Metonga at the main public boat landing and swimming beach, and residential areas, respectively. The main public boat landing on the north shore of Lake Metonga, viewpoint No. 13 (Figure 4.2-13), represents the scale of the headframe at a viewing distance of approximately 8.9 km (5.5 miles).

Adjacent Lakes - The headframe will be visible from the southwest shore of Little Sand Lake but not from Oak and Duck lakes.

Headframe Simulation Located
at the Center of the Scene
8.5 km (5.3 mi.) viewing distance

HEADFRAME SIMULATION
VILLAGE OF CRANDON
VIEWPOINT NO. 13

FIGURE 4.2-13

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The lakes represent recreation areas within a 2.4-km (1.5-mile) radius of the proposed structure. The headframe will be visible from the south shoreline of Little Sand Lake, which currently is not as developed as other parts of the lake's shoreline and supports an extensive area of wetland vegetation. A residential concentration is established on the northwest edge of the lake, but the headframe will not be visible from this area because of vegetational screening. Viewpoint No. 3 (Figure 4.2-14) documents the view of the headframe from Little Sand Lake.

Sugarbush Hill Lookout Tower - The Sugarbush Hill Lookout Tower was the most distant viewpoint, 11.6 km (7.2 miles), from which the headframe was visible. The elevation at the base of the tower, 591 m (1,939 feet), is higher than that at the headframe location, 508 m (1,666 feet). In addition, upon ascending the tower a viewer gains even greater vantage points. This added height differential may allow views of not only the headframe but also the mine/mill site clearing and other mine/mill structures. A simulation of the headframe from Sugarbush Hill Lookout Tower (viewpoint No. 26) is provided on Figure 4.2-15.

Sand Lake Road - The portion of Sand Lake Road represented by viewpoint No. 19, located 0.8 km (0.5 mile) southeast of the headframe, was the closest location from which the headframe was visible in this area (Figure 4.2-16). Orientation of the road in the direction of the headframe allows views of the facility from the road corridor. Vegetation close to the road edge will obstruct visibility of the headframe from other portions of Sand Lake Road which are not oriented in the direction of the structure.

Headframe Simulation Located
at the Center of the Scene
2.25 km (1.4 mi.) viewing distance

HEADFRAME SIMULATION
LITTLE SAND LAKE
VIEWPOINT NO. 3

FIGURE 4.2-14

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Headframe Simulation Located
at the Center of the Scene
11.6 km (7.2 mi.) viewing distance

HEADFRAME SIMULATION
SUGARBUSH HILL TOWER
VIEWPOINT NO. 26

FIGURE 4.2-15

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Headframe Simulation Located
at the Center of the Scene
0.8 km (0.5 mi.) viewing distance

HEADFRAME SIMULATION
SAND LAKE ROAD
VIEWPOINT NO. 19

FIGURE 4.2-16

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Mine Waste Disposal Facility

The visual presence or absence of the MWDF from selected viewpoints is noted in Table 4.2-19. Viewpoint numbers correspond to those illustrated on Figure 4.2-17.

The MWDF will not be visible from the land-based viewpoints. The facility will cover less area and have a lower pond crest elevation than the original design. At locations closest to existing roads, the southwest corner of the facility will be 335 m (1,100 feet) from Sand Lake Road and the southeast corner of the facility will be approximately 275 m (900 feet) from Deep Hole Lake Road. Duck Lake, viewpoint No. 30, is located 485 m (1,600 feet) west of the facility. In all three instances, the existing forest cover, 15 to 21 m (50 to 70 feet) in height, in combination with viewpoint elevations lower than the facility embankments, will screen views to the MWDF.

Similarly, the MWDF should not be visible from viewpoints No. 31 through 34 (Figure 4.2-17) because of the height and screening characteristics of the existing vegetation, the proximity of the vegetation to the viewpoint and the fact the pond crest will typically be lower than the intervening vegetation.

Railroad Siding

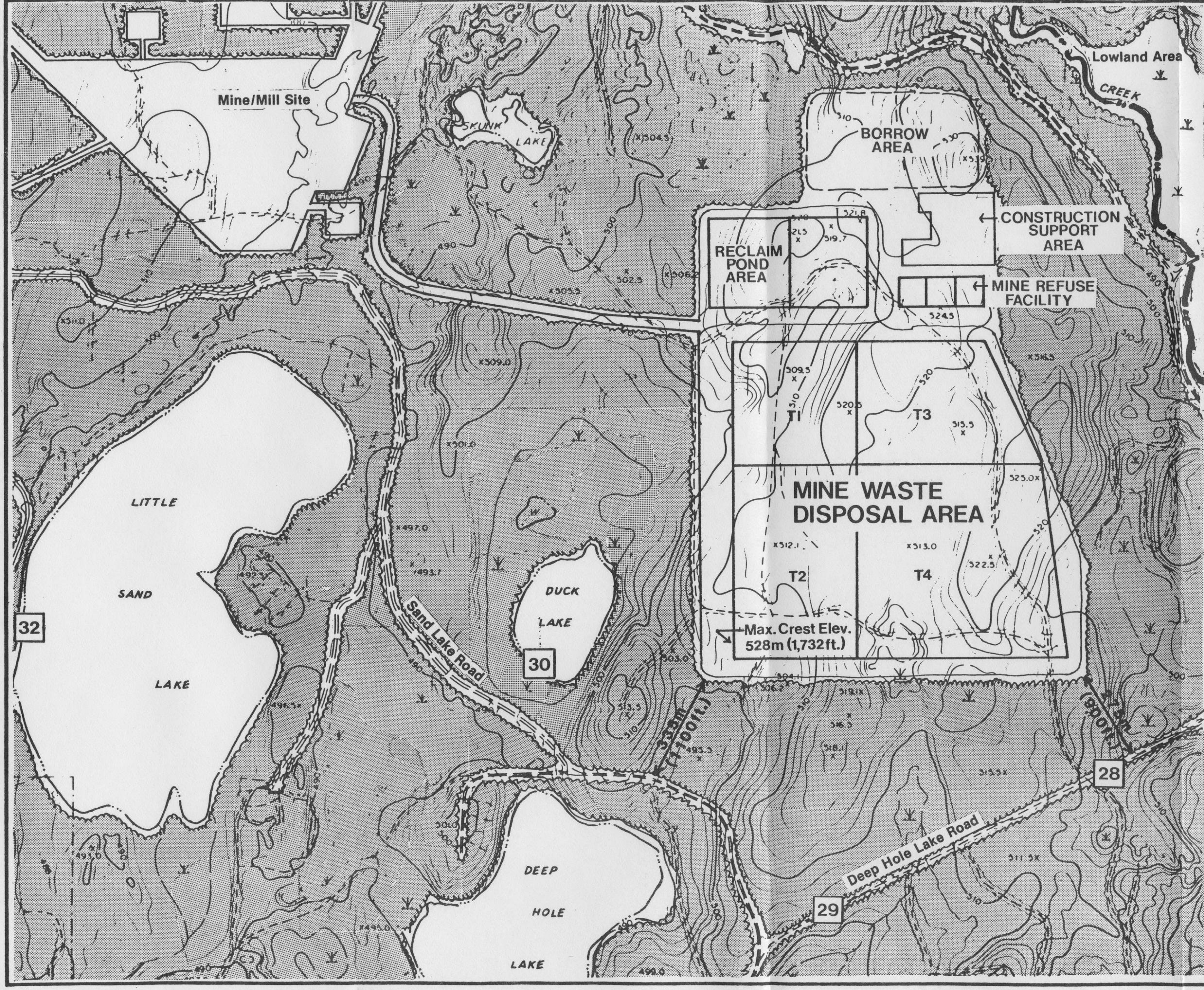
The visibility of the railroad siding from selected viewpoints is identified in Table 4.2-20. Viewpoint numbers correspond to those illustrated on Figure 4.2-18.

The railroad siding will be visible from a segment of Keith Siding Road located approximately 3.2 km (2 miles) west of the

TABLE 4.2-19

MINE WASTE DISPOSAL FACILITY VISIBILITY

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VISUAL PRESENCE OR ABSENCES OF MINE WASTE DISPOSAL FACILITY
28	Deep Hole Lake Road, East of Balloon No. 1	Absence
29	Deep Hole Lake Road West of Balloon No. 1	Absence
30	Southwest Shore of Duck Lake	Absence
31	Southwest Shore of Deep Hole Lake	Absence
32	West Shore of Little Sand Lake	Absence
33	County Highway Q	Absence
34	Sand Lake Road	Absence



Note

Topographic Landforms and Vegetation Screen All Views of the Mine Waste Disposal Area.

Legend

Existing Vegetative Screen

29 Viewpoint Location

North

Scale 1 Inch = 305 m (1000 ft.)

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EXISTING VEGETATIVE SCREEN & VIEWPOINT LOCATIONS, MINE WASTE DISPOSAL FACILITY AREA

FIGURE 4.2-17

TABLE 4.2-20

RAILROAD SIDING VISIBILITY

VIEWPOINT NO.	VIEWPOINT DESCRIPTION	VISUAL PRESENCE OR ABSENCES OF RAILROAD SIDING
21	Keith Siding Road	Presence
22	Keith Siding Road	Presence
35	County Highway W	Absence*

*No photography was taken at this viewpoint. An evaluation of 1:24,000 USGS mapping and field investigation indicated that intervening landforms and vegetation conceal the siding.

Note

The Plan Identifies the Prevalence of Forest Cover Resulting in Limited Visibility of the Rail Siding

Legend

●●●● Rail Siding Visibility Area

•••••• Visible Portion of Rail Siding

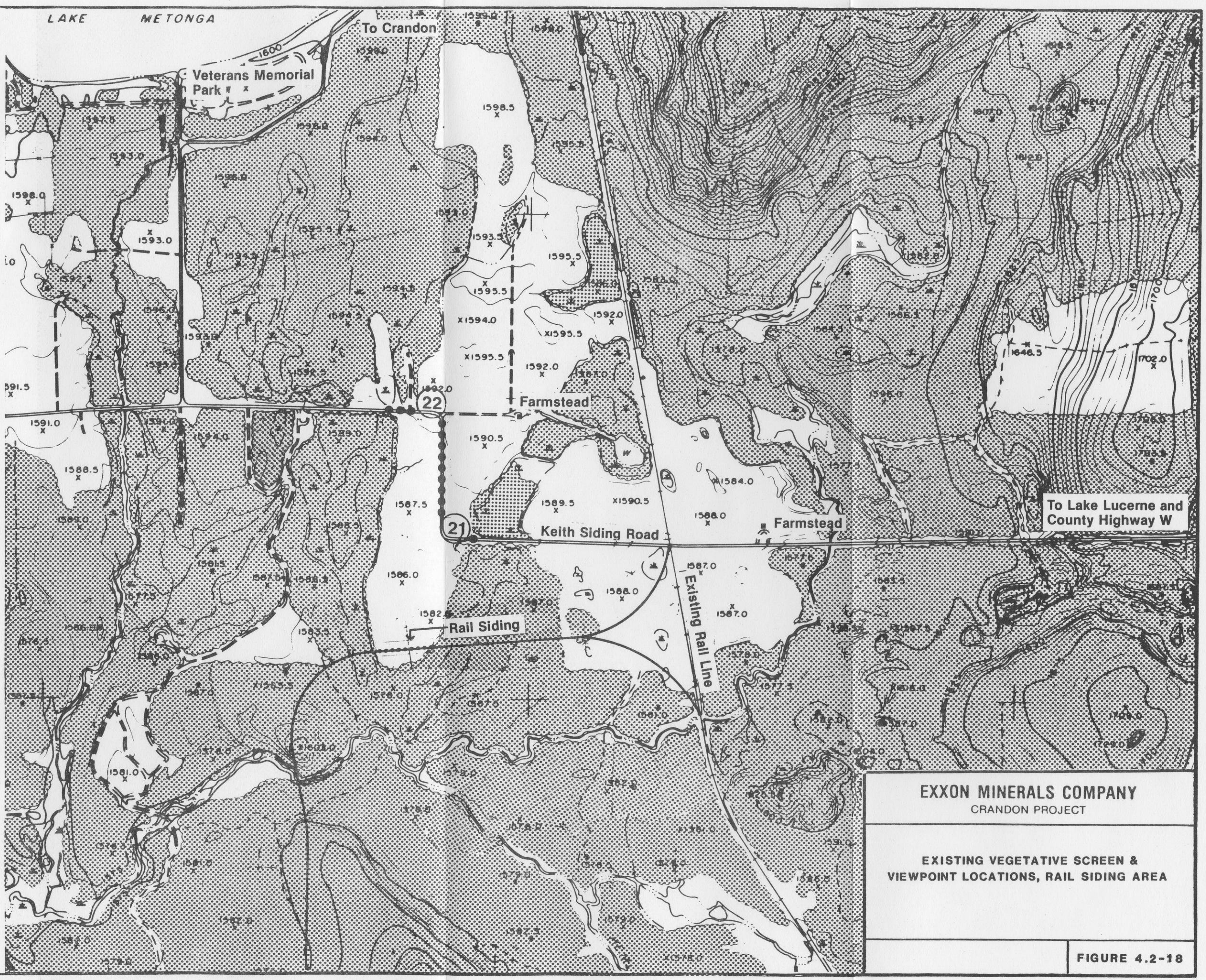
Forest Cover; Mixed Deciduous/Coniferous Stands

Agricultural Field

(21) Viewpoint Location

North

Scale 1 Inch = 305m (1000 ft.)



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EXISTING VEGETATIVE SCREEN & VIEWPOINT LOCATIONS, RAIL SIDING AREA

FIGURE 4.2-18

intersection with County Highway W and extending westerly for approximately 0.8 km (0.5 mile). Keith Siding Road is a combination secondary and light-duty highway which, along with County Highway W, is a primary traffic artery connecting the Crandon and Lake Metonga vicinities with the Lake Lucerne area.

Figure 4.2-18 illustrates the viewing area and identifies the factors affecting the visibility of the siding. A simulation of the railroad siding from the Keith Siding Road viewing area (viewpoint No. 21) is illustrated on Figure 4.2-19. In this example, Keith Siding Road exhibits a north/south orientation which will allow views of the siding when approaching from the north.

The siding will not be visible from County Highway W, or any of the unimproved roads within a 3.2-km (2-mile) radius of the siding. Vegetative screening is the principal reason for the lack of visibility.

Summary of Visibility of Project Facilities - Viewpoints where Project surface facilities will be visible have the following terrain characteristics:

1) The presence of man-made openings in the forest cover resulting from agricultural or urban development;

2) The presence of natural openings in the forest cover, i.e., waterbodies and selected wetlands. The mine surface facilities will only be visible from shorelines farthest from the headframe when viewed over open expanses of water; and

3) The absence of intervening landforms and tall, dense foreground vegetation, which, if present, would obstruct views of Project surface facilities.

Rail Siding Simulation
Located at the Center of the Scene
.34 Km (.21 Mi.) Viewing Distance

RAILROAD SIDING SIMULATION
KEITH SIDING ROAD
VIEWPOINT NO. 21

FIGURE 4.2-19

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4.2.9.2.2 Mitigation of Visual Impacts

Headframe - The headframe will exhibit varying degrees of visual contrast and visual dominance which are a result of form, line, and scale disparities between the structure and other distinct objects or areas in the landscape. Appropriate color selection, headframe design, and the placement of vegetation to screen views of the headframe are procedures which can be employed to mitigate visual impacts resulting from the headframe.

Color Selection - Color selection is important in mitigating the visual contrast and dominance created by the headframe. Color selection for the headframe should be based on local conditions and the relative distance from the viewpoints where the headframe is most visible. The headframe color should not appear distinct and should be lower in color brilliance and value from the middle ground and background viewing distances. In addition to atmospheric effects, the surface material texture of the headframe will affect the perception of color over distances. The reflectivity of the surface of the headframe will result in a lightening of the surface color, even if a matte-finish is used. The headframe should be colored somewhat darker than the sky background to compensate for this reflection. A roughened surface texture, which would tend to absorb rather than reflect light, may also be helpful in reducing the reflectivity of the headframe.

Vegetative Screening - Observations made of the headframe and landscape setting from Highway 55 west of Crandon and from Sand Lake Road, discussed earlier in this subsection, indicate the importance of vegetative screening in reducing the visual contrast and visual dominance created by the headframe. Existing vegetation was also the major reason for the headframe not being visible at most of the viewpoints.

Existing vegetation may satisfactorily absorb or screen the headframe from most viewpoints, thus making further mitigation unnecessary. If mitigation measures are required, plantings could be placed to screen views of the headframe.

The wintertime views of the headframe should not be significantly different than the summer scenes. Even without leaves, the presence of evergreens in the landscape and the vegetation texture and depth will continue to partially or totally mitigate views.

<u>Mine Waste Disposal Facility</u> - The MWDF will not be visible from the selected viewpoints with the possible exception of Sugarbush Hill Lookout Tower, viewpoint No. 26. The tall, dense vegetation in the foreground and middleground of viewpoints No. 28 through 34 is the primary factor affecting visibility. During winter months the effectiveness of the vegetation in mitigating views should not be greatly different than in summer. The presence of evergreens in the landscape, tree and shrub density, and the branching character and depth of the vegetation should screen views to this facility in winter.

<u>Railroad Siding</u> - Several factors affect the visibility of the siding and its subsequent visual mitigation, including:

1) When viewed from a moving automobile, the perceived visual contrast created by the siding may be minimal because it will only be visible for a short viewing time and distance;

2) The 0.3-km (0.2-mile) setback from Keith Siding Road will reduce the relative scale of the railcars and their visual importance; and

3) An existing rail line is located approximately 0.4 km (0.2 mile) east of the railroad siding; thus, viewers are accustomed to the presence of rail activity in the area of the railroad siding.

The siding will not create major visual contrasts in form and line with other features in the landscape setting; therefore, it should not create a visual impact.

4.2.10 SOCIOECONOMICS

4.2.10.1 Introduction

This section discusses the socioeconomic effects of the Crandon Project. The focus is on conditions in the local study area as previously defined in Chapter 2, subsection 2.2.10. Also discussed are the economic, demographic, and fiscal effects of the Crandon Project on the State of Wisconsin.

Subsection 4.2.10.2 describes the methodology, assumptions, and key definitions employed in the socioeconomic assessment. Subsequent subsections describe forecasts of each of the elements of the Socioeconomic Study. The final subsection presents the findings and conclusions.

The section is both a quantitative and qualitative analysis of the potential impacts of the proposed Crandon Project on the local study area. The quantitative results reported are largely drawn from the Forecast of Future Conditions (FOFC) and its accompanying Data Summary (RPC, 1983). The quantitative results were projected through the use of integrated series of computer models assembled specifically for this Project, a broad collection of literature, attitudinal surveys conducted in the local study area, and direct observation.

The type of computer modeling tools employed in the analysis are widely used in socioeconomic assessments. Every effort was made to insure reasonableness and validity of the projections. Nevertheless, any modeling effort has limited precision and are best thought of as simulation tools, not future prediction tools. Because of the limitations of computer modeling, the model output must be subject to interpretation. The FOFC represents the results of both the modeling process and the professional interpretations of the consultants. The interpretations form the basis of the qualitative results reported in this section.

The qualitative results are grounded on a comprehensive understanding of the entire data base, not the precise details of any particular scenario. Consequently, the qualitative results are very stable and would not be significantly affected by the changes in the Project Plan announced by EMC in May 1985.

Following publication of the FOFC, two important events occurred which have a material affect on the quantitative results. In May of 1985, EMC announced a revision in the Project Plan which reduced the overall scale of the Project and changed the timing. The reduction in scale placed the Project employment estimate somewhat below the range covered by the computer projections. The change in timing shortened the construction period from 54 to about 30 months and lengthened the operation period from 22 to about 29 years.

The second event concerns the assumption used by RPC for the source of construction workers. RPC assumed that only 10 percent of the construction work force would be commuters. This very low level was set to ensure that no potentially adverse impacts were overlooked. The recent experience at a comparable project (Champion International's Quinnesec Pulp Mill) located about 70 miles northeast of the Project clearly shows that the only construction phase workers likely to be temporarily residents of the Local Study Area are the engineering and supervision employees of the main construction contractors, the EMC construction management staff, and the specialized work force which would sink the shaft and construct the underground facilities. In light of the new information provided by the Quinnesec example and the lack of significant adverse impacts in the FOFC, a more useful assumption is that about 40 percent of the construction work force will be commuters.

The statements contained herein represent the judgment of EMC with regard to the outcome of the development of the Crandon Project. As additional data becomes available and further analysis is made of the data, the projections may change. The projections are not statements of fact but rather are forecasts of future conditions, and as such, should not be treated with the degree of certainty normally accorded to statements of fact, and cannot be interpreted as commitments by EMC.

4.2.10.2 Methodology

This subsection provides general information on the methods used to analyze the likely socioeconomic effects of the proposed Project on the local study area. The following are presented below: (1) the method of defining the geographical limits of the analysis; (2) an overview of the computer modeling system; and (3) an outline of the assumptions used in forecasting future conditions with and without the Project and a comparison of those assumptions to the Project as currently planned and the updated assumptions. More detailed information on each of the topics in this subsection is available in the methodology reports submitted to DNR and released to the public over the 1980 to 1982 period (RPC, 1980, 1981a, 1981b, 1982a) and the Forecast of Future Conditions.

Local Study Area - The "local study area" as defined for the socioeconomic assessment is that geographic area reasonably expected to be most impacted by the mining activity (Wis. Stats. 144.85(5)(e)). In addition to areas immediately adjacent to the mine/mill complex, the local study area includes areas where new residents are expected to locate in reponse to jobs directly or indirectly created by the Project. It also includes areas with existing industries that may compete with the Project for workers.

Defined on the basis of an analysis of area housing markets and the factors affecting residential location decisions (RPC, 1980), the local study area consists of 40 townships and four incorporated areas in Forest, Langlade, and Oneida counties. The four incorporated areas are White Lake Village, Crandon, Antigo, and Rhinelander. Chippewa and Potawatomi Native American communities are also located within the local study area. A map of the local study area and a list of jurisdictions included therein is presented in the description of baseline conditions (see Section 2.10). While the Project may have socioeconomic effects outside the local study area, effects which may require mitigation are most likely to occur within its boundaries.

Assessment Methodology - To assess the effects of the mine/mill complex on communities in the local study area, a number of computer models, as well as other impact assessment techniques, have been employed. The assessment methodology used in the study is based on established socioeconomic principles.

The use of computer models is widespread in socioeconomic impact assessment (Murdock and Leistritz, 1980). Portions of this study used models adapted specifically to the Crandon local study area, which have been used in previous assessment efforts (e.g., the economic-demographic, housing and land use, and spatial allocation models). In other cases, because of unique institutional considerations in the local study area, new models have been developed (e.g., the fiscal model and the public facilities and services model). A brief description of the quantitative models used in the assessment is presented in Table 4.2-21.

Assumptions - The socioeconomic effects of the Project during the construction, operation, and post-operation periods are projected by comparing forecasts of future conditions if the Project is implemented (with-Project scenarios) with a forecast of future conditions if the Project is not implemented (without-Project scenario). The assumptions used in this assessment were developed from analysis of current conditions and trends, examination of comparable projects, and information on the proposed Project.

To estimate a range of likely effects of the Project, three scenarios of project conditions were developed. These three scenarios represent the low, medium, and high impact that the Project would have on the area if it were developed. A detailed list of the major assumptions used in the computer models is included as part of the FOFC. Table 4.2-22 contains a description of some of the major assumptions dealing with Project life and manpower used for the scenarios examined in the FOFC and the Project as currently planned. It should be pointed out that while every effort has been made to make reasonable assumptions based on sound professional judgment, certain of the assumptions used in the study, such as in the area of revenue generation, are subject to economic variables beyond the control of EMC.

TABLE 4.2-21

MODELS USED IN ASSESSMENT

MODELS	OUTPUT
Economic Model	Household Income Business Activity by Sector Employment by Sector
Demographic Model	Population by Age, Sex, and Type Net Migration by Age, Sex, and Type
Labor Market Model	Work Force by Age, Sex, and Type Employment-Related Migration by Age, Sex, and Type
Housing Market Model	Number of New Housing Units by Type Housing Prices Housing Shortages
Spatial Allocation Model	Distribution of Employment, and Population to Counties and Municipalities
Land Use Model	Acres of Developed Land by Jurisdiction Acres of Undeveloped Land by Jurisdiction
Public Facilities and Services Model	Staffing Requirements by Service Reserve Capacity by Facility Operating Cost by Service or Facility Capital Expansion by Service or Facility Construction Start Dates to Prevent Capacity Shortfall
Transportation Model	Average Daily Traffic Levels Truck Traffic Nontruck Traffic
Fiscal Model	Intergovernmental Transfers by Source and Recipient Property Tax Impacts
State Model	Statewide Employment and Population Tax Collections

TABLE 4.2-22

COMPARISON OF ASSUMPTIONS
USED IN CRANDON PROJECT SCENARIOS AND CURRENT PROJECT PLAN

ASSUMPTIONS	FOFC SCENARIOS LOW	FOFC SCENARIOS MEDIUM	FOFC SCENARIOS HIGH	CURRENT PLAN
1. Number of Construction Workers				
1985	435	485	535	0
1986	790	875	960	0
1987	465	515	565	0
1988	930	1035	1140	570
1989	970	1080	1190	735
1990	0	0	0	1128
2. Source of Construction Workers by Percent				
Local	50	35	25	25
Temporary Residents	40	55	65	30-45
Commuters	10	10	10	45-30
3. Number of Operation Workers				
1985	45	45	45	0
1986	90	100	110	0
1987	290	320	350	0
1988	380	425	470	71
1989	520	580	640	204
1990	660	735	810	524
1991	685	760	835	620
1992-2011	700	780	860	620
2012	325	360	395	620
2013-2018				620
2019				580
2020				325
2021				165
2022				55
4. Source of Operations Workers by Percent				
Local	60	60	60	60
Inmigrants	40	40	40	40
5. Life of Mine	22 Years	22 Years	22 Years	29 Years

For purposes of the FOFC study, the assumed Project schedule is that permit applications for the Crandon Project are filed in late 1982, that operation begins in 1990 and continues until 2011. The Project plan has been revised and the new schedule is somewhat different; operations still could begin in 1990 but would continue until 2019. As stated in Chapter 1, the actual schedule can vary depending upon permit terms, market factors, and corporate decision-making process.

Current Plan Assumptions - The Project plan now calls for a somewhat smaller operation with a correspondingly lower level of operations work force than the estimate when the computer models were assembled. The current full production work force estimate of 620 workers is 11 percent less than the 700 figure on the low end of the range covered in the FOFC. Additionally, the current plan now calls for a shorter construction period than used in the FOFC, approximately a 30-month schedule compared to a 54 month-schedule.

A complete description of the Project work force and schedule is contained in subsection 1.1.3.3. Based on the current Project plan construction work force characteristics (see Table 1.3-3), the number of workers (peak quarter) likely to be temporary residents during the construction phase is 202 in Year 1 of construction, 236 in Year 2, and 319 in Year 3. The peak number is less than one-third of the peak number of temporary residents in the high impact scenario and about 40 percent of the peak number in the low impact scenario. Because the peak number of temporary residents is likely to be much less than the number assumed in the various impact scenarios the population growth and resulting public facilities and services costs are also likely to be less than the projections in the impact scenarios.

4.2.10.3 Economic Analysis

This subsection analyzes the economic effects of the Project on employment, unemployment, personal income, and business activity. In addition, the effects of the Project on several of the local study area's major industries (retail trade, forestry and wood products, hospitality, recreation and tourism, agriculture, and mining) are evaluated.

Without Project Forecast - Projections of local study area without- Project economic conditions indicate that, without development of the Crandon Project, the local study area is unlikely to experience periods of sustained, substantial economic growth. With the exception of the Crandon Project, there are no published plans for new large scale industrial developments. The slow growth in the economic sectors of the local economy is expected to result in relatively moderate employment growth. Income levels probably will remain below the statewide average.

The slow economic growth and the corresponding level of unemployment could result in outmigration of working age population from the local study area. This occurs when young persons, who are unable to find local jobs, outmigrate in order to find employment elsewhere. Whether this occurs in the local study area and the extent to which it occurs will depend on the level of unemployment and the time period over which high unemployment levels are sustained. This phenomenon has been observed frequently in rural areas where employment opportunities are not increasing at a rate sufficient to keep pace with the natural growth of the labor force (Bowles et al., 1975; Murdock and Leistritz, 1979).

Per capita income growth in the local study area is forecast to be slow under without-Project conditions. This is because of the level of economic growth which is expected and the continued inmigration of retired people with transfer payments as their primary source of income.

Business activity and total personal income are expected to show slow, but steady growth over the study period. Growth in business activity is expected to vary among the sectors of the local economy.

Construction Phase - Development of the Project will result in the creation of an entirely new sector within the local study area economy. Project development will increase local study area employment levels and, during the late 1980s, will account for a large share of the growth in area employment. Construction activity is projected to begin in 1988 and to be completed in 1990. Construction employment peaks in the last year of construction at approximately 1200. In addition, the permanent (operations) work force for the facility also will build up during the construction phase, reaching levels of approximately 620 by 1990.

In order to ensure that no potentially adverse impact was overlooked, RPC assumed that only 10 percent of the construction workers would commute from outside the local study area. The experience at the construction of Champion International's Quinnesec pulp mill (Blount Brothers, 1985), which is substantially larger than the Crandon Project, demonstrates that this very conservative assumption is no longer necessary.

EMC now anticipates that 25 percent of the construction workers will be from Forest, Langlade or Oneida County and that about 40 percent of the construction workers will commute from their homes in other parts of northern Wisconsin. The only construction phase workers that will temporarily relocate in the local study area are expected to be associated with engineering and supervisory tasks of the main construction contractors, the EMC construction management team and the specialized work force which would sink the shaft and construct the underground facilities. Some of these workers will undoubtedly be drawn from both the local study area and other nearby counties, but because the overall number is so small, the proportion cannot be reliably estimated.

As is generally the case in the RPC analysis, Forest County is still expected to host about 46 percent of the construction phase work force temporarily relocating to the local study area, an average of about 120 workers (ranges from 90 to 150). Langlade and Oneida counties are expected to host 19 and 35 percent, respectively.

Project construction activities will also lead to the creation of secondary (indirect and induced) jobs in other sectors of the local study area economy. Most of the secondary jobs probably will be caused by purchases made by Project employees. The majority of the indirect jobs probably will be within trade, recreation, and other services. Secondary jobs created during the construction phase will likely be filled primarily by local residents, or by family members of immigrating construction or operation workers. These patterns are consistent with those observed in connection with other large construction projects

(Wieland, et al., 1979; Gilmore, et al., 1982; Dunning, 1981; Malhotra and Manninen, 1980).

EMC expects that about $212 million will be spent on the purchase of goods and services in Wisconsin during the construction phase (see Table 4.2-23). The construction payroll would make up slightly more than 55 percent of the total. Other major groups are fabricated metals, non-electrical machinery and transportation, communication and public utilities (C.P.U).

EMC has adopted a policy which gives all the preference allowed by law to the hiring of local citizens, including Native Americans, and has prepared a provision to be inserted into any construction contract, whereby each potential contractor must agree to utilize local people to the extent possible and practicable (Exxon Minerals Company, 1980). The effect of this policy will be to limit the amount of inmigration. In addition, the Project will result in an upgrading of job opportunities by providing skilled jobs along with training opportunities for those people who are hired locally.

Overall, Project construction will enhance employment opportunities in the local study area. The labor market in the local study area will probably tighten and some competition for labor may ensue due to the temporary nature of the construction period, and the relatively well developed local labor force. No long-term shortages of labor should occur.

Project construction should increase total personal income in the local study area. This higher total personal income translates into higher per capita income for local residents because a higher percentage of local residents will be employed and construction jobs will pay

TABLE 4.2-23

DIRECT PURCHASES WITHIN STATE OF WISCONSIN
CONSTRUCTION PHASE AND SAMPLE OPERATION YEAR

Millions of Dollars
(1st Qtr. 1985)

Sector	Construction (30 Month)	Operation (Full Production Year)
Agriculture	0	0
Metal Mining	0	0
Nonmetal, Nonfuel Mining	-	-
Construction	-	-
Food Products	0	0
Textile Mill Products	0	0
Apparel	0	0
Lumber and Wood Products	5	1
Furniture and Fixtures	2	-
Paper and Allied Products	-	-
Printing and Publishing	0	0
Chemicals	1	2
Petroleum and Coal	6	2
Rubber and Plastics	0	1
Leather Products	0	0
Stone, Clay, and Glass	5	4
Primary Metal Products	4	-
Fabricated Metals	36	1
Nonelectrical Machinery	14	5
Electric and Electronics	1	-
Transportation Equipment	1	-
Instruments Manufacturing	-	-
Miscellaneous Manufacturing	2	-
T.C.P.U.[1]	10	14
Wholesale Trade	7	2
Retail Trade	0	0
F.I.R.E.[2]	0	0
Hospitality, Recreation and Tourism	-	-
Other Services	-	1
Government	0	0
Labor	118	16
Total	$212	$ 49

[1]Transportation, Communications and Public Utilities.
[2]Finance, Insurance and Real Estate.
-Less than $1 million.

Note: Typical representation for the purpose of socioeconomic analysis. Refinements may be made during final engineering. Final estimate expected to be within ± 25% of this estimate.

higher wages than other local jobs. Project construction will also lead to increases in levels of business activity in the local study area due to induced and indirect effects.

The economic effects of Project construction will not be distributed evenly throughout the local economy. For this reason, five sectors have been chosen for special consideration: retail trade, forestry and wood products, recreational tourism, agricultural, and mining.

When large-scale resource development projects are initiated, the effects on other sectors of the local economy generally fall into two categories. Some local sectors may experience substantial increases in receipts as a result of purchases of supplies and materials by the Project and/or expenditures by Project employees. Some sectors may, however, experience problems of competition for labor and rising wage rates if Project development results in tight labor market conditions characterized by shortages of labor, either overall or in certain skill categories (Murdock and Leistritz, 1979; Gilmore, 1976).

In the case of Project construction, no substantial long-term effects on other local economic sectors are anticipated. As discussed above, construction of the Project is not expected to lead to an overall long-term shortage of labor in the area. Furthermore, two of the sectors (retail trade and hospitality, recreation and tourism) will not tend to compete directly with the Project for labor. Many jobs in these sectors are held by people who are not the primary source of their household's income. Construction jobs, on the other hand, will tend to be primary jobs taken by household heads.

In the forestry and wood products sector, the competition for labor will be more direct. Many of the workers in this sector are probably of the same type as those who will seek employment with EMC. However, as discussed above, it is not expected that long-term labor shortages should occur.

There should be no substantial difference in agricultural output and employment due to Project construction. While the higher population levels associated with Project construction will somewhat increase the pressure for conversion of agricultural land to residential uses, the amount of agricultural land removed from production should not be enough to substantially affect the total output of this sector. Project construction may benefit unemployed or underemployed agricultural workers by providing them with alternative employment opportunities.

Operation Phase - Project operation will increase local study area employment substantially, in comparison to without-Project conditions. The Project is expected to reach full production in the early 1990s, which will result in the creation of about 620 jobs for plant and mine operation. It is expected that approximately 60 percent of those jobs can be filled with residents of the local study area.

Local residents are expected to fill a much higher proportion of the operations jobs than the construction jobs. This is due to three interrelated factors: the local level of interest in operation jobs is higher than for construction jobs, the match of education and experience characteristics indicated for operation jobs is better than the match for construction jobs and, consequently, the pool of potential applicants compared to available jobs is much greater for the operation jobs compared to the construction jobs.

The high level of interest in Project-related jobs is shown by both the surveys conducted in the LSA and the requests EMC has received for employment notification cards.

The RPC survey of permanent resident households was conducted in 1980. They found that about 8.1 percent of the people in households in the three county local study area would apply for a Project-related job. The 1980 Census counted 60,238 people in households in the three counties. Assuming that the level of interest remains constant the Project will have nearly 4,900 local residents to select from to fill Project jobs, nearly 8 times the number of available jobs.

The City of Crandon conducted a household survey in the Fall of 1983. Sixty-two percent of the households participated. While the results are not directly comparable to the RPC survey (the question was asked differently) this survey also found a high level of interest in Project jobs. Thirty-three percent of the survey respondents said that a member of the household would apply for work at the Project. An additional 24 percent said a member possibly would apply.

Native Americans in the area have also expressed a high level of interest in Project jobs. A household survey of the Potawatomi community in December of 1984 was conducted by the Denver Research Institute. They report that 53 percent of the respondents who are aged 16 and above and in the labor force would apply for a job at the Project (Denver Research Institute, 1985).

During August of 1985, EMC conducted a mail survey of Forest County households. Six hundred eighty usable survey forms containing information on 1,495 people over the age of 16 were received. Fifty-three percent of the respondents said they either very likely or somewhat likely would apply for a job in the surface operations of the Project. Nineteen percent and 44 percent said the same about the underground operations and construction jobs, respectively (Exxon Minerals Company, 1986).

About 40 percent of the operations jobs call for a combination of education and experience not readily available in the local study area (see Tables 1.3-4 and 1.3-5). The requirements of the remaining 60 percent of the jobs are very compatible with the skills of the current population. When combined with EMC's commitment to preferentially hire qualified local people and the large pool of potential applicants a local hire rate of at least 60 percent would be readily achievable (see Table 1.4-12).

Mine/mill operation also results in the creation of secondary jobs in existing local industries. The FOFC projection of secondary jobs in the low impact scenario ranged from 338 to 397 during the operation phase. Because the operations work force under the current plan is less than that of the low impact scenario, the number of secondary jobs will also be somewhat less. As during the construction phase, most of these jobs are created due to purchases by Project employees. The major difference in the composition of secondary employment between the construction and operation phases is in the forestry and wood products. Secondary employment in the forestry sector is likely to be less during the operation phase because the Project's demand for timber and other wood products is less during the operation period than during construction.

Most of the secondary jobs should be filled by local study area residents. The local labor pool is expected to be adequate to meet these demands and employment-related inmigration is expected to be minimal. Because of the well developed labor force and the relatively moderate rates of non-Project employment growth prevailing throughout this period competition for workers will not create long-term shortages of labor.

Total and per capita levels of personal income in the local study area will be higher during the Project operation period than under without-Project conditions. This results from the relatively higher incomes of the Project work force compared to the local study area average. Experiences elsewhere indicate that compensation rates paid to workers in other sectors should not be noticeably affected by the Project.

The income generated from the Crandon Project's mineral output is expected to cause an immediate increase in local study area business activity during construction and operation. The primary economic stimulus of the Project to the other sectors of the local economy is from the additional demand for consumer goods that result from the increased employment generated by EMC and the Project's $16 million annual payroll. EMC's statewide direct purchases, expected to amount to about $49 million annually, should have a noticeable effect in the nonelectric machinery and nonproject mining sectors and in the transportation and utilities sector. These purchases primarily consist of replacement machinery, gravel, railroad freight costs, and utility payments; some of these purchases will filter to the local economy (see

Table 4.2-24). Forestry and wood products are another potential source of EMC's local purchases.

The major induced economic activity should be in the consumer sectors of finance, insurance, and real estate; retail trade; services; recreation; and utilities. Consumer activity in finance, insurance, and real estate will be for financing housing, bank accounts, and insurance policies. Activity in trade will be for direct purchases of consumer goods. The local trade sector imports a large portion of its saleable goods, so local manufacturing should not be greatly affected. Activity in services and recreation will consist of normal consumer activity. Purchases of utilities will be for supplying consumer energy needs.

These forecasts are conservative in that they do not assume the development of any satellite industries. All new jobs are with either EMC or existing local sectors. The forecasts do not address the possibility of the development of, for example, a local mining supply firm. If new industries enter the local study area with the development of the Project, more local jobs would be created resulting in a stronger economic base.

Post-Operation Phase - Post closure impacts are difficult to project because the net impacts of closure are very related to advanced planning for alternate economic opportunities. If no such planning occurs and the special fund resulting from the Net Proceeds Tax is not used for redevelopment activities, the closure of the mine/mill complex would result in the loss of about 620 operational jobs and a loss of almost all of the secondary jobs over the following three years. However, it is expected that the level of area employment after closure with the Project would be still slightly higher than in the without Project forecast. After the area mine/mill complex closes, total income would probably be slightly higher in the with-Project forecast than in the without Project forecast due to the slightly higher number of jobs in the local study. However, while the total income may be higher during this period, the larger total population due to the Project may cause per capita income to be lower.

Business activity in the local study area drops substantially with the closure of the mine/mill complex. In the absence of appropriate planning before mine closing, recovery from the closure of the complex is expected to be slow. With advance planning, potential negative effects of Project closure can be minimized and alternate economic development scenarios could be pursued.

4.2.10.4 Demographic Analysis

The purpose of the demographic analysis is to determine the change in local study area population which could be expected due to the Crandon Project. This analysis is necessary because many of the housing, public facilities and services, fiscal, and social effects of a given project are related to population changes associated with the project. For these reasons, the demographic analysis specificially examines population changes expected to be brought about by development of the Project.

Without Project Forecast - Over the forecast period, population is expected to grow at a modest rate of 0.4 percent per year. This is about a third of the rate during the 1970s but slightly faster than in the 1950 - 1980 period overall. The bulk of the local population growth is expected to result from natural increase (more births than deaths), and immigration of retired persons. The main reason for the growth rate being lower than during the 1970s is a slowdown in the rate of inmigration of retired persons.

No major changes are expected in the composition of the population. However, over the entire forecast period the local study area population is expected to increase its percentage of the elderly and females by 1 or 2 percentage points.

Construction Phase - The population growth due to the Project will occur steadily over the 30 month construction period. Peak population growth will be less than that of any of the RPC scenarios because of the reduction in the number of construction workers expected to be temporary residents. Based on the population characteristics of immigrant construction workers (RPC, 1983) the peak annual population growth due to workers and their families temporarily residing in the local study area would range between 504 and 584 persons.

In addition to direct Project jobs, the business activity generated by the Project will create a number of secondary jobs. The job growth should push the unemployment rate lower than would be the case without Project. The secondary jobs probably will be filled mostly by local residents or by family members of inmigrating construction and operations households. Population growth due to secondary job growth should be very modest.

The announced EMC policy of hiring as many local residents as possible within the limits prescribed by applicable laws and by the skills required in the work force will tend to reduce inmigration to the area.

Development of the Project is not expected to substantially alter the composition of the local population. However, Project development will probably cause the population to be somewhat younger due to inmigration of working age individuals. These changes, however, are not expected to be substantial and the overall rate of natural increase (births minus deaths) is not expected to be altered by a large amount.

Operation Phase - The demographic effects of the Project during the operations phase are a continuation of those during construction. As the operations work force comes to full strength and the secondary job growth matures the local study area population growth will inch higher. The low and medium impact senario projections for population growth is generally in the range of 1,700 - 2,200 people. Because the current Project plan calls for fewer workers and the secondary job growth would also be somewhat less, the growth in population would also likely be somewhat less than what was projected in the FOFC.

In the low impact senario, the population growth during the operations period is more or less evenly distributed between the three counties. This same sort of pattern should prevail with the Project as currently planned and the population growth would not be concentrated in any one locality or county.

Development of the Project also could potentially alter the rate of household formation. Young adults who live with family members and who become employed as a result of the Project will be able to afford separate households. This would result in increased demand for housing in the local area.

Population growth rates are often good indicators of potential problems in absorbing new populations. When an area is unable to absorb growth, problems such as social disruption and inadequacy of public services can occur. These effects are frequently termed "boomtown problems" (Gilmore et al., 1982; Gilmore, 1976). Whether these growth rates would produce similar effects in the local study area depends on the total magnitude of the growth and the capacity of the existing infrastructure to absorb it. Given the baseline conditions existing in the local study area, the well developed infrastructure, and the magnitude of growth expected during the study period, it is highly unlikely that these types of conditions would occur anywhere in the local study area. These findings are consistent with other recent analyses of the demographic effects of large-scale projects, which suggest that "boomtown" growth rates occur in only a small percentage of the affected communities (Murdock et al., 1982).

Post-Operation Phase - If no planning for closure occurs, closure will cause a drop in employment and result in outmigration of working age adults. These effects can be moderated, however, by advanced planning on the part of local community leaders with emphasis on development of new industries. For several years after closure, the local study area population will be larger in the with-Project scenarios. Thereafter, however, the without-Project and with-Project population totals will approach each other. During and after the closure of the Project, the elderly population, as a percentage of total population, is expected to increase.

To summarize, the proposed Project will have limited effects on the local study area population. The Crandon Project will not cause a large influx of workers with their families. The population growth expected indicates that major problems are not expected to occur due to mine/mill complex development. The Project will probably result in a somewhat younger population.

4.2.10.5 Housing and Land Use Analysis

The purpose of conducting the housing and land use analysis is twofold. First, the analysis is needed to determine what changes in local study area housing market conditions are likely to occur due to development of the Project. Project effects on the amount, mix, and minimum market price of housing units supplied are identified in order to gauge whether sufficient housing will be provided for Project-related population.

The second purpose of this analysis is to determine what changes in local study area land use patterns are likely to result from increased population and employment levels associated with the Crandon Project. Project effects on local study area land use are measured in terms of the amount of land converted from undeveloped to developed uses. Analysis of the amount, timing, and location of Project-induced residential, commercial, industrial, and public use development allows us to determine whether prime agricultural or commercial forestland is likely to face substantial development pressures.

Taken together, the housing and land use analysis provides a picture of how the Project will affect the physical character of the local study area. The amount, type, and value of Project-induced development also directly affects the local study area property tax base and source of revenues used by local jurisdictions to fund their activities.

The state aid system is designed to moderate or "equalize" the fiscal differences among the different local jurisdictions. These equalization aids to schools, municipalities and counties are specifically designed to respond to fiscal disparities and socioeconomic changes which affect local fiscal conditions (FOFC, Appendix C). The property tax rate of a local jurisdiction on the aid system is relatively insensitive to moderate changes in either population or tax base. A major exception to this general situation is when the tax base growth is large enough to displace the local jurisdiction's state equalization aids.

With the exception of the local jurisdictions where the Project is located -- Town of Lincoln and Nashville, Crandon School District and Forest County -- the local fiscal conditions are not expected to be affected enough to overcome the equalizing forces of the state aid system. The estimated value of the direct Project improvements is used to determine the Project-related fiscal effects in the local jurisdictions where the Project is located.

Without Project Forecast - Demand for housing units in the baseline future is generated by the formation of new households. The number of new households that form is a function of demographic changes and, to a lesser extent, economic conditions. Demand for new units is also generated by existing households living in housing units that are removed from the housing stock by decay, demolition, or conversion to nonresidential uses.

The housing developers in the local study area have demonstrated the capacity to construct upwards of 700 units annually in the recent past (see Chapter 2, subsection 2.10.3.2). In addition, the local study area is serviced by a well developed manufactured housing industry such that housing supply could probably be expanded beyond historical levels, at least for short periods of time. Therefore, unless the capacity of the housing industry is reduced from the baseline year, it appears unlikely that a long term housing shortage would occur. However, due to conservative lending and development policies, it is expected that no housing units will be supplied in excess of those demanded by new households and existing households residing in units that are removed from the housing stock. As a result, vacancy rates in general are not expected to increase, and minimum sales prices for new single-family homes are expected to increase at a slow rate over the study period. Assuming that the current 30-year trend toward smaller households continues for the next 30 years but at a rate half as fast, the local study area will see a net addition to the housing stock of more than 9,000 units.

Land use characteristics are not expected to undergo any major changes during the study period. Due to the relatively stable population and the lack of sustained economic growth, pressure for conversion of land from undeveloped to developed uses is expected to be minimal.

Construction Phase - As in the baseline forecast, demand for new housing units in with-Project forecasts will be generated by new household formation and the replacement of housing units removed from the total housing stock. As the construction phase begins, household formation will increase over without-Project levels, and the demand for housing units will increase correspondingly. The increase in demand for housing during the construction phase will be moderated by the EMC policy of maximizing local hiring since current residents of the local study area will, for the most part, tend to already have their housing needs met. During the construction phase, most inmigration will be by construction workers who will stay in the local study area for a short time and will likely utilize rental, hotel/motel and similar temporary housing in lieu of moving their households. This demand will probably reduce vacancy rates and may cause the rental housing market to tighten, but it should not substantially affect the long-term housing market.

During the construction phase, the permanent EMC operations work force will be in its buildup stage. Even though the majority of the operations work force will be local, the remaining workforce (approximately 40 percent) will be nonlocal, and thus there will be new households migrating to the area. The new households will generate an increase in demand for permanent housing. Based on the capacity of local builders, and the relatively well developed manufactured housing industry, this increased demand should not create any long-term housing shortages.

Operation Phase - Throughout the period of mine and mill operation, the total number of local study area households will exceed the level of the without-Project forecasts. The increase in the number of households is a result of two effects. First, new families will inmigrate for employment purposes and create new households. And, second, the rate of household formation may increase due to improved economic conditions as young adults, who otherwise would not be able to afford it, form households separate from their families. The end result is that the demand for housing will increase over the without-Project level.

Minimum sales prices for single-family units during the operation phase are expected to be slightly higher than in the without-Project future. No long-term housing shortages are projected, and no production of speculative housing units is anticipated during this phase of the Project.

Project development will affect the timing of land conversion from undeveloped to developed uses, but will not substantially affect the total amount of land converted. With the Project, land is converted to developed uses at an accelerated pace throughout Project construction and operation. However, following Project closure, decreased residential and other development slows this conversion process.

Post-Operation Phase - If no planning for closure occurs, employment related outmigration after closure is expected to cause a decrease in housing demand, an increase in vacancy rates and, therefore, a slow down in the rate of increase of housing prices. Housing units made available by outmigrating households are likely to be purchased by outmigrating households are likely to be purchased by remaining local study area residents requiring replacement housing. Decreased demand for new housing units from remaining residents coupled with the demand slump associated with outmigrating Project-related population may lead to a 3 to 5 year slowdown in construction of primary residences. As discussed earlier, advanced planning on the part of local communities can moderate post-closure impacts.

4.2.10.6 Public Facilities and Services Analysis

This subsection presents without-Project and with-Project forecasts of public facilities and services for the local study area. The differences between the without-Project and with-Project forecasts represent the effects of the Project on these public facilities and services. The purpose of this analysis is to show the range of possible effects of the Project, not to forecast actual expenditures. The categories of public facilities and services which are considered in this analysis are listed in subsection 4.2.10.2.

Without Project Forecast - The level of demand for public facilities and services is determined by the population residing in the jurisdiction providing the service. The slow growth of population projected to occur in the local study area indicates that service requirements will also increase slowly. In addition, the local study area has a well developed system of public services such that, with few exceptions, there appears to be no immediate need for upgrading. The permanent residents of the area also view public facilities and services as being adequate (see Chapter 2, subsection 2.10.4.1). These factors, coupled with the fact that most new and existing housing units rely on private wells and septic tanks, should allow local jurisdictions to maintain current levels of basic public facilities and services without straining the system.

Even though requirements for public facilities and services should grow at a relatively moderate pace in the local study area, there will be some changes. The population growth which is expected to occur will result in increased operations and maintenance costs, even if per capita expenditure levels are held constant. In addition, several jurisdictions probably will require capital expenditures. Most of these expenditures will be in the general operations and general government categories.

Construction Phase - The public facilities and services impacts from the development of the Crandon Project for the construction and operations phases are treated jointly in the following section. However, one basic difference between the construction and operations work force should be pointed out. While the operations workers will be long term residents, the construction workers will be commuters and/or temporary residents living in rental housing. As a result, they will tend to demand less facilities and services.

Operation Phase - The impact resulting from development of the Project to the local study area's public facilities and services will vary among the communities. The three scenarios studied in the FOFC cover a wide range of conditions for individual jurisdictions. The sensitivity of an individual jurisdiction to a particular set of circumstances can be determined by examining all three scenarios.

An indepth discussion of the Project's impacts to each of these communities is provided in the FOFC and summarized below. For purposes of this discussion, the local jurisdictions can be combined into five categories:

1) Counties
2) Cities
3) Secondary service centers
4) Towns
5) School districts

Secondary service centers are unincorporated areas distinguished from other towns by their larger populations, particularly population concentrations in a single center within a town, and by a greater variety of available services made possible by a larger population.

The development of the Project will affect public facilities and services in two ways. First, assuming per capita expenditures are maintained at their current levels, the Project-related population will cause an increase in the total cost of providing facilities and services. The second potential effect of the Project could be to increase the level and/or quality of service (in particular education) demanded by local residents in those jurisdictions with taxing authority over the EMC property, thereby causing a rise in per capita expenditures. This type of effect has been reported in other areas experiencing industrial development (Ramana, 1968). This could occur as a result of the higher income levels of local residents derived from Project development and the increased revenues, in jurisdictions with taxing authority over the EMC property, such as the Crandon School District.

Table 4.2-24 summarizes the potential impact of the development of the Project for each type of jurisdiction and for each service category. In addition to increasing operation and maintenance expenditures over without-Project levels, Project development will probably accelerate the timing of capital expenditures and personnel additions, and in some cases, require additional small capital expenditures. Even in the case of the high impact scenario, no shortfall in capacity of schools, water and wastewater treatment, roads or other major infrastructure items was identified. Due to the fairly moderate increases in population growth resulting from Project development, no major adverse impacts are expected to occur.

Post-Operation Phase - The decrease in area population which is projected to occur during the first few years after closure of the mine/mill complex will result in a commensurate decline in the demand for most public services. A few services, however, may experience some increase in demand as a result of increased unemployment of area residents. Services most likely to experience increased demand include public health and social services. Some increase in police caseloads may also occur if unemployment and related effects of closure lead to increased stress for area residents (Hansen et al., 1981). However, as previously noted, proper planning by local officials can minimize adverse effects of mine closure.

TABLE 4.2-24

PUBLIC FACILITIES AND SERVICES

FACILITY/SERVICE	COUNTIES	CITIES AND SECONDARY SERVICE CENTERS	TOWNS	SCHOOL DISTRICTS
Police Protection	• Increase O&M[a] Expenditures • Accelerate Addition of Personnel	• Same as Counties	-	-
Fire Protection	-	• Increase O&M Expenditures • Accelerate Addition of Personnel	• Increase O&M Expenditures	-
Streets and Roads	• Increase O&M Expenditures	• Same as Counties	• Same as Counties	-
Water Supply	-	• Increase O&M Expenditures	-	-
Wastewater Treatments	-	• Increase O&M Expenditures	-	-
Solid Waste Disposal	-	• Increase O&M Expenditures	-	-
Library Services	-	• Increase O&M Expenditures	-	-
Recreation	• Increase O&M Expenditures	• Same as Counties	• Same as Counties	-
General Government	• Increase O&M Expenditures	• Increase O&M Expenditures • Accelerate Timing of Capital Expenditures • Require Additional Capital Expenditures • Increase Amount of Capital Expenditures	-	-

TABLE 4.2-24 (continued)

FACILITY/SERVICE	COUNTIES	CITIES AND SECONDARY SERVICE CENTERS	TOWN	SCHOOL DISTRICTS
Public Education	–	–	–	• Increase O&M Expenditures • Accelerate Addition of Personnel • Acclerate Timing and Increase Amount of Capital Expenditures
General Operations and Other Services	• Increase O&M Expenditures • Accelerate Timing and Increase Amount of Capital Expenditures • Require Some Additional Capital Expenditures	–	• Same as Counties	–
General Facilities and Services[b]	• Increase O&M Expenditures • Accelerate Addition of Personnel	• Same as Counties		

[a] O&M - Operation and Maintenance.
[b] Health facilities, public health and social services, and emergency medical services.

4.2.10.7 Transportation Analysis

The Project is expected to employ a sizeable work force, stimulate economic activity, produce a substantial amount of material which will be shipped out of the local study area for further refining and receive materials and supplies by both rail and highway. Such changes in conditions could potentially affect the transportation systems serving the local study area, including highways, and air and rail services.

Without Project Forecast - Growth in traffic volume is a function of growth in population and employment in the areas linked by the road segment. Based on the demographic and economic projections, growth in traffic volume should be fairly moderate. The segment of US 8 between Rhinelander and Monico, however, is expected to increase by a greater amount than the remainder of the roadways. Likewise, passenger enplanements through the Rhinelander/Land O'Lakes Airport (the only airport in the local study area that provides regularly scheduled commercial service) are expected to grow at a relatively moderate pace.

EMC expects to normally utilize the Soo Line Railroad for its shipments of concentrates and supplies. Despite recent railroad abandonments in the area, it appears that the Soo Line will continue operating throughout the forecast period. Substantial improvements have been made to the line in recent years, and no further major physical improvements are anticipated at this time. Currently, operations over the line consist of two trains daily, one northbound and one southbound, carrying mixed carload and containerized cargo traffic.

Construction Phase - As previously noted, increases in traffic volume are generally a result of growth in employment and population. Since population growth due to the Project is expected to be moderate, no widespread traffic increases are projected. Most of the Project's impact will be due to commuting and truck delivery to the mine/mill site during both operation and construction. Thus, the Project's impacts are expected to be localized.

The Project will increase traffic volume along major and minor roadways which provide relatively direct pathways between employee residential locations and the Project site. See subsection 1.3.3.4 for a description of the amount and timing of traffic during construction. Roadways with especially notable increases in traffic include US 8 between Rhinelander and Crandon, Langlade County Roads A, T, and K, and SH 55 between Crandon and Langlade County Road T. Potential roadway congestion may occur during the latter part of the construction period within the City of Crandon due to the discontinuous alignment of the through east-west and north-south highways. Any congestion is likely to be brief and concentrated before and after primary shift changes. Roadway congestion may also occur throughout the construction period along SH 55 at the intersection with the Project's main access road, concentrated primarily during shift changes. Crandon Project truck traffic should not pose major problems on any roadway. Some difficulties could be experienced on SH 55 at the access road if truck deliveries occur at times when work force shifts change. Problems of congestion at the intersection of SH 55 and the access road will likely be minimized if adequate provision is made for through traffic lanes, separated space for turning traffic, and traffic control during shift change periods. Highway improvements required due to Project development will most likely be limited to intersection improvements involving the addition of turning lanes and installation of traffic controls. Other than the proposed access road from SH 55 to the Project, no major highway modifications, such as road widening or construction of urban area bypasses, are projected to be needed as a result of Project development.

The Project will increase annual passenger enplanements through the Rhinelander/Oneida County Airport throughout the construction phase. The increases are not expected to create operational problems at the air facility, unless the additional traffic reinforces any existing pattern of extreme seasonal variation.

The Project's effects on rail traffic will occur primarily during the operation phase.

Operation Phase - The effect of the Project on traffic volumes during the operations phase will be similar to the construction period. The Project will increase traffic volume on the roadways which provide direct routes for EMC employees. The same roadways identified in the preceding subsection will be affected during the operations phase. The amount and timing of operations phase traffic is described in subsection 1.4.7. It should be noted that, with advanced planning, potential problems can be avoided. As during the construction period, no major highway modifications will be required.

The Project will modestly increase annual passenger enplanements through the Rhinelander/Land O' Lakes Airport throughout the operations phase. However, no operational problems should result from this growth.

The Project will probably not require any new, additional train movements over the Soo Line's Argonne mainline, which will be used to transport EMC materials to and from the Project site. Average train lengths operating over the Argonne line will be increased by varying degrees, depending on the mine/mill complex output level and the frequency in the final pickup and delivery schedule agreed to by EMC and the Soo Line. Longer trains will be concentrated on the Argonne lines south from the Crandon site, with the potential for creating minor increases in motorist delays at roadway crossings with substantial vehicular traffic volumes and in the Langlade-White Lake Village area. Motorist safety at railroad crossings is not likely to be substantially affected due to ongoing Wisconsin Department of Transportation programs to upgrade traffic control devices at major roadway-railroad intersections. The additional activity generated by the Project will increase the economic viability of the railroad and increase the likelihood that the Northwoods area will continue to receive rail service in future years.

Post-Operation Phase - Once the mine/mill closure has occurred and site reclamation activities have been completed, transportation requirements will depend primarily on the levels of population and economic activity in the local study area. Thus, road and rail traffic and air passenger enplanements will likely return to levels close to the without-Project forecast values within a few years after closure. As previously noted, advance planning could alter post-closure effects.

4.2.10.8 Fiscal Analysis

The Project will be a substantial generator of various taxes, including income and sales taxes, to the State of Wisconsin. Perhaps more importantly, the Project will be a substantial addition to the tax base in Forest County, the Crandon School District, and the Towns of Lincoln and Nashville.

The proposed Project would also create socioeconomic changes which will have some impact on local governmental finances. This results largely because the State is a major revenue source for most local governments, and because State payments to localities are distributed according to some measure of need. These specific needs are affected by construction and operation of the Project.

The general property tax is the most important local source of revenue to local jurisdictions, although a variety of fees, fines, charges, special assessments, and miscellaneous revenues contribute to total local tax revenues. Aside from property taxes, this latter set of revenue sources is referred to as "user fees."

Although Wisconsin limits the revenue alternatives which may be imposed by localities, the State allocates most of its own revenues to local governments. In 1980 the State collected approximately $3.3 billion in taxes and sent $2.1 billion of that amount (over 63 percent) to its local governments, including school districts. These State payments may be used by the localities to increase their spending levels and/or to reduce their property tax levies or other locally-imposed revenues.

Heavy dependence of local governments on State revenues, and the equally heavy obligation of the State to provide them, is one of the most important characteristics of public finance in the State. Equally important, and especially relevant to the local fiscal impacts, is the manner in which State payments are distributed. Virtually all of the State's payments to local governments are based upon relative need, and they all attempt to moderate or "equalize" the fiscal disparities among different local governments. State transfer payments to local governments, distributed according to need, are the dominant aspect of Wisconsin's State fiscal policy. A variety of extremely complicated formulas have evolved "to gauge local fiscal equity," and to target State payments to relieve local fiscal needs or reduce inequities.

The local study area contains over fifty jurisdictions. A forecast of with- and without-Project conditions is made within the FOFC published in 1983 for those jurisdictions which will experience significant impact. It is assumed that the State tax sharing arrangements will remain as provided in State law as of November, 1982.

Four of the major types of State aids available to local communities are Shared Revenues, Wisconsin State Property Tax Relief (WSPTR), State Vocational and Technical Adult Education (VTAE) aids, and School Aids. All of these aids operate on the concept discussed above, namely that of equalizing fiscal disparities among local governments. State aid for highways is another very important revenue source for municipalities and counties.

The largest component of the local property tax is for school purposes. The Crandon Project lies wholly within the Crandon School District, which includes both the Towns of Lincoln and Nashville. The State of Wisconsin guarantees the school districts a specific level of property value per pupil through its School Aids formula. The difference between the guaranteed value and the actual value is compensated by the State through equalization aids. In 1981-82, for example, the property value per pupil for the Crandon School District was only 54.8 percent of the value guaranteed by the State. Therefore, the district's tax levy was required to cover only 54.8 percent of the district's net costs, with State equalization aids paying the remaining 45.2 percent of costs.

Without-Project Forecast -- It is expected that the local area will not experience additional sources of revenue other than those now known and that the per capita expenditure level, if the Project does not come into being, will remain about the same. It is unlikely that fiscal conditions, including property tax rates, will change dramatically.

The full value property valuation for those jurisdictions which would be most directly affected by mining are as follows: Forest County's full value property valuation for 1981 was $235 million; the Towns of Nashville and Lincoln in which mining would occur were $35 million and $32 million, respectively.

The Project is located entirely within the Crandon School District which has a 1981 property valuation of approximately $135 million. The future without-Project forecast suggests that property valuation would basically increase with inflation. Property now held by EMC would probably continue to be classed as at present and would result in minor contributions to the County and School District. School aids, which now constitute 45 percent of Crandon School District funds, probably would not change drastically from their present level.

If the Project is not constructed, properties held by EMC in Nashville and Lincoln would continue to contribute moderately to the property valuation of the Towns of Nashville and Lincoln.

With-Project Forecast - The filing of permit applications by EMC resulted in Mining Investment and Local Impact Fund payments under ss. 70.395 Wisconsin Statutes. Accordingly, the two municipalities where the mine/mill complex would be located (Lincoln and Nashville) and the two Native American communities (Sokaogon Chippewa and Forest County Potawatomi) began receiving $100,000 annually until a final decision is made on permit applications or for a maximum of 4 years.

Upon start of construction EMC would fund an annual grant program through prepayment of net proceeds taxes. The municipalities (Lincoln and Nashville), and the Native American communities (Sokaogon Chippewa and Forest County Potawatomi) would receive annual payments of

$100,000 each. Upon start of operations, Forest County would join the recipients eligible for an annual payment of $100,000 and would receive an annual payment of 20 percent of the Project's net proceeds taxes up to a maximum of $250,000.

These impact fund payments would be indexed to the GNP price deflator after 1983, and would continue throughout the operation of the mine as "first dollar" payments from net proceeds tax revenues. In addition, discretionary funds from the State would also be available to the communities.

The 1985 Legislative session added Forest County to the recipients of construction period payments funded by EMC through prepayment of net proceeds taxes. The County must demonstrate the need to the Mining Investment and Local Impact Fund Board before receiving a grant. The County grant can be as much as $300,000 per year (not inflation adjusted). The maximum is reduced by the amount of increased property tax paid by EMC on EMC property added to the tax base as a result of construction under the mining permit.

EMC's Crandon Project, if constructed, would represent a large addition to the Forest County tax base. At this point in time, the Project's exact assessed valuation cannot be established because the property does not exist. The actual assessment will be completed by the Wisconsin Department of Revenue in the manner specified by the statutes once the property actually exists. A surrogate value of $275 million was calculated to allow the local property tax analysis (Klauser, 1985). Conservatively, Project development could result in more than doubling the County's taxable property value of $235 million (1981 valuation). Property tax revenues would flow from the Project to Forest County, the Crandon School District, and the Towns of Nashville and Lincoln, as well as the Vocational-Technical School District, the State of Wisconsin and any special purpose district containing the Project.

The County's tax rate could be lowered as a result of the increase in County's full value tax base. The more than doubling of full value assessment will generate more than sufficient funds to cover any realistic increase in the cost of County services due to the Project and still be enough to allow for a reduction in the tax rate.

Most of the facility will be constructed in the Town of Lincoln, which had a 1981 assessed value of approximately $32 million. If constructed, the EMC plant would represent at least 80 percent of the Town property value. Property constructed within the Town of Nashville could represent up to 25 percent of the total property value. For both towns this should allow improvements in service and facilities with the potential for lowering the current Town tax levy even without considering the effect of the $100,000 first dollar payment.

Construction of the Project would likely more than double the Crandon School District's 1981 property valuation of approximately $135 million. School enrollment would also increase as a result of the Project but at a nominal rate when compared to the increase in value.

Total enrollment in the Crandon School District has been decreasing since 1976 and is forecast to continue declining. In the 1984-85 school year enrollment stood at 986 pupils about 82 percent of the District's capacity. The low impact scenario increase in enrollment was projected to range from 116 to 46 students during the Project's operations phase. Actual enrollment increase is likely to be somewhat less because of the reductions in the planned employment at the Project from the level used in the low impact scenario.

Because EMC's portion of the school taxes would be much greater than the portion of enrollment (and thus costs) due to the Project, the tax burden on other property tax payers could be reduced. If current per student spending rates are maintained, the Project's value would drive school property tax rate's down by about 40 percent.

The potential reduction in school property taxes takes into consideration the probable loss of the Crandon School District's school equalization aids. These aids, which totaled $907,361 in 1983-84, probably would no longer be received as a result of the District's much higher valuation. The property taxes for school purposes paid by EMC will far outweigh the state equalization aids and the District will become almost completely self-reliant for funding.

Actual assessed valuation (as for all industrial properties) will vary during the Project life, based upon review and attendant procedures and interpretations of the Department of Revenue assessor. EMC's share of school, county and township taxes, accordingly could be different than those tax contributions outlined above.

Whereas property taxes and payments through the Mining Investment and Local Impact Fund Board are dominant positive factors to mitigate costs created by mining to local government, there are at least four additional state tax credit programs: "Homestead," Farm Land Preservation, Wisconsin State Property Tax Relief, and standard property tax credit on income tax which would also reduce property tax impact.

Population changes attributable to the Project may also have a fiscal impact to some communities which do not have taxing authority over the EMC property. The actual dollar effects in these municipalities would be moderate. While inmigrant population will probably increase public facilities and services costs in these jurisdictions which do not share directly in EMC property taxes, the positive benefits of state aids continue to apply. The inmigrant population also will contribute to the tax base. When combined, the overall effects of on these jurisdictions will be, for the most part, neutral to positive. Also, increases in governmental costs which are directly attributable to mining may be accommodated by applying for and receiving grants from the Mining Investment and Local Impact Fund Board.

Post Operations Phase -- Due to the system of State aid formulation, the closure of the mine should not have serious, if any, adverse fiscal impacts. In addition, sound financial and land use planning by local officials, with the assistance of state mining impact fund revenue, can direct and moderate fiscal effects after Project closure.

4.2.10.9 Sociocultural Analysis

The effects of the Crandon Project on the sociocultural conditions of the local study area are described in terms of four sociocultural factors: reproduction, sustenance, order and safety, and socialization.

Without Project Forecast - Given the level and the type of changes forecasted for the six socioeconomic factors examined in the preceding sections, it is unlikely that the area will experience major changes in its sociocultural environment. There are, however, a few trends which could affect some sociocultural conditions in the area.

One of these trends is the historical pattern of increase in the elderly population of the area due to the inmigration of retirement aged population. Should this trend continue or accelerate, the area's reproductive capability could be affected. Birth rates will decrease, while morbidity and mortality will rise. If economic conditions worsen, such that large numbers of the working age people outmigrate, this effect would be accentuated. A more elderly population would also affect the sustenance of the local area since most senior citizens are supported by transfer payments and thus income levels could stagnate.

Results of the survey of permanent residents indicated a general lack of satisfaction with local employment opportunities (RPC, 1982b). Without Project development, this is not likely to change. The major sustenance base of the area probably will continue to be those industries and employers who comprised the major sectors of the economy in the baseline year of the study. These industries are unlikely to expand sufficiently to change the local attitudes surrounding employment opportunites. Growth in per capita personal income, as well as employment opportunities, probably will be relatively moderate.

The rural nature of the local study area is not anticipated to change. Order and safety characteristics within the local study area probably will follow trends similar to those within the State of Wisconsin. Participation in community and religious activities may increase due to the aging of the local society. The process of socialization should undergo little change.

Construction Phase - The sociocultural impact of the Project's construction and operation are discussed jointly in the following subsection. However, as with the other elements of the study, one major difference between these two time periods which should be pointed out will be the timing of the buildup of EMC manpower and the temporary nature of the construction workers. Academic research has shown that feelings of a local population regarding project development are generally favorable during predevelopment and early construction. However, as construction peaks, attitudes become less favorable and, subsequently, return to their former favorable state as the project progresses (Jones and Murdock, 1978; Murdock and Leistritz, 1979; Murdock and Schriner, 1979).

During construction, some forms of social disorder may increase. The exact nature of this potential problem is difficult to predict.

Operations Phase - Even though inmigration of Project-related workers is expected to be quite small, the age structure of the area may be younger as a result of those workers who do inmigrate. The end result would be higher birth rates and lower morbidity and mortality rates. However, due to the size of the Project relative to the overall local study area population, these changes should not be noticeable.

Perhaps the greatest effect of the Project will be in the area of sustenance. The Project will provide a substantial number of direct and indirect jobs to the local economy, the majority of which will be filled by local residents. Project development will increase the level of income. In addition to providing high paying jobs, the Project will offer the local residents the opportunity for learning new skills from EMC's training programs. Thus, the benefits to be derived from mining employment may extend beyond the construction and operation periods since employees will gain skills and experience transferable to other operations once the Project closes.

In the permanent residents survey, respondents felt that those who were most likely to benefit from the Project were the unemployed and local merchants; whereas the elderly would be among those potentially harmed by the Project. Harmful effects to people on fixed incomes, especially the elderly, would occur if the cost of living in the local area increased substantially (Murdock and Leistritz, 1979). Since no long-term housing shortages are expected, housing prices should increase at a relatively moderate pace over the long run, and large increases in the cost of living for the elderly should be avoided.

Because of the size of the Project relative to the population base, order and safety should not be affected in a major way. The greatest impact on order and safety probably will occur in the area of traffic safety. As discussed in subsection 4.2.10.7, the Project will increase traffic volumes along roadways which provide direct pathways between employee residential locations and the Project site. These impacts may require minor highway modifications to the area highways.

With regard to the socialization process, the changes brought about due to Project development may lead to increased expectations with respect to school systems (Ramana, 1968). This effect is most likely to occur in jurisdictions with taxing authority over the EMC property. The result would be a higher level of expenditure on education and a higher quality and quantity of educational programs.

The types of people who inmigrate to the local area to take professional jobs at the Project probably will be of higher than average income level. As a result, their expectations may be somewhat different than those of the local population. These differences could result in some competition between inmigrants and local citizens.

The rural nature of the study area is not likely to change as a result of the Project. Even though some changes in the social structure may result from the transition to an economy which is based, in part, on mining, the other basic sectors, such as forestry and wood products, hospitality, recreation and tourism, will maintain a high level of economic dominance. Based on the favorable reactions of respondents to the survey of permanent residents with regards to economic development, conflicts are expected to be minimal.

Post-Operation Phase - If no planning for closure occurs,, employment and per capita personal income may decrease temporarily after closure. Outmigration may ensue, since the unemployment rate probably will increase. Housing vacancy rates may also increase temporarily after closure of the facility.

During Project closure, local study area residents may experience resumed predevelopment dissatisfaction due to lack of employment opportunities. Without proper planning, economic conditions in the post-operation period may cause increased anxiety and stress. As discussed in the previous sections, planning on the part of local officials and business leaders could minimize post-closure adverse impacts.

4.2.10.10 Native American Communities Analysis

Two Native American communities are located within the local study area--the Forest County Potawatomi community and the Mole Lake Sokaogon Chippewa community. An additional Native American Community (the Menominee) is located just outside the designated local study area. It is important to examine possible effects of the Project on these Native American communities because they represent an important subculture in the local study area. Development of the Project may affect the socioeconomic characteristics of the communities differently than the rest of the local study area.

Without Project Forecast - Populations change as a result of the interplay of three factors: births, deaths, and migration. It is unlikely that the birth rates or death rates in the Native American communities will show substantial changes during the study period. Thus, the potential for natural population increase exists in the communities due to the large percentage of population in the young child-bearing ages. In addition, migration of Native Americans both on and off the reservation probably will be a very important determinant of population levels in the future.

It is quite possible that the labor force on the reservations will continue growing at least as fast as employment opportunities, thus increasing or maintaining the already high unemployment on the reservations. Economic development on the reservations is hindered by several factors, including the economic conditions in the local study area, lack of capital, lack of entrepreneurial expertise, and an apparent preference not to develop natural resources.

Since the economic outlook for the local study area is not one of substantial growth, Native Americans' chances to find employment or start businesses is not expected to improve substantially. As a result, economic development will be difficult to achieve. The wild-rice harvesting, the Great Northern Bluegrass Festival, and the Bingo games probably will continue to provide income and employment for Mole Lake Sokaogon Chippewa residents, but they will provide few jobs and are seasonal in nature.

The reservations are greatly dependent on funds from outside the reservation, especially the Bureau of Indian Affairs, for development capital. It is assumed, at least under the present administration, that Federal support for economic development will be harder to obtain. This could cut the availability of jobs on the reservations, since many of the jobs are Federally funded.

The housing stock on the reservations is limited (see Chapter 2, subsection 2.10.7.4). The communities' ability to replace and expand the existing stock depends on their ability to obtain outside funding and to succeed in economic development. It is very likely that mobile homes may become a primary source of housing if funding continues to be difficult to obtain.

Nearby communities furnish necessary public facilities and services such as law enforcement, fire protection, education, and solid waste disposal. Payment for these services has been obtained almost exclusively from transfer payments.

There are limitations on the Native American communities capability to generate own-source fiscal revenue. While they do have the power to tax, there is little business activity or private property that would yield revenue. The future of the Native American communities' fiscal situation depends largely on the course of national politics. The Bureau of Indian Affairs provides Federal funds to support services which, in other communities, are typically supported by property taxes and user fees. Changes in the nation's philosophy regarding Federal assistance could greatly affect the Native American communities.

Construction Phase - The presence of the Project may affect the size of the population on the reservations. The Project is not expected to alter birth rates, morbidity rates, or mortality rates on the reservations in the near future. However, return migration of off-reservation Native Americans may occur due to the Project. Even the anticipation of the Project may attract some off-reservation Native Americans back in hope of finding jobs and better conditions on the reservations than existed in the past. In addition, some of the present reservation residents who would otherwise outmigrate may stay on the reservation because of the Project.

The construction of the Project should open opportunities for Native Americans to find employment and raise their per capita personal income. The exact number of project-related jobs filled by Native Americans will depend on many factors including the number of job openings, skill qualifications, and the competition in the labor force. EMC plans to maximize local hiring, including Native Americans, within the limits allowed by law and by the necessary skill requirements.

EMC will also develop training programs for new hires. Therefore, the Project should generate economic opportunity during both the construction and operation phases.

New jobs filled by Native Americans, during both construction and operation, will be filled by those willing to work in a nontraditional culture. Therefore, Native Americans with previous related work experience will probably have the best opportunity of obtaining employment.

Operations Phase - The effects of the Project during the operations phase are very similar to those during construction. As in the construction phase, development of the Project may cause return migration to the reservation in response to increased employment opportunities. This would lead to increased demand for facilities, services, and housing. Along with this increased demand will be the potential for realizing an economic gain from the increased economic activity and net proceeds tax revenues.

Employment on the reservation may increase not only from direct Project employment and indirect Project-related jobs, but also from secondary activity, if some of the net proceeds tax payments are invested in tribal enterprises. Proceeds from new enterprises could, in turn, be reinvested in other enterprises or in expansion of existing enterprises, as in the case of the Great Northern Blue Grass Festival.

Factors hindering economic development on the reservations such as the lack of capital and entrepreneurial experience listed in the forecast of without-Project conditions, may change for the better due to the Crandon Project. Employment, business activity, and personal income in the local study area probably will increase due to the Project. The increases may stimulate demand in the local study area, such that expansion of tribal activities becomes economically feasible.

Demand for housing conditions on the reservation is expected to increase with the onset of the Project because of return migration to the reservations. Whether this becomes a problem depends on how many Native Americans return to the reservations and on how the potential increased revenues from the net proceeds tax are utilized.

The Project should provide an opportunity for the Native American communities to become more self-sufficient with regard to facilities and services. Part of the funds from the net proceeds tax payments could be used for expansion or improvement of public facilties and services.

Post-Operation Phase - If no planning for closure occurs, closure of the mine/mill complex likely will result in some decreases in employment and income for the Native American communities. Project-related jobs will be terminated, and unemployment levels can be expected to increase. Decreased employment opportunities resulting from Project closure can be expected to result in higher levels of migration from the reservations. A major factor which will determine the longer run outlook for the Native American communities, however, is the use made of any net proceeds tax payments which are received during the operations period. If these funds are used effectively to establish viable economic enterprises, improve housing and public services, and enhance the skills of the labor force, the long-term outlook could be greatly enhanced.

Menominee Reservation - The Menominee Reservation is located just south of the local study area. The community is relatively large (approximately 5,000 population) and well organized. Even though the community is located outside the local study area, it is anticipated that some interest may exist among the Menominees in Project employment opportunities during both its construction and operations phases. The Reservation is eligible for discretionary payments in the event it does sustain any impacts. In addition, it would stand to gain from any employment for reservation residents resulting from the Project.

4.2.10.11 Analysis of State Economic and Fiscal Conditions

Even though most of the effects of the Crandon Project will take place within the local study area, Project development will also affect conditions in other areas within the State of Wisconsin. The construction and operation of the Project will generate secondary employment throughout the State. The increase in employment opportunities may have an upwards effect on population levels. Project development will also result in positive effects on statewide income.

The Project will also lead to an increase in State tax revenue collections during both construction and operation. EMC activity should generate tax revenues to the State through sales tax, income tax, net proceeds tax, and other less substantial sources of revenue (such as tobacco and motor fuels tax).

4.2.10.12 Conclusions

The effects of the Crandon Project on the various study elements are summarized below:

1) Development of the Project will benefit local residents by increasing employment and income in the local study area. Due to the relative size of the Project work force and the availability of labor, no substantial negative effects on other local industries, such as long-term labor shortage, should take place.

2) The demographic effects of the Project will probably be relatively limited. EMC's hiring policy and the well developed local labor force should prevent large amounts of inmigration.

3) Based on local builder capacity and the relatively limited amount of demographic change, no long term housing shortages are expected. Land use characteristics should not undergo any major changes as a result of the Project.

4) The overall effect of the Project on the area's public facilities and services will be to increase operation and maintenance expenditures, accelerate the timing of capital expansion, and in some cases, require additional small capital expansions.

5) Project development will cause brief peaks in traffic volumes along the roadways which serve as routes for the mine/mill employees to commute to work. Minor improvements in roadways should minimize impediments to traffic flow and traffic safety.

6) The overall fiscal effects of the Project should be positive. Project development will generate additional tax revenues to both the local study area and the State of Wisconsin. The increase in tax revenues from property, sales, and other miscellaneous taxes, should result in a positive net fiscal effect, even without consideration of the net proceeds tax.

7) The Project is not expected to have a substantial effect on the area's sociocultural characteristics. The rural nature of the local study area will not change due to Project development.

8) The Project represents a potential source of benefit to the Native American communities. The increased employment, economic activity, and tax revenues generated from project development, could benefit the Forest County Potawatomi and the Mole Lake Sokaogon Chippewa communities.

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4.3 POST-OPERATION

Generally, the environmental impacts associated with the mine/mill facility after closure are largely dependent upon whether alternative uses are made of the facilities. In addition, changes that will occur during construction and operation in the Project area will affect the existing environmental baseline conditions as discussed in Sections 4.1 and 4.2. Even though some long-term changes in the environmental and socioeconomic conditions will occur in the environmental study area as a result of the Project and from future non-project related activities, the area developed specifically for Project facilities, absent a need for the facilities at closure, will be returned to as natural a state as reasonably practicable. Detailed information on closure and reclamation of the Project is presented in the Reclamation Plan.

4.3.1 Meteorology and Air Quality

Following the reclamation phase of the Project, any Project related air quality impacts will be eliminated. The local air flow pattern in the MWDF area will be altered slightly because of the change in height of the terrain. This change, however, is not expected to affect local meteorological conditions.

The closure (reclamation) phase activities are estimated to have very minor emissions (see the December 1985 Revised Air Quality Permit Application Report). The major air contaminant expected to be emitted during reclamation of the Project facilities is TSP (Table 4.3-1). Most of the TSP will be from hauling and grading of soil for

TABLE 4.3-1

SCHEDULE ASSOCIATED WITH PROJECT ACTIVITIES DURING CLOSURE (RECLAMATION) PHASE AND THE ESTIMATED TSP AIR EMISSIONS FROM THE PROPOSED SOURCES (st/yr)

Project Activities	CLOSURE 1	2	3	4
Reclamation Phase				
1. Remove Surface Facilities and Reclaim Mine/Mill Site		41.8	41.8	41.8
2. Reclaim Tailing Pond T2				36.0
3. Reclaim Tailing Pond T4			66.2[a]	66.2[a]
4. Reclaim Reclaim Pond - Cells A and B	41.8			
5. Reclaim Construction Support Area			30.0	
6. Final Site Reclamation		18.0	18.0	18.0
a. Reclaim Railroad Spur			41.8	
b. Reclaim Access Road				30.2
7. Develop Borrow Area		48.0		
8. Reclaim Borrow Area				48.0
9. Mobile Sources	0.13	*[b]	*	*
TOTAL	41.9	107.9	197.9	240.3

[a] Includes installation of reclamation cap seal (liner) and hauling of bentonite to MWDF (see Tables 2.5 and 4.1, and Appendix B in the December 1985 Revised Air Quality Permit Application Report).

[b] *-Indicates previous annual estimate was used for this year.

final contouring and cover of the mine/mill and MWDF sites. The total estimated TSP emission rates (Table 4.3-1) are approximately the same as those provided for the maximum year (Table 4.2-4). Therefore, the reclamation phase estimated TSP emissions will not greatly alter ambient air quality (see Table 4.2-5).

4.3.2 Geology and Topography

At the end of the operation phase of the Project, the site will be restored over a 4-year period.

Long-term impacts to the site geology and topography will be minimized by measures to be implemented in the closure plan. Backfilling of remaining underground mined areas will prevent surface subsidence over the site area. Shafts will be plugged with concrete to prevent caving of abandoned openings and differential settlement of the surface landforms over the mine that would result in undesirable long-term impacts.

Removal of above-ground structures in the mine/mill site will be followed by restoration to its original appearance if no continuing use is found for the facilities. Regrading of the site will include salvaging topsoil, maintaining existing drainage patterns, and seeding new embankments to provide erosion control. The creation of the new landforms and the reshaping of the intrinsic landscape will closely resemble the existing ground surface topography and will result in minimal long-term impacts.

The Reclamation Plan (see Section D of the Mining Permit Application) for the waste disposal facilities includes landscaping of the topcover to resemble intrinsic landforms, establishing drainage patterns, and revegetation for erosion control. The reclaimed waste disposal area will have a maximum height above the final tailings surfaces of approximately 6 m (20 feet). This new landform is a long-term change to the site area topography but landscaping techniques will minimize the visual effect. Physical impacts will be minimal because of new grades, drainage patterns, and vegetation that will be similar to plant communities on existing landforms.

4.3.3 Ground Water

The two primary influences assessed for the post-operation phase are the time for ground water potentiometric surface recovery and the long-term influence of MWDF seepage on ground water quality. Both assessments were conducted by continuation and extrapolation of methodologies previously described for the construction and operation phases.

Immediately after mine closure the potentiometric surface in the main aquifer will begin to recover. This recovery will continue until the ground water potentiometric surface has returned to its preconstruction level. At this time the effects caused by lowering of the potentiometric surface on local users of ground water will no longer exist.

4.3.3.1 Ground Water Hydraulics

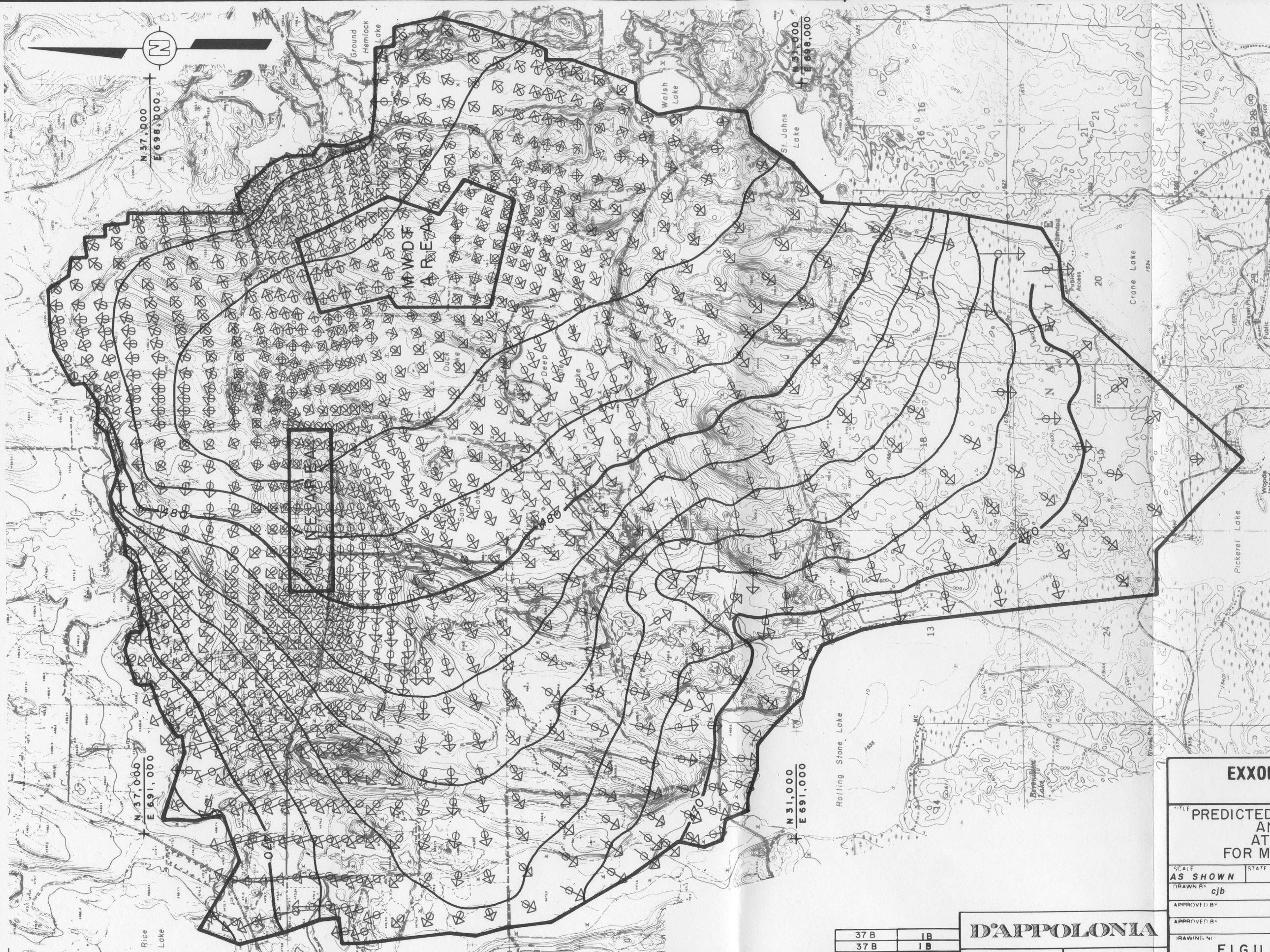
The recovery of the potentiometric surface after mining and any long-term influence of MWDF seepage will be governed by the hydrogeologic conditions and flow mechanisms discussed in subsection 4.1.3.1. The recharge for potentiometric surface recovery will occur primarily from precipitation infiltration. As the ground water returns to its preconstruction condition, ground water flow will resume in the directions observed prior to construction.

The horizontal two-dimensional planar model discussed in Appendix 4.1A was used to analyze the ground water levels through Year 60, or approximately 28 years after cessation of operation. At approximately Year 60, the potentiometric surface will have returned to near the preconstruction level (see Appendix 4.1A). Figure 4.3-1 presents the estimated potentiometric surface at Year 60 for the middle recharge mine inflow case.

4.3.3.2 Ground Water Quality

As the tailing ponds at the MWDF are reclaimed during the operation phase, the seepage rates will first increase then decrease to a steady-state rate as shown in Table 4.3-2. The increase will be caused by the accumulation of water in the underdrain from tailings leachate after cessation of underdrain pumping. A slight increase in head from the accumulated water in the underdrain will cause an increase in seepage from the pond. The continued pumping of the underdrain layers of the earlier tailing ponds during the operations phase will reduce the potential increase in seepage rate to a negligible amount. The subsequent reduction of the seepage rate will occur as the accumulated tailing water is dissipated. The steady-state seepage rate reflects a balance between precipitation infiltration through the reclamation cap and outflow through the liner at the bottom of the ponds.

To assess the influence of continued MWDF tailing pond seepage, the one-dimensional and two-dimensional models were used in the calculations for the middle recharge case. Analyses were continued until an approximate steady-state ground water condition was achieved after approximately 8,800 years. In the analysis interim results were also determined at 600 years and 4,800 years. Movements of the chemical



SCALE

0 1000 2000 meters

NOTE:

LENGTH OF VECTOR IS PROPORTIONAL TO THE MAGNITUDE OF FLOW. EACH cm IS APPROXIMATELY EQUAL TO 787.4 m^3/y PER HORIZONTAL UNIT WIDTH IN METERS.

LEGEND

470 — PREDICTED POTENTIOMETRIC SURFACE IN METERS ABOVE MSL

PREDICTED FLOW VECTOR

37B	1B
37B	1B
100% BLUE	50% BLACK

D'APPOLONIA

PROJ NO 846498 DWG NO B55

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE PREDICTED POTENTIOMETRIC SURFACE AND FLOW VECTORS AT PROJECT YEAR 60 FOR MIDDLE RECHARGE CASE

SCALE AS SHOWN	STATE		COUNTY	
DRAWN BY cjb	DATE 10-10-84	CHECKED BY MMR		DATE 12/10/85
APPROVED BY	DATE	APPROVED BY SHD		DATE 12/10/85
APPROVED BY	DATE	EXXON		DATE
DRAWING NO FIGURE 4.3-1			SHEET OF	REVISION NO

TABLE 4.3-2

PROJECTED SEEPAGE RATE OF MWDF[a,b,c]

POND NO.	SURFACE AREA		OPERATION SEEPAGE RATE[d]				MAXIMUM POST-OPERATION SEEPAGE RATE[d]				POST-OPERATION STEADY-STATE CONDITION SEEPAGE RATE[d]			
			POND		PER UNIT AREA		POND		PER UNIT AREA		POND		PER UNIT AREA	
	ha	acre	m^3/s	gpm	mm/y	in/y	m^3/s	gpm	mm/y	in/y	m^3/s	gpm	mm/y	in/y
T1	33.08	81.7	0.00018	2.9	17.3	0.68	0.00018	2.9	17.3	0.68	0.000018	0.29	1.68	0.066
T2	43.86	108.4	0.00024	3.8	17.3	0.68	0.00024	3.8	17.3	0.68	0.000023	0.37	1.68	0.066
T3	40.29	99.6	0.00022	3.5	17.3	0.68	0.00022	3.5	17.3	0.68	0.000021	0.34	1.68	0.066
T4	39.98	98.8	0.00022	3.5	17.3	0.68	0.00041	6.5	32.3	1.27	0.000021	0.34	1.68	0.066
TOTAL	157.21	388.5	e	-	-	-	-	-	-	-	0.000083	1.33	1.68	0.066

[a]Data in this table follow the modeling results presented in Appendix 4.1A. The Project plan as presented in Chapter 1 includes smaller tailing ponds which would have reduced seepage (per unit area seepage rates remain the same).

[b]Source: Exxon Minerals Company (1984b).

[c]Refer to Appendix 4.1A, Figure A-2 for location of ponds and Appendix 4.1A, Figure A-3b for seepage rate distribution.

[d]Refer to Appendix 4.1A, Figure A-3b for period of each rate.

[e]Operational seepage rates are not cumulative because of tailing ponds operation schedule (Appendix 4.1A, Figure A-3b).

constituents with a retardation of 1.0 were analyzed although movement of most of the constituents will be far less with their greater retardation factors (Tables 4.3-3 and 4.3-4).

The glacial soil materials that form the overburden, including the main ground water aquifer, have been preconsolidated by the pressure and movement associated with the glaciers' occurrence. Because of this preconsolidation the soil materials should not undergo further compression and consolidation. Therefore, removal of water from them should not result in any measurable subsidence of the land surface.

The exposure of the glacial aquifer soil materials to partially unsaturated conditions during mine operations will be relatively short. Dewatering during the operation phase will expose the aquifer soil materials to partially unsaturated conditions for approximately 32 years; however, the water level in the aquifer is predicted to recover about 90 percent of the drawdown in approximately 6 years. Reduction and oxidation processes in geologic materials generally require hundreds or thousands of years to effect measurable changes.

After closure of the mine, the ground water flow regime will return to its approximate premining condition (Prickett & Associates, 1984). The premining bedrock-overburden ground water flow regime does not exhibit strong gradients within the mine area and mining operations

TABLE 4.3-3

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]Source: D'Appolonia (1982). 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.

TABLE 4.3-4

REPRESENTATIVE RETARDATION FACTORS (R_d)
FOR THE GLACIAL DRIFT

Parameter	R_d[a]
Filterable residue (TDS)	1
Sulfate	1
Arsenic	111
Barium	BD[d]
Cadmium	113
Chromium	BD
Copper	32
Iron	>14
Lead	>14
Manganese	2
Mercury	BD
Selenium	>14
Silver	>14
Zinc	>14

[a]From D'Appolonia (1982) for projected tailing seepage pH of 7 to 8, extrapolated from pH = 6 and 9 attenuation data.

[b]R_d values reported as "BD" represent soluble metal concentrations which were below the detection limit before the tailings leachate was allowed to react with the glacial drift or which were too low to allow the determination of changes in concentration as a result of the interaction of the tailings leachate with the glacial drift, thus below U.S. EPA Drinking Water Standards.

are not expected to alter the overburden-bedrock interface. Therefore, once the mine is closed and the ground water levels have returned to premining conditions, the approximate premining ground water flow regime will be re-established.

Placement of an impermeable reclamation cover over the tailing ponds will have the effect of reducing surface water recharge to the ground water under the ponds. There will be some water recharge from pond seepage, but the amount will be far less than the average annual precipitation recharge. Precipitation falling on the reclamation cover will be subject to evapotranspiration, surface drainage, and drainage layer runoff. This surface drainage and runoff will be reintroduced into the hydrologic regime through the embankments of the ponds and at the perimeter of the tailing ponds where it will infiltrate into the subsoil to recharge the ground water. This infiltration process will occur as the water seeps through the embankments and will result in a higher than ambient ground water recharge in the area around the ponds (Ayres Associates, 1984). This higher recharge value has been calculated and included in the hydrologic impact modeling results presented in Appendix 4.1A.

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, 1982). 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 that there is sufficient buffering capacity within the tailings 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 an infiltration rate of water through the seal of 1.7 mm/y (0.066 inch per year), is shown below (see the MWDF Feasibility Report):

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 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 most representative for seepage from the tailings. Acidic tailings seepage (pH <6) should never occur.

Even at ten times the expected infiltration rate, the number of years to consume available calcium carbonate within the tailings is only reduced by a factor of ten.

The attenuation studies utilized synthetic leachates and representative soil composites to determine the constant pH batch distribution ratios 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 average velocity of the ground water.

The studies indicated that the soils under the MWDF have 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 characterized as migrating at the same velocity as the expected seepage from the MWDF (Tables 4.3-3 and 4.3-4). However, there is evidence that sulfate may also undergo some biological/chemical attenuation (Exxon Minerals Company, unpublished data). 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, soils beneath the proposed MWDF have a moderate to high acid neutralization capacity (0.7 to 2.3 percent calcium carbonate equivalent). This buffering is even much larger than that indicated 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, the soils have a high capacity for acid neutralization in all directions of seepage movement from the facility (D'Appolonia, 1982). Because of this large buffering capacity of the soils, any metals in the seepage will be controlled by acid neutralization (i.e., greater attenuation with increasing pH).

Studies also indicated that a liner material of bentonite and glacial till soil will not undergo appreciable permeability changes from chemical reactions with facility seepage (D'Appolonia, 1982). Some evidence, in fact, indicates permeability reductions with time (Exxon

Minerals Company, unpublished data). Consequently, the integrity of this type of liner and the soils underlying the MWDF should be maintained throughout the life of the facility and should not degrade over time.

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 tailings seepage on ground water. Several analytical assessments were conducted (Appendix 4.1A) 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 the one-dimensional modeling for chemical constituent movement through the partially saturated till are presented on Figure 4.2-3. These results indicate that full concentrations ($C/C_o = 1.0$) of chemical constituents with a retardation factor of 1.0 could not reach the saturated till for hundreds of years. Figure 4.2-3 indicates that the full concentration of chemical constituents with a retardation factor of 1.0 may reach the 8-m (26-foot) level in the partially saturated till below the MWDF sometime after 600 years. Constituents with a normalized concentration of 0.1 passing through the unsaturated till will reach the 8-m (26-foot) level in approximately Year 70. The minimum thickness of till under tailing pond T4 is approximately 8 m (26 feet). In areas where till depths are thicker, the time will be proportionally longer.

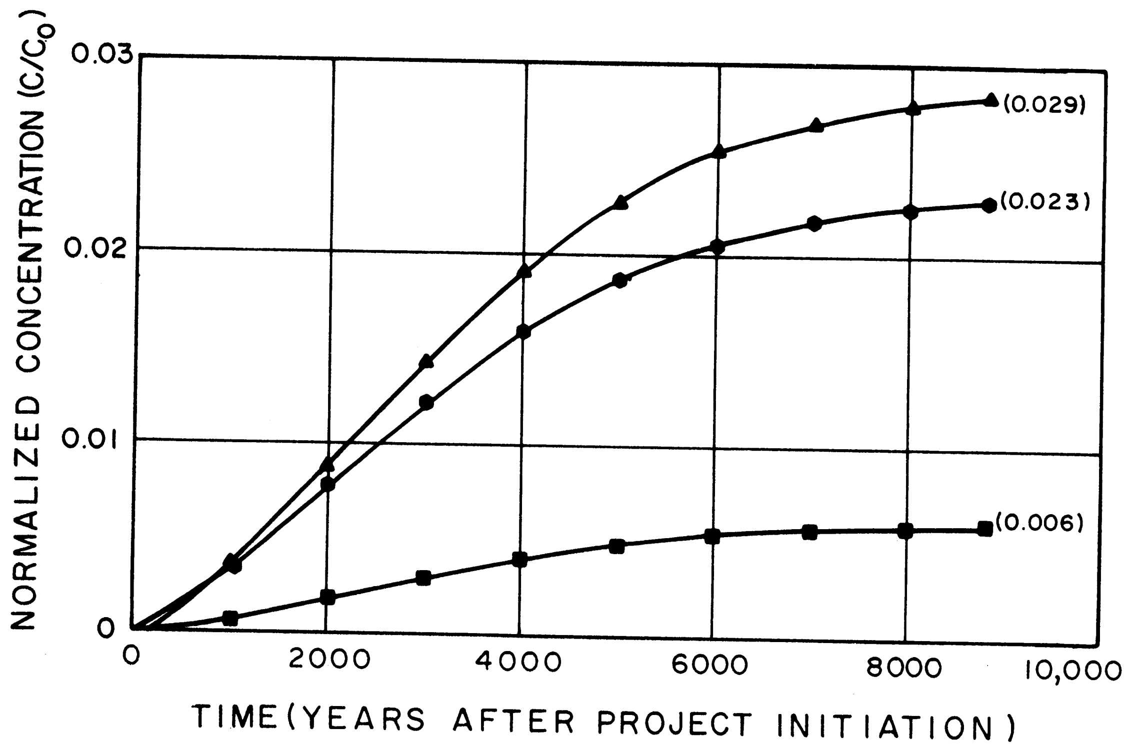
Simulation of seepage movement and concentration using the two-dimensional vertical model indicated that the 0.1 normalized concentration will remain in the till beneath the majority of the MWDF after 800 years as shown on Figure 4.2-5. Based on this assessment of chemical constituent migration, no adverse impact on water quality outside the area of the ponds will occur for 800 years after Project initiation.

Other chemical constituents with retardation factors greater than 1.0 will move at much slower rates and/or the source concentrations will dissipate. For example, the estimated cadmium, manganese, and iron concentrations could exceed U.S. EPA Drinking Water Standards in the initial tailing pond seepage (Table 4.2-6). The concentrations of all constituents in seepage at the bottom of the tailing ponds are predicted to decrease to acceptable limits within 50 years after the operation phase by achieving chemical equilibrium with the tailings. Because cadmium (estimated retardation factor equal to 113.0) moves at a rate 113 times slower than sulfate, it will have traveled only a fraction of a foot beneath the MWDF during the first 50 years. As a result, based on the decrease in seepage concentration and the retardation factor, no impact from cadmium concentrations is anticipated.

Manganese and iron will also have minimal to no impact on water quality. Manganese and iron have estimated retardation factors equal to 2.0 and greater than 14.0, respectively (Table 4.3-4). Manganese concentration in the seepage for the first 50 years of the post-operation phase is approximately 400 times the U.S. EPA Drinking

Water Standards or 50 times greater than the mean ground water concentration of 0.4 mg/l (Dames and Moore, 1982). Because of its higher retardation factor, manganese will not have moved through more than 8 m (26 feet) of the partially saturated till below the MWDF in the first 50 years after the operation phase. It will take approximately 800 years for any measurable change in manganese concentration to be observed at the top of the ground water table. The maximum estimated manganese concentration to reach the top of the ground water table is predicted to be 3.0 mg/l (C/C_o = 0.15), but only under the MWDF. The above calculations were performed for partially saturated conditions and it was assumed there would be no dilution. As the manganese enters the saturated stratified drift, it will be appreciably diluted; therefore, little to no modification to the present ground water quality is anticipated. Similar discussions are valid for iron and its movement will be less because of its relatively higher retardation factor.

Figure 4.3-2 presents plots of normalized concentrations (C/Co) versus time for chemical constituents with a retardation factor of 1.0 at three different locations in the vertical section: (1) at the compliance boundary, 36 m (118 feet) below the water table (depth of greatest concentration); (2) at the eastern edge of the MWDF embankment, 6 m (20 feet) below the water table; and (3) at Hemlock Creek, at the water table. The steady-state concentration values, as predicted by the steady-state analysis (Appendix 4.1A, Attachment A.4), are also given for each of the three points. The plots indicate that normalized concentrations at these locations will reach approximately one-third of



SOURCE: APPENDIX 4.1A

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: PREDICTED NORMALIZED CONCENTRATION VERSUS TIME SECTION N-N' FOR MIDDLE RECHARGE CASE

SCALE: AS SHOWN	STATE	COUNTY	
DRAWN BY: D. Weick	DATE: 9-26-84	CHECKED BY: MMR	DATE: 12/10/85
APPROVED BY	DATE	APPROVED BY: SHD	DATE: 12/10/85
APPROVED BY	DATE	EXXON	DATE
DRAWING NO: FIGURE 4.3-2		SHEET ___ OF ___	REVISION NO.

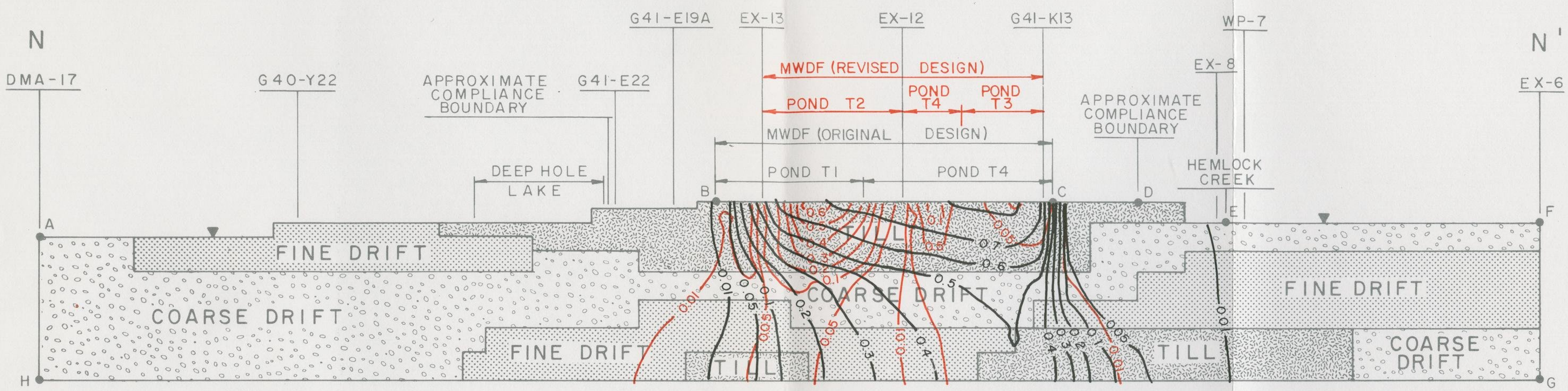
D'APPOLONIA

PROJ. NO 846498 | DWG. NO A10

their steady-state values after 2,000 years; concentrations will approach their steady-state values 8,800 years after Project initiation.

A review of the analysis conducted for seepage constituent movements up to 8,800 years, or approximately steady-state conditions, indicates that the U.S. EPA Drinking Water Standard limit for sulfate concentration will not be exceeded at the compliance boundary. Based on analytical and two-dimensional vertical model assessments discussed in Appendix 4.1A, the average normalized steady-state concentration (C/C_o) is predicted to be substantially less than 0.01 around the compliance boundary at steady-state because of dilution. Peak values of normalized concentrations over small portions of the compliance boundary will occur because of maximum gradient ground water flow in the northeast and southwest directions, but even these peak values are not anticipated to exceed 0.125 (Figure 4.3-3).

Other seepage chemical constituents with retardation factors greater than 1.0 will move at a much slower rate, or the source concentrations will dissipate prior to reaching the drinking water limits in the stratified drift. Appendix 4.1A provides additional detail and contains a discussion of other chemical constituents and their potential for modifying ground water quality.



NOTES:

1. SOURCE: APPENDIX 4.1A
2. VERTICAL EXAGGERATION 15X

LEGEND

A● POINTS REFERRED TO IN TEXT

—0.1— NORMALIZED CONCENTRATION CONTOUR (REVISED MWDF DESIGN)

—0.1— NORMALIZED CONCENTRATION CONTOUR (ORIGINAL MWDF DESIGN)

▼ WATER TABLE (RECHARGE BOUNDARY)

HORIZONTAL SCALE

0 300 600 900 meters

VERTICAL SCALE

0 20 40 60 meters

7B	6B
7B	6B
100% ORG.	50% BLK.

D'APPOLONIA

PROJ NO 611101 DWG NO B4

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

TWO—DIMENSIONAL VERTICAL MODEL, PREDICTED STEADY STATE NORMALIZED CONCENTRATIONS FOR REVISED MWDF DESIGN

SCALE AS SHOWN	STATE		COUNTY	
DRAWN BY R. Weible	DATE 11-12-85	CHECKED BY MDR	DATE 12/9/85	
APPROVED BY	DATE	APPROVED BY SND	DATE 12/10/85	
APPROVED BY	DATE	EXXON	DATE	
DRAWING NO FIGURE 4.3-3		SHEET ___ OF ___	REVISION NO	

4.3.4 Surface Water

As the potentiometric surface of the ground water recovers to its preconstruction level, the effects on the streams and lakes bordering the site area will diminish. When the preconstruction potentiometric level is reached, the base flow to these streams and lakes will be at the preconstruction rate and the effects of mine inflow will no longer exist.

4.3.4.1 Surface Water Quantity

For the post-operation period, mine discharge will cease at approximately Year 33 and the potentiometric head will return to initial preconstruction conditions by approximately Year 45. The ground water discharge along streams bounding the site area will also return to initial conditions. After recovery and sealing of the mine openings to eliminate potential hydraulic connections to the underground workings, no measurable post-operation consequences on surface water quantity are anticipated.

4.3.4.2 Surface Water Quality

The quality of the ground water discharged into the streams and lakes of the site area will not be noticeably altered in the post-operation period.

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 MWDF seepage rates shown in Table 4.3-2.

Figure 4.3-3 shows the steady-state impacts to Hemlock Creek based on the modeled 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 for Hemlock Creek (4.0 cubic feet per second at SG 6 upstream of its juncture with Swamp Creek) and for Swamp Creek (19.0 cubic feet per second at Highway 55) and the modeled seepage rate resulted in a change in sulfate in Hemlock Creek of less than 2 mg/l and less than 0.5 mg/l in Swamp Creek.

These calculations conservatively assume that all the sulfate contained in the MWDF seepage quantity (total leachate quantity of approximately 1 gallon per minute) 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. Changes of this magnitude would be unnoticeable and the entire increase would not occur until after 8,800 years.

4.3.4.3 Wetlands Hydrology

4.3.4.3.1 Perched Wetlands

Access Road - The access road will be reclaimed after the operation phase. The pavement and stone base will be removed and minor grading will be performed. Herbaceous vegetation consisting of indigenous and introduced species will be established following grading to stabilize the soil surface and to minimize erosion. Invasion of native plant species from adjacent communities will be allowed to occur in the reclaimed corridor. No major changes in the wetland watershed areas or cover types will occur during reclamation, and the hydrology of all affected wetlands during post-operation will be similar to that described in subsection 4.2.4.1.4.

Railroad Spur - Post-operational activities will include the reclamation of the railroad spur by regrading after removal of rails, ties and ballast, and seeding and revegetation of all disturbed areas. Native vegetation will be allowed to become reestablished. There will be no changes of wetland watershed areas or cover types and the post-operational hydrology of all affected wetlands will be similar to that of existing conditions.

Mine/Mill Site - In the post-operational phase the buildings and impervious surfaces of the mine/mill site will be removed. The site will be regraded to approximate existing land surface contours (see Figure 1.5-1). Disturbed areas will be seeded and allowed to become revegetated. There should be no major change in watershed areas or cover types from those of existing conditions and as a result no change in the water balance of the existing perched wetlands.

Mine Waste Disposal Facility - To evaluate the potential effects of the reclaimed MWDF on wetland hydrology, existing wetland water balances were compared with predicted wetland water balances for the final phase of MWDF development (phase 5). The methods used to develop the water balance data and the results of the analyses are described in reports by IEP, Inc. (1982) and Ayres Associates (1984, 1985). In these reports phase 6 is identified as the final MWDF development phase; however, due to changes in the construction schedule and modifications in the design of the MWDF, one construction phase was eliminated (see Chapter 1, Figure 1.4-12) and phase 5 is currently the final development phase.

Ayres Associates revised their 1984 calculated water balances for the final phase of the new MWDF cap design (Ayres Associates, 1985). The MWDF design, as described in Chapter 1, will be a smaller facility than previous designs and will significantly reduce overall wetland impacts. Both IEP, Inc. and Ayres Associates generated similar existing conditions wetland water balances. The calculations by Ayres Associates were based on the NOAA Station at Rhinelander, Wisconsin and an average annual precipitation of 762.8 mm (30.03 inches). The independent investigations show nearly identical seasonal patterns of saturation (outflow) and unsaturation (no outflow) for the perched wetlands.

During the post-operational phase (phase 5), all tailing ponds, the water reclaim pond, MRDF, and construction support area will have been reclaimed and the final grading and revegetation of the previous pond areas will have been implemented.

The seasonal runoff values for existing and phase 5 conditions are presented in Tables 4.3-5 through 4.3-8. The existing water balance data are presented in this subsection, rather than Section 2.4, Surface Water, for comparative purposes and convenience. These data are an integral part of the impact assessment and were also utilized to determine the effectiveness of proposed mitigative measures.

TABLE 4.3-5

EXISTING AND PHASE 5 WATER BALANCES
DRAINAGE AREA F57

Sub-area Identification		Seasonal Runoff Values (cfs) Winter	Spring	Summer	Fall	Annual Runoff (cfs)
F66	E	.004	.019	0.0	.003	.078
	P	--	--	--	--	--
F65	E	.002	.024	0.0	.001	.081
	P	--	--	--	--	--
F64	E	.002	.018	0.0	.001	.144
	P	--	--	--	--	--
F63*	E	.004	.026	0.0	.003	.099
	P	.007	.014	S	0.0	.063
F62	E	.005	.047	0.0	.002	.162
	P	.024	.048	S	0.0	.216
F72	E	.013	.024	.001	.002	.120
	P	S	S	S	S	S
F61	E	.027	.094	.007	.012	.420
	P	.033	.071	.006	.007	.351
F60	E	.041	.163	0.0	.007	.633
	P	.090	.147	0.0	0.0	.711
F57	E	.062	.201	.002	.011	.642
	P	.079	.178	.005	0.0	.786

E - Existing conditions runoff values.
P - Proposed phase 5 runoff values.
- - MWDF covers sub-area for phase 5, area is included in other sub-area.
S - Proposed phase 5 runoff values are the same as existing conditions.
* - Basin modified for phase 5, see discussion in Ayres Associates (1985) for details.

Source: Ayres Associates (1985).

TABLE 4.3-6

EXISTING AND PHASE 5 WATER BALANCES
DRAINAGE AREA K AND M

Sub-area Identification		Drainage Area K Seasonal Runoff Values (cfs) Winter	Spring	Summer	Fall	Annual Runoff (cfs)
K4	E	.003	.009	.003	.003	.054
	P	S	S	S	S	S
K5	E	.005	.010	.003	.003	.063
	P	S	S	S	S	S
K3	E	.005	.033	0.0	.003	.123
	P	.036	.054	S	S	.279
K2	E	.030	.082	.004	.013	.387
	P	.063	.110	.012	.021	.618
K1	E	.032	.088	.008	.016	.432
	P	.065	.116	.018	.024	.669
		Drainage Area M Seasonal Runoff Values (cfs)				
M4	E	.004	.011	.004	.003	.066
	P	S	S	S	S	S
M3*	E	.017	.032	.003	.006	.174
	P	.016	.047	.025	.017	.489
M5	E	.001	.003	0.0	0.0	.012
	P	S	S	S	S	S
M6	E	.003	.008	.003	.002	.048
	P	S	S	S	S	S
M2	E	.023	.054	.011	.013	.303
	P	.019	.057	.031	.021	.384
M1	E	.026	.060	.011	.014	.333
	P	.025	.071	.034	.025	.465

E - Existing conditions runoff values.
P - Proposed phase 5 runoff values.
- - MWDF covers sub-area for phase 5, area is included in other sub-area.
S - Proposed phase 5 runoff values are the same as existing conditions.
* - Basin modified for phase 5, see discussion in Ayres Associates (1985) for details.

Source: Ayres Associates (1985).

TABLE 4.3-7

EXISTING AND PHASE 5 WATER BALANCES
DRAINAGE AREA F28 WITH DUCK LAKE

Sub-area Identification		Seasonal Runoff values (cfs) Winter	Spring	Summer	Fall	Annual Runoff (cfs)
F31	E	.011	.025	0.0	.002	.114
	P	--	--	--	--	--
F32	E	.002	.004	0.0	.001	.021
	P	--	--	--	--	--
F30	E	.019	.052	.015	.011	.291
	P	--	--	--	--	--
F81	E	.001	.003	0.0	.001	.015
	P	--	--	--	--	--
F29	E	.030	.071	.011	.015	.381
	P	.014	.031	.006	.008	.177
F28	E	.021	.082	0.0	.013	.348
	P	0.0	0.0	S	0.0	0.0
Duck Lake	E	.039	.114	.006	.052	.633
	P	.018	.032	.010	.040	.300

E - Existing conditions runoff values.
P - Proposed phase 5 runoff values.
- - MWDF covers sub-area for phase 5, area is included in other sub-area.
S - Proposed phase 5 runoff values are the same as existing conditions.

Source: Ayres Associates (1985).

TABLE 4.3-8

EXISTING AND PHASE 5 WATER BALANCES
DRAINAGE AREA F15 AND F23

Sub-area Identification		Drainage Area F15 Seasonal Runoff values (cfs) Winter	Spring	Summer	Fall	Annual Runoff (cfs)
F17	E	.007	.013	.001	.003	.072
	P	S	S	S	S	S
F16	E	.004	.014	0.0	.002	.060
	P	S	S	S	S	S
F33*	E	.006	.013	.001	.003	.069
	P	.005	.011	.002	.002	.060
F15	E	.011	.048	0.0	.008	.201
	P	.067	.139	0.0	0.0	.681
		Drainage Area F23 Seasonal Runoff Values (cfs)				
F27	E	.010	.020	0.0	.001	.093
	P	--	--	--	--	--
F26*	E	.013	.028	.005	.004	.150
	P	.007	.025	.015	.009	.168
F25	E	.029	.068	.016	.017	.390
	P	.025	.066	.032	.023	.438
F24	E	.032	.075	.020	.019	.438
	P	.028	.078	.042	.029	.531
F23	E	.044	.092	.011	.022	.507
	P	.040	.097	.038	.033	.609

E - Existing conditions runoff values.
P - Proposed phase 5 runoff values.
- - MWDF covers sub-area for phase 5, area is included in other sub-area.
S - Proposed phase 5 runoff values are the same as existing conditions.
* - Basin modified for phase 5, see discussion in Ayres Associates (1985) for details.

Source: Ayres Associates (1985).

These data show that there will only be minimal changes to the water balances of the wetlands associated with the MWDF. Seasonal discharge variations from existing to proposed phase 5 conditions for the majority of wetlands are less than 0.00028 m^3/s (0.01 cubic feet per second). Most of these changes result in slightly wetter conditions (more discharge). The greatest annual increase in surface water runoff is predicted for wetland F15, an increase of 0.014 m^3/s (0.48 cubic feet per second). With the exception of those wetlands covered by the MWDF (F27, F30, F31, F32, F64, F65, F66 and F81), the water curve for the wetlands does not change.

These minimal changes in wetland water balances will not result in an alteration of the wetlands vegetative community, thus no changes in any of the wetland functions are anticipated.

Haul Road/Tailings Transport Pipeline Corridor - Post-operational activities call for the removal of the haul road and leaving the tailings transport pipelines in place. The corridor for these facilities will be regraded and seeded with a mixture of indigenous and introduced plant species. With the removal of these facilities, the contiguous nature of wetland F11 should be restored, resulting in no change in watershed areas from existing conditions. Natural vegetation cover of the reclaimed haul road/tailings transport corridor will restore the runoff characteristics to those of existing conditions. The net result will be no change to the existing water balance of wetland F11.

4.3.4.3.2 Water Table Wetlands

Access Road - As described in subsection 4.3.4.3.1, the access road will be removed and the corridor reclaimed during the post-operation phase. The water table wetlands associated with the access road are wetlands W1, W2, Z6, Z7, Z8, and Z9. The potential impacts to these wetlands will be the same as those described in subsection 4.2.4.1.4.

Railroad Spur - The railroad spur is associated with water table wetlands T1, T2, T3, and T4. The railroad will be reclaimed and the impacts will be similar to those described in subsection 4.2.4.1.4. Overall, there will be no major change in wetland water balances from existing conditions (IEP, Inc., 1982). Culverts and ditches should be maintained to allow for continuous flow-through of surface water.

4.3.5 Aquatic Ecology

During the post-operation period, no impacts are expected on the aquatic biota in the major streams and lakes in the Project site area. Surface water runoff will be controlled during facilities closure and reclamation following procedures similar to those used during construction and operation. Overall, the surface water bodies and associated aquatic biota in the site area that will be affected during construction and operation will return to the conditions existing prior to construction. No major changes in biota are projected to occur during construction and operation (subsections 4.1.5 and 4.2.5, respectively); therefore, during post-operation no noticeable changes in aquatic biota and habitats will occur.

4.3.6 Terrestrial Ecology

4.3.6.1 Vegetation

4.3.6.1.1 Upland Communities

The disturbed areas that were forested prior to Project construction will be reclaimed to forest land after closure of the Project facilities. The early successional stages of this reclaimed land will provide habitat for a variety of wildlife species. As this reclaimed forest land matures, it will more closely resemble the existing forest and will again provide forest products for industrial use and habitat for those species presently inhabiting the site.

4.3.6.1.2 Wetland Communities

Following facilities removal, final site grading and reclamation changes will occur in the hydrology of wetlands located down-gradient from the MWDF area that were affected during the construction and operation phases (subsection 4.2.6.1.2). Site reclamation will occur throughout Project phases 1 through 5; however, for assessing effects on wetlands these phases were considered collectively rather than separately. Because of modifications in the shape and size of the watershed of each wetland resulting from final grading, hydrologic changes will occur in these wetlands. The changes will be minor and slightly less than those occurring during the operation phase. Of the water discharge (outflow) measurements for the potentially affected wetlands (four seasonal averages per wetland), the difference between existing conditions and those after final grading will not exceed 0.0028 m^3/s (0.10 cubic feet per second) for any given season (Table 4.3-9). The maximum change in any outflow will be 0.0026 m^3/s (0.091 cubic feet per second) during spring in wetland F15 (Ayres Associates, 1985).

Following the same approach used to assess impacts during the construction and operation phases, the effects of these hydrologic changes on the wetland vegetative communities were evaluated based on the differences between the outflow from the wetlands under existing conditions and that after Project closure, and on scores assigned in the Storm and Floodwater Storage Function Model (the model). Short-term consequences of change in water level, assessed as potential damage to plant species, and long-term effects resulting from successional changes in the wetland community provided the basis for assessing effects on biological function. These potential effects are discussed below by wetland community type.

Green Ash/Aspen Deciduous Swamp - The minor change in outflow and the high model scores indicate that the change in water level in the wetlands during the post-operation phase will be small. Six deciduous swamps will experience minor hydrologic changes during post-operation, including wetlands F15, F57, F61, F62, K2, and M3. Five of these wetlands will have slightly increased annual average outflows and one will have a slight decrease in annual average outflow. The changes in biological function in these wetlands during post-operation will be imperceptible because of minor changes in outflow and their high storm and floodwater storage function value.

Black Spruce/Tamarack Coniferous Swamp - Four coniferous swamps (wetlands F23, F60, F63, and K3) were evaluated during

TABLE 4.3-9

STORM AND FLOODWATER STORAGE FUNCTION AND WETLAND OUTFLOWS UNDER EXISTING CONDITIONS AND DURING POST-OPERATION[a]

WETLAND NO.	STORM AND FLOODWATER STORAGE FUNCTION MODEL SCORE	OUTFLOWS DURING EXISTING CONDITIONS (cfs)[b]					OUTFLOWS DURING POST-OPERATION (cfs)					VARIATION IN ANNUAL AVERAGE
		WINTER	SPRING	SUMMER	AUTUMN	ANNUAL AVERAGE	WINTER	SPRING	SUMMER	AUTUMN	ANNUAL AVERAGE	
F15	98	0.011	0.048	0	0.008	0.201	0.067	0.139	0	0	0.681	+0.480
F23	106	0.044	0.092	0.011	0.022	0.507	0.040	0.097	0.038	0.033	0.609	+0.102
F24	69	0.032	0.075	0.020	0.019	0.438	0.028	0.078	0.042	0.029	0.531	+0.093
F25	97	0.029	0.068	0.016	0.017	0.390	0.025	0.066	0.032	0.023	0.438	+0.048
F26	58	0.013	0.028	0.005	0.004	0.150	0.007	0.025	0.015	0.009	0.168	+0.018
F28	103	0.021	0.082	0	0.013	0.348	0	0	0	0	0	-0.348
F29	96	0.030	0.071	0.011	0.015	0.381	0.014	0.031	0.006	0.008	0.177	-0.204
F57	95	0.062	0.201	0.002	0.011	0.642	0.079	0.178	0.005	0	0.786	+0.144
F60	101	0.041	0.163	0	0.007	0.633	0.090	0.147	0	0	0.711	+0.078
F61	84	0.027	0.094	0.007	0.012	0.420	0.033	0.071	0.006	0.007	0.351	-0.069
F62	94	0.005	0.047	0	0.002	0.162	0.024	0.048	0	0	0.216	+0.054
F63	101	0.004	0.026	0	0.003	0.099	0.007	0.014	0	0	0.063	-0.036
K1	59	0.032	0.088	0.008	0.016	0.432	0.065	0.116	0.018	0.024	0.669	+0.237
K2	101	0.030	0.082	0.004	0.013	0.387	0.063	0.110	0.012	0.021	0.618	+0.231
K3	102	0.005	0.033	0	0.003	0.123	0.036	0.054	0	0.003	0.279	+0.156
M1	90	0.026	0.060	0.011	0.014	0.333	0.025	0.071	0.034	0.025	0.465	+0.132
M2	60	0.023	0.054	0.011	0.013	0.303	0.019	0.057	0.031	0.021	0.384	+0.081
M3	98	0.017	0.032	0.003	0.006	0.174	0.016	0.047	0.025	0.017	0.489	+0.315

[a] Source: Ay[illegible] Associates (1985).
[b] The metric [illegible]valent of 1 cubic foot per second is $0.028 m^3/s$.

post-operation. In wetlands F23, F60, and K3 an increase in outflow will occur on an annual basis and in F63 there will be a modest net decrease in outflow. All four wetlands scored above the actual mean for the Storm and Floodwater Storage Function Model. These changes in outflow will be minor and when considered with the high scores for storm and floodwater storage for these wetlands, indicate that the change in water level will be imperceptible. These minor changes will not cause any short or long-term effects on wetland plants or wetland communities.

Other Wetland Communities - Other wetland community types that will undergo hydrologic changes during post-operation include: (1) shallow marsh (wetland F25); (2) shrub swamp (wetlands F24 and M1); (3) bog (wetlands F26, F28 and F29); and (4) streamside wetlands (wetlands K1 and M2). The magnitude of the seasonal and annual changes in outflow in these wetlands is minor in each wetland and subsequent short and long-term consequences on wetland community structure and biological function will be minimal.

Mitigation - Mitigation during post-operation will focus on reestablishment of existing surface water drainage patterns to the extent possible in the vicinity of the MWDF. Existing or new retention ponds will be used for erosion control during reclamation. Reestablishment of drainage patterns will ameliorate effects to wetlands caused by hydrologic changes during Project construction and operation. Salvaged topsoil will be reapplied over disturbed areas, and then seeded with a mixture of indigeous and introduced grasses and legumes to provide erosion control. Native herbaceous and woody plant species from the surrounding undisturbed plant communities and from established landscape planting in the mine/mill site will be allowed to invade these seeded areas. Long-term maintenance of the reclaimed areas will include filling and reseeding of eroded areas to ensure establishment of a stable vegetative cover and restoration of wildlife habitat. Reestablishment of native plant communities in all areas that had been disturbed during Project construction and operation will mitigate the loss of upland habitat. No wetland habitat will be created during post-operation to replace wetlands removed during construction.

4.3.7 Cultural Resources

Post-operation activities will not have any adverse effects on the landscape coincident with archaeological and historical sites that have been identified and determined as potentially eligible for The National Register of Historic Places. As a result, the mitigation measures specified in Tables 4.1-8 and 4.1-9, applied to the construction phase, will be effective in the post-operation phase of the Project. These mitigation measures will be effective for the duration of Exxon Minerals Company's ownership of the property where the sites are located.

4.3.8 Noise

Noise levels will decrease from construction activity levels over a 2 to 3 year period following Project closure to the levels that existed prior to Project construction.

4.3.9 Land Use and Aesthetics

Post-operational land use will eventually be similar to what it was prior to construction and operation of the Project if alternative uses are not identified. Reclamation activities during the 3 to 4 year period following the operation phase will be designed to allow the disturbed land areas to return to premining land uses. Vegetation consisting of indigenous and introduced species will be established and through invasion of plant species from adjacent undisturbed areas, the reclaimed land will be returned to a forested environment in those areas where forestry was the premining land use. The proposed final land uses of the reclaimed areas (forestry, recreation, and agriculture) are described in Section D, Reclamation Plan in the Mining Permit Application.

Aesthetically, the mine/mill site will be reclaimed to a forested state and the MWDF will be graded and planted to be compatible with the surrounding undisturbed plant communities. The area around the Project site will eventually return to a condition similar to what it was prior to Project construction.

4.3.10 Socioeconomics

Post-operational socioeconomic impacts are presented in subsection 4.2.10 along with a complete discussion of the construction and operation phase assessments.

4.3.11 References

Ayres Associates, 1984a, Mine waste disposal facility reclamation cap design and water balance analysis: Report prepared for Exxon Minerals Company by Ayres Associates, Eau Claire, Wisconsin (September).

_____, 1984b, Water balance analysis for wetlands in the mine waste disposal facility area: Report prepared for Exxon Minerals Company by Ayres Associates, Eau Claire, Wisconsin (October).

_____, 1985, Water balance analyses for wetlands in the revised mine waste disposal facility area: Report prepared for Exxon Minerals Company by Ayres Associates, Eau Claire, Wisconsin (November).

Colorado School of Mines Research Institute, 1982, Study on characterization of Crandon mill tailings. CSMRI Project J10523. Golden, Colorado (April).

D'Appolonia Consulting Engineers, Inc., 1982, Soil attenuation study: Crandon Project, Crandon, Wisconsin: Report prepared for Exxon Minerals Company, Rhinelander, Wisconsin, by D'Appolonia Consulting Engineers, Inc., Pittsburgh, Pennsylvania. Volumes I and II.

Exxon Minerals Company, 1984, Hydrologic stresses for ground water modeling with GEOFLOW: Memorandum by C. C. Schroeder, dated August 16, 1984.

Interdisciplinary Environmental Planning, Inc., 1982, Hydrological balance for selected wetlands, Crandon Project: Report prepared for Exxon Minerals Company, Rhinelander, Wisconsin by Interdisciplinary Environmental Planning, Inc., Wayland, Massachusetts.

Thomas A. Prickett and Associates (TAP Associates), 1984, Predicted ground water inflow modeling and sensitivity analysis for the proposed Crandon Mine: Exxon Minerals Company, Crandon Project, TAP Associates, Urbana, Illinois.

4.4 ALTERNATIVES

4.4.1 Facility Siting Alternatives

4.4.1.1 Mine/Mill Facilities

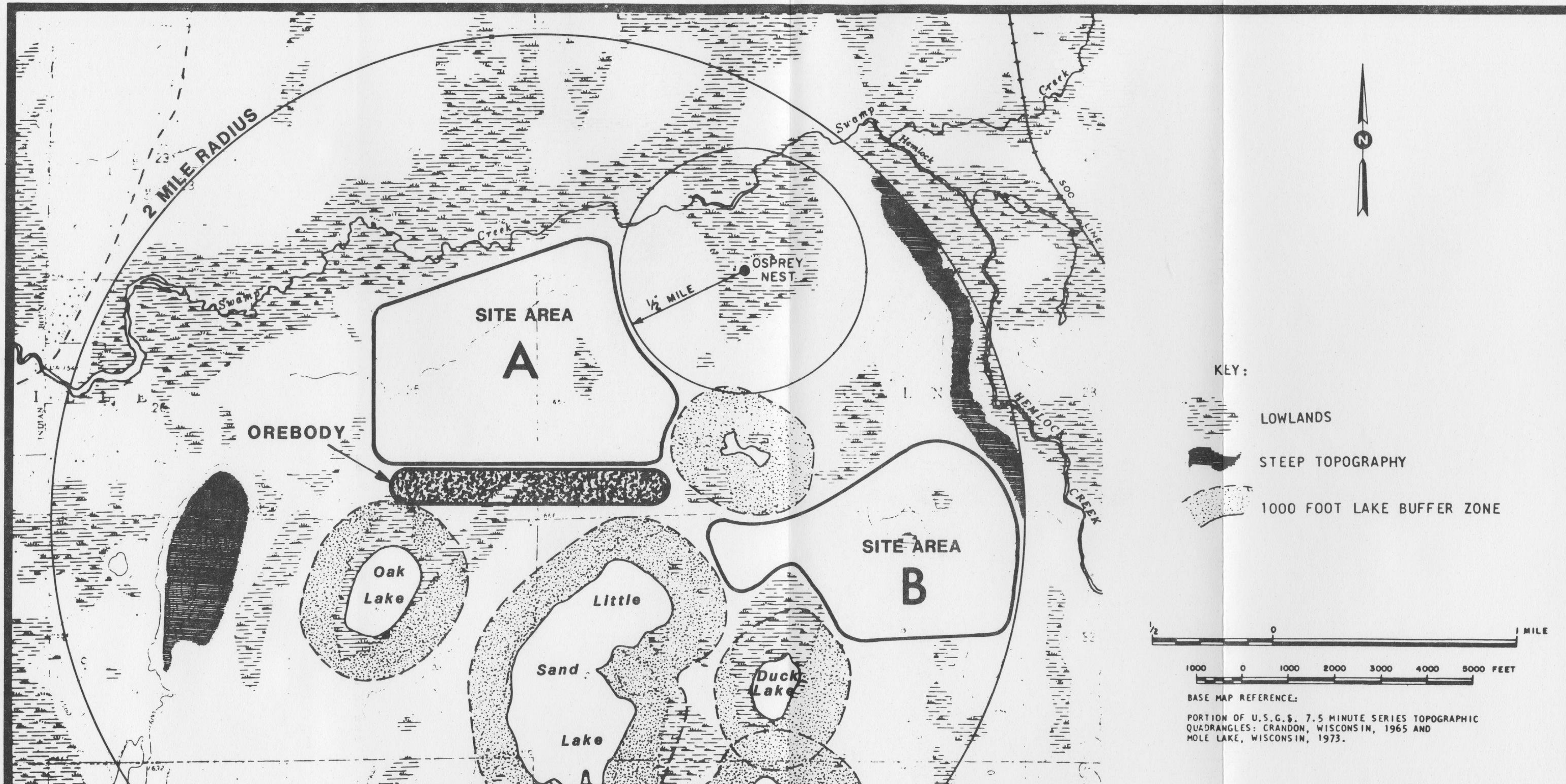
The two site areas shown on Figure 4.4-1 met the siting criteria discussed in Chapter 3, subsection 3.4.1, for the mine/mill surface facilities. Environmental impacts of mine/mill facility siting are essentially limited to land disturbance and operation life pre-emption of existing land use.

Either area could be utilized for location of the proposed facilities and the actual acreage required for the various mine/mill facilities would be similar at either site. However, because the mine facilities must be located near the orebody, utilization of Site B would require a split-site design with duplication of some support facilities and transport of the ore and wastewater a considerable distance to the mill facilities. This would require unnecessary land disturbance for transportation facilities such as pipelines, conveyors, and rail, as well as the increased land, construction, and operating cost.

Therefore, because Site A, the proposed site, is located adjacent to the orebody and does not disturb any unique or sensitive habitats, it represents the alternative site for mine/mill facilities with the least overall environmental impact.

4.4.1.2 Mine Waste Disposal Facility Siting

Areas 40 and 41 were identified in Chapter 3 as the most acceptable of the numerous areas studied for placement of the MWDF. This determination was made after evaluating a wide range of ecological and engineering factors. A detailed explanation of the siting



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE

SITE SELECTION LOCATIONS, PROPOSED SURFACE FACILITIES

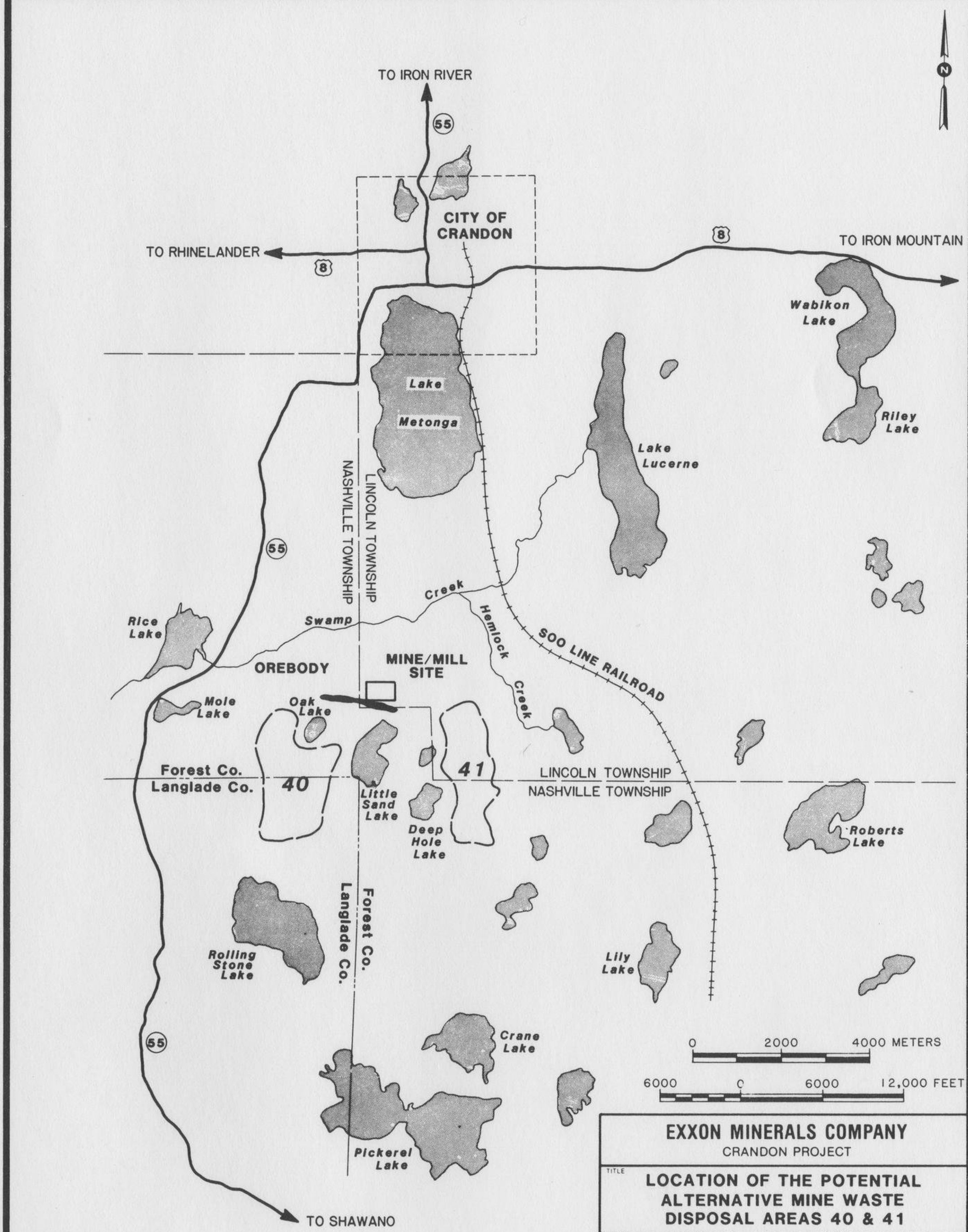
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY R.C. DIETZ	DATE 11/82	CHECKED BY H.S. Luri		DATE 12/8/82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12/82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO FIGURE 4.4-1			SHEET OF		REVISION NO. 0

process and description of potential areas are presented in the MWDF Feasibility Report. The two areas are shown on Figure 4.4-2.

Both areas are approximately equal in distance from the mine/mill facilities, neither offering significant operational or transportation advantages over the other. Both areas are also underlain by relatively low permeability upper soil layers of fine-grained till and offer considerable potential to retard seepage from the ponds. Both areas also contain similar wetland acreage, approximately 16.2 ha (40 acres) in Area 40 and approximately 22.3 ha (55 acres) in Area 41.

However, there are differences between the two areas which indicate the potential overall environmental impacts would be less at Area 41 than at Area 40. Area 40 is located in the headwaters of trout streams draining into Rolling Stone Lake. Additionally, the length of ground water flow paths to surface water discharge areas (i.e., wetlands, trout streams) in Area 40 is only 305 m (1,000 feet) and less than 1.6 km (1 mile) to domestic users. These factors are undesirable because of the more immediate and direct potential effects on aquatic ecosystems and existing domestic ground water users around the north side of Rolling Stone Lake. Moreover, Area 40 is located within the Rolling Stone Lake Deeryard (see Chapter 2, Section 2.6).

In contrast, Area 41 would not physically impact headwaters of a trout stream and there is very little domestic use of ground water down-gradient. Also Area 41 offers a greater margin of environmental protection of the hydrological regime than does Area 40. Both areas are underlain by low permeability glacial till which will retard migration



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
LOCATION OF THE POTENTIAL ALTERNATIVE MINE WASTE DISPOSAL AREAS 40 & 41

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY S. J. Harvey	DATE 12/82	CHECKED BY H.S. Lewis		DATE 12/82	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 12/82	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO FIGURE 4.4-2			SHEET ___ OF ___	REVISION NO. 0	

of seepage from the tailing ponds. However, whereas Area 40 has approximately 12.2 m (40 feet) of till above the water table, Area 41 has approximately 27.4 m (90 feet) of till which more than doubles both the time required for any seepage to reach the water table and the attenuation capacity offered by the till (D'Appolonia, 1982).

Area 40 would require disturbance of transportation along Sand Lake Road because it would be crossed by the transportation facilities from the mine and mill and vehicles utilizing this transportation corridor. Area 41 is also more isolated from residental and recreational areas and its location within the higher elevation areas of the region offers minimum disturbance to aesthetic resources. Area 40 also requires more earthwork than Area 41 because of the topographic relief.

For these reasons placement of the MWDF in Area 41 was considered to offer the greatest overall environmental protection and would have the least overall impact to the existing environment.

Sites Within Area 41 - Once Area 41 was selected as the preferred area, numerous sites were evaluated within Area 41 to determine the facility with the least overall cost and environmental impact. Four viable sites are identified in Chapter 3. These are shown on Figures 4.1-8 through 4.1-11.

The impacts associated with operation of the MWDF are presented in Section 4.2. The primary environmental effects of pond construction and operation which differentiate the three alternatives are: wetlands disturbed, potential hydrologic effects, reclamation constraints, and land area required.

Site 41-114C, the proposed site, will directly affect approximately 18 ha (45 acres) of wetlands, compared to 22 ha (55 acres) in site 41-114B, 17 ha (42 acres) in site 41-121 and 14 ha (34 acres) in site 41-103 (see Chapter 3, subsection 3.4.2.1). It is not possible to lay out the MWDF in Area 41 without directly impacting some wetlands.

Site 41-114C is a modification of site 41-114B and it is a smaller facility with less tailings storage capacity than the other alternatives. Therefore, the following comparisons among sites are primarily restricted to sites 41-114B, 41-103 and 41-121 which were designed to contain a similar volume of waste materials.

Mine Waste Disposal Facility - Alternative 41-103 - Eleven wetlands would be affected by Alternative 41-103 (Table 4.4-1), eight (F24, F25, F26, F27, F32, F64, F65, F66) of which would be completely removed. Wetlands F24, F25, F26, F27, and F32 were all deciduous swamps which scored below the actual mean for the Biological Function Model (the model). In general, deciduous swamps received low scores because of less class richness, less vegetation interspersion, and the lesser weighting as a dominant class. This wetland type is common in the study area and region. In view of their low importance in the study area and regional contexts, the effects of removal of these wetlands on biological function would be minor.

Wetland F64 was a bog which scored slightly below the actual mean for biological function when compared to other wetlands in the study area. This score was attributed to poor conditions for such elements as wetland type variety, water/cover ratio and interspersion.

TABLE 4.4-1

COMPARISON OF WETLAND AREA REMOVED BETWEEN PROPOSED AND ALTERNATIVE ACTIONS DURING CONSTRUCTION OF THE MINE WASTE DISPOSAL FACILITY

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE[a]	AREA OF WETLAND TYPES REMOVED ha (ACRES)								
			CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL	ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[b]
MINE WASTE DISPOSAL FACILITY											
Proposed Action			10.29 (25.42)	2.21 (5.64)	2.13 (5.26)	3.38 (8.34)	0.14 (0.35)		18.23 (45.01)		
Alternative 41-103	F24	DS		0.02 (0.05)				0.02 (0.05)	13.58 (33.57)	0.02 (0.05)	56
	F25	DS	1.42 (3.53)					1.42 (3.53)		1.42 (3.53)	70
	F26	DS		0.02 (0.05)				0.02 (0.05)		0.02 (0.05)	52
	F27	DS		0.83 (2.06)		0.85 (2.12)		1.69 (4.18)		1.69 (4.18)	57
	F31	CS		0.27 (0.69)				0.35 (0.88)		2.42 (6.00)	83
	F32	DS		0.22 (0.55)				0.22 (0.55)		0.22 (0.55)	53
	F62	DS		0.13 (0.34)				0.13 (0.34)		2.96 (7.31)	76
	F63	CS	0.29 (0.73)					0.29 (0.73)		3.90 (9.64)	90
	F64	B			1.83 (4.54)			1.83 (4.54)		1.83 (4.54)	78
	F65	SS				1.01 (2.52)		1.01 (2.52)		1.01 (2.52)	96
	F66	CS	5.28 (13.07)			1.26 (3.13)		6.55 (16.20)		6.55 (16.20)	94

TABLE 4.4-1 (continued)

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE[a]	AREA OF WETLAND TYPES REMOVED ha (ACRES)						ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[b]
			CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL			
Alternative 41-121	F24	DS		0.02 (0.05)				0.02 (0.05)	17.36 (42.86)	0.02 (0.05)	56
	F25	DS	1.42 (3.53)					1.42 (3.53)		1.42 (3.53)	70
	F26	DS		0.02 (0.05)				0.02 (0.05)		0.02 (0.05)	52
	F27	DS		0.83 (2.06)		0.85 (2.12)		1.69 (4.18)		1.69 (4.18)	57
	F60	CS	6.36 (15.74)	2.26 (5.60)		0.95 (2.37)		9.59 (23.71)		9.59 (23.71)	93
	F61	DS		0.81 (2.02)				0.81 (2.02)		0.81 (2.02)	58
	F62	DS	2.03 (5.04)	0.91 (2.27)				2.95 (7.31)		2.95 (7.31)	76
	F69	DS		0.40 (1.01)				0.40 (1.01)		0.40 (1.01)	59
	F127	DS		0.40 (1.00)				0.40 (1.00)		0.40 (1.00)	70

TABLE 4.4-1 (continued)

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE[a]	AREA OF WETLAND TYPES REMOVED ha (ACRES) CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL	ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[b]
Alternative 41-114B	F25	DS		0.93				0.93	22.25	1.42	70
				(2.32)				(2.32)	(54.94)	(3.53)	
	F26	DS		0.02				0.02		0.02	
				(0.05)				(0.05)		(0.05)	52
	F27	DS		0.68		1.00		1.68		1.68	57
				(1.69)		(2.49)		(4.18)		(4.18)	
	F30	DS		0.23				0.23		0.23	53
				(0.57)				(0.57)		(0.57)	
	F31	CS	1.83	0.58				2.41		2.41	83
			(4.55)	(1.45)				(6.00)		(6.00)	
	F32	DS		0.22				0.22		0.22	53
				(0.55)				(0.55)		(0.55)	
	F33	DS		0.63				0.63		0.63	52
				(1.56)				(1.56)		(1.56)	
	F62	DS	0.77	0.72				1.49		2.96	76
			(1.92)	(1.78)				(3.70)		(7.31)	
	F63	CS	3.59		0.30			3.89		3.89	90
			(8.89)		(0.75)			(9.64)		(9.64)	
	F64	B			1.83			1.83		1.83	78
					(4.51)			(4.51)		(4.51)	
	F65	SS					1.01	1.01		1.01	96
							(2.52)	(2.52)		(2.52)	
	F66	CS	5.30			1.18		3.64		6.55	94
			(13.08)			(2.92)		(16.00)		(16.20)	
	F81	SM					0.14	0.14		0.14	58
							(0.35)	(0.35)		(0.35)	
	M3	DS	0.67	0.53				1.20		1.69	73
			(1.67)	(1.32)				(2.99)		(4.18)	

[a]B=Bog; CS = Coniferous swamp; DS = Deciduous swamp; SM = Shallow marsh; SS = Shrub swamp.

[b]Model Range: 29-158; Model Mean: 93; Actual Range: 44-131; Actual Mean: 78.7.

The effect on biological function of removing this wetland would be minor given its relatively low importance in a regional context.

Wetland F65, a shrub swamp, and F66, a coniferous swamp, both scored above the mean for the Biological Function Model which distinguished their biological function from those of the wetlands in the region. These high scores were attributed to favorable conditions for major elements such as heavy weighting for each type as a dominant class, number of wetland classes and interspersion. The magnitude of this loss on biological function in a regional context would be minor, however, given the commonness of shrub swamps and coniferous swamps in the region.

The remaining three wetlands would be partially affected by Alternative 41-103. Wetlands F31 and F63, both coniferous swamps, would be reduced 0.35 ha (0.88 acre) and 0.29 ha (0.73 acre), respectively. Wetland F62, a deciduous swamp, would undergo a reduction of 0.13 ha (0.34 acre). Wetlands F31, F62, and F63 currently occupy 2.42 ha (6.00 acres), 2.95 ha (7.31 acres), and 3.90 ha (9.64 acres), respectively. Wetlands F31 and F63, with scores of 83 and 90 in the Biological Function Model, respectively, were distinguishable from other wetlands in the study area but not in the region with respect to biological function. Wetland F62 scored below the actual mean in biological function. The effect of alternative site 41-103 on these wetlands would be minimal considering their respective sizes in relation to the amount of each wetland lost and given the commonness of coniferous and deciduous swamps in the region.

Compared to the site 41-114B, the losses associated with alternative 41-103 represent decreases in disturbance to deciduous swamp, coniferous swamp, bog and shrub swamp communities (Table 4.4-1). Also, when compared to site 41-114B, 0.14 ha (0.35 acre) of shallow marsh would not be affected by 41-103.

For informational purposes, Table 4.4-2 provides comparative data on the differences in wetland area disturbance between site 41-103 and the proposed site, 41-114C.

The losses in carrying capacity for the five indicator species in alternative site 41-103 are presented in Table 4.4-3. Because less area would be required for Alternative 41-103, losses of wildlife habitat and associated carrying capacity would be less than that experienced at site 41-114B. The effect of site 41-103 on threatened and endangered wildlife species would be similar to that described for the proposed action (subsection 4.1.6.3).

Mine Waste Disposal Facility - Alternative 41-121 - In alternative site 41-121, nine wetlands would be completely removed (Table 4.4-1). Wetlands F24, F25, F26, F27, F61, F62, F69, and F127 were deciduous swamps and wetland F60 was a coniferous swamp. With the exception of F60, all scored below the actual mean. These low scoring wetlands were not considered to be important in terms of biological function compared to other wetlands in the study area. This was attributed to unfavorable conditions for the major elements giving rise to biological function. Based on their low importance in the study area and regional contexts, the consequence of the loss of biological function associated with these low scoring deciduous swamp type wetlands would be minor. Wetland F60 received a score equal to the mean for the model and, therefore, its biological function was distinguishable from those of other wetlands in the region. This higher score was a result

TABLE 4.4-2

DIFFERENCE IN WETLAND AREA REMOVED BY ALTERNATIVE ACTIONS DURING CONSTRUCTION OF PROJECT FACILITIES COMPARED TO PROPOSED ACTION

PROJECT FACILITIES	AREA OF WETLAND TYPES REMOVED ha (Acres)					
	CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	ALTERNATIVE TOTAL
Mine Waste Disposal Facility						
Proposed Action	10.29 (25.42)	2.21 (5.64)	2.13 (5.26)	3.38 (8.34)	0.14 (0.35)	18.23 (45.01)
Alternative 41-103	-3.28[a] (-8.09)	-0.77 (-1.90)	-0.29 (-0.72)	-0.23 (-0.57)	-0.14 (-0.35)	-4.71 (-11.63)
Alternative 41-121	-0.45 (-1.11)	+3.41[b] (+8.42)	-2.13 (-5.26)	-1.56 (-3.85)	-0.14 (-0.35)	-0.87 (-2.15)
Alternative 41-114B	+1.90 (+4.69)	+2.28 (+5.65)	+0.01 (+0.02)	-0.17 (-0.41)	0.00 (0.00)	+4.03 (+9.95)
Access Road						
Proposed Action	1.08 (2.67)	0.09 (0.23)		0.13 (0.33)		1.30 (3.23)
Alternative A	+1.47 (+3.63)	-0.09 (-0.23)		+0.12 (+0.28)		+1.49 (+3.68)
Alternative E	-1.08 (-2.67)	+0.19 (+0.45)		-0.13 (-0.33)	+0.12 (+0.30)	-0.90 (-2.25)
Haul Road/Tailings Transport Pipeline Corridor						
Proposed Action	0.26 (0.63)					0.26 (0.63)
Alternative 1	-0.14 (-0.33)			+0.06 (+0.14)		-0.08 (-0.19)
Alternative 3	0.00 0.00					0.00 0.00
Alternative 4	-0.09 (-0.22)					-0.09 (-0.22)
Alternative 5	-0.23 (-0.56)					-0.23 (-0.56)

TABLE 4.4-2 (continued)

PROJECT FACILITIES	AREA OF WETLAND TYPES REMOVED ha (Acres)					ALTERNATIVE TOTAL
	CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	
<u>Railroad Spur</u>						
Proposed Action	0.73 (1.80)		0.34 (0.85)	0.18 (0.44)		1.25 (3.09)
Alternative A	+0.75 (+1.84)		-0.15 (-0.39)	+0.73 (+1.80)		+1.33 (+3.25)
Alternative B	+0.87 (+2.14)		-0.11 (-0.29)	-0.07 (-0.16)		+0.69 (+1.69)
Alternative C	+0.12 (+0.30)	+0.79 (+1.96)	-0.34 (-0.85)	+0.26 (+0.64)	+0.79 (+1.95)	+1.62 (+4.00)
Alternative E	+1.00 (+2.47)		0.00 0.00	0.00 0.00		+1.00 (+2.47)
Alternative F	+0.83 (+2.06)		0.00 0.00	+0.10 (+0.24)		+0.93 (+2.30)
<u>Water Discharge Pipeline</u>						
Proposed Action	1.54 (3.82)	0.35 (0.86)	0.29 (0.72)	0.23 (0.57)	0.35 (0.86)	2.77 (6.83)
Alternative B	-1.31 (-3.24)	-0.35 (-0.86)	-0.29 (-0.72)	-0.21 (-0.52)	-0.35 (-0.86)	-2.51 (-6.20)

[a]Decrease in acreage removed compared to the proposed action.
[b]Increase in acreage removed compared to the proposed action.

TABLE 4.4-3

COMPARISON BETWEEN PROPOSED AND ALTERNATIVE ACTIONS OF THE EFFECT OF HABITAT LOSS ON CARRYING CAPACITY FOR FIVE INDICATOR SPECIES

PROJECT FACILITIES	ACRES OF HABITAT LOST	ESTIMATED NUMBER LOST				
		WOOD FROG (50/ACRE)[a]	VEERY (0.22/ACRE)	RUFFED GROUSE (0.02/ACRE)	SOUTHERN RED-BACKED VOLE (1.7/ACRE)	WHITE-TAILED DEER (0.03/ACRE)
Mine Waste Disposal Facility						
Proposed 41-114C	390	19,500	86	8	663	12
Alternative 41-114B	577	28,850	127	12	981	17
Alternative 41-103	505	25,250	111	10	858	15
Alternative 41-121	485	24,250	107	10	824	15
Access Road						
Proposed Alignment	35	1,750	8	<1	60	1
Alternative A-1	29	1,450	6	<1	49	<1
Alternative E	20	1,000	4	<1	34	<1
Haul Road/Tailings Transport Pipeline Corridor[b]						
Proposed Alignment	5	250	1	<1	8	<1
Alternative 1	8	400	2	<1	14	<1
Alternative 3	5	250	1	<1	8	<1
Alternative 4	6	300	1	<1	10	<1
Alternative 5	7	350	2	<1	12	<1
Railroad Spur[c]						
Proposed Alignment	33	1,650	7	<1	56	1
Alternative A	29	1,450	6	<1	49	<1
Alternative B	30	1,500	7	<1	51	<1
Alternative C	26	1,300	6	<1	44	<1
Alternative E	26	1,800	8	<1	61	1
Alternative F	35	1,750	8	<1	60	1
Water Discharge Pipeline						
Proposed Alignment	35	1,750	8	<1	60	1
Alternative B	5	250	1	<1	8	<1

[a]Estimated carrying capacity for the study area in number per acre.
[b]Acreage of habitat loss is based on a corridor length from the mine/mill site to the previous reclaim pond location (see Figure 3.4-8) and a width of 40 m (130 feet).
[c]Railroad siding not included in acreage lost.

of favorable conditions for major elements such as size, number of wetland classes and interspersion. The consequence of this wetland's removal could be detrimental to wetlands located up and down-gradient from it.

Compared to site 41-114B, these losses represent an increase in the amount of deciduous swamp taken, and decreases in the removal of coniferous swamp and shrub swamp communities (Table 4.4-1). In addition, when compared to site 41-114B, 0.14 ha (0.35 acre) of shallow marsh and 2.13 ha (5.26 acres) of bog would not be affected by 41-121.

For informational purposes, Table 4.4-2 provides comparative data on the differences in wetland area disturbance between site 41-121 and the proposed site, 41-114C.

The impact of site 41-121 on wildlife species would be less than that of site 41-114B (Table 4.4-3). Less wildlife habitat would be affected by site 41-121 and, therefore, the overall reduction in carrying capacity would be lower in comparison to site 41-114B. The effects of site 41-121 on threatened and endangered species are considered to be similar to those described in subsection 4.1.6.3 for the proposed action.

<u>Mine Waste Disposal Facility - Alternative 41-114B</u> - Fourteen wetlands would be affected by construction of Alternative 41-114B. Eight of these wetlands were deciduous swamps (F25, F26, F27, F30, F32, F33, F62 and M3) and three were coniferous swamps (F31, F63 and F66). A bog (F64), shallow marsh (F81), and shrub swamp constitute the remaining wetlands within the perimeter of this alternative site. Four of these wetlands (F31, F63, F65 and F66) scored above the actual mean for the biological function model and, therefore, have greater biological value than other wetlands in the study area but not in the region. All of the

deciduous swamps and the bog and shallow marsh scored below the actual mean which indicated that compared to other wetlands in the study area none were high in terms of biological function. The major factors contributing to the low scores for deciduous swamps have been described under Alternative 41-103.

Wetland F81, a shallow marsh, scored considerably below the actual mean because of the element conditions for biological function. One of the major contributing factors for the low biological function score was its small size (0.14 ha [0.35 acre]). The removal of this wetland would have a minor effect in the study area and region because of its low biological function score.

Table 4.4-2 indicates, for informational purposes only, the differences in wetland acreages affected by site 41-114B and the downsized facility site 41-114C. More area of coniferous and deciduous swamps would be affected by site 41-114B than in the proposed site. Also, more wildlife habitat would be affected by site 41-114B than the proposed site (Table 4.4-3). With site 41-114B, a greater loss of habitat would occur when compared to the proposed action (234 ha [577 acres] versus 158 ha [390 acres]). The effects of site 41-114B on threatened and endangered species are assumed to be similar to those described in subsection 4.1.6.3 for the proposed action.

Summary of Mine Waste Disposal Alternatives - None of the three sites contains all of the optimum environmental characteristics. The advantages of site 41-114B over the other alternatives are in the areas of ground water protection and reclamation which compensate for the incremental disturbance of the moderate to low value wetlands encountered. Alternatives 41-103 and 41-121 are closer to the water table than 41-114B and 41-114C, and as shown below, the depth to saturated stratified drift is equal to or less than that of 41-114B and 41-114C:

Site	Depth to Ground Water		Depth to Stratified Drift	
	m	(feet)	m	(feet)
41-114C*	15	49	35	115
41-114B	15	49	35	115
41-103	10	33	35	115
41-121	8	26	10	33

*Proposed site.

The proposed alternative has an average of 50 percent more till thickness above the water table than does 41-103 and almost twice the thickness of 41-121. The additional till depth at 41-114C provides a greater capacity to attenuate constituents which may seep from the pond and, therefore, offers greater protection to the ground water. Site 41-121 has small quantities of till beneath its southern tailing pond and a portion of it is located directly on the more permeable stratified drift.

Surface water effects vary primarily with regard to reduction in drainage area and surface water input to lakes and wetlands. Unlike sites 41-114C and 41-114B, the alternative sites 41-103 and 41-121 are located within 305 m (1,000 feet) of Duck and Deep Hole lakes. For this reason, use of these sites is prohibited by NR 182.07(b). Alternative 41-103 would be closer to Duck Lake than Alternative 41-121, resulting in a greater potential impact to Duck Lake and associated wetlands.

located further south in area 41 and would remove or alter a major portion of the drainage to Deep Hole Lake.

4.4.1.3 Haul Road/Tailings Transport Pipeline Corridor

The environmental consequences to wetlands and wildlife habitat of the four alternative haul road/tailings transport pipeline corridors are summarized below. Figure 4.1-4 illustrates the various routes.

The total length of Alternative 2 (1,245 m [4,080 feet]), the proposed route, is approximately the same as that for Alternatives 1 (1,265 m [4,150 feet]), 3 (1,302 m [4,270 feet]) and 4 (1,408 m [4,610 feet]) (see Chapter 3, subsection 3.4.2.2) and each would cause a disturbance to, and partial filling of, wetland F11, a coniferous swamp, which drains into F10 and ultimately into Little Sand Lake. Only Alternative 1 would cross wetland F116. The total length of Alternative 5 is the longest (1,543 m [5,060 feet]) of all routes considered and it is the only alternative that avoids all wetlands.

The proposed route and Alternative 3 would fill slightly more of F11 than would Alternative 4 and both would exist entirely in the watershed of F11. This would increase the discharge of F11 slightly because of increased surface water runoff as a result of the haul road. Alternative 4 is primarily located in the watershed of wetland F11, but part of the route follows the watershed divide between F11 and F10. However, given the small area that would be affected with any of the alternatives compared to the size of F11, the effect on biological function would be minimal. Table 4.4-4 presents a comparative analysis of wetland acreages removed by the various alternatives. This analysis

TABLE 4.4-4

COMPARISON OF WETLAND AREA REMOVED BETWEEN PROPOSED AND ALTERNATIVE ACTIONS DURING CONSTRUCTION OF ANCILLARY PROJECT FACILITIES

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE	AREA OF WETLAND TYPES REMOVED ha (ACRES): CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL	ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[a]
Access Road											
Proposed			1.08 (2.67)	0.09 (0.23)		0.13 (0.33)			1.31 (3.23)		
Alternative A-1	W1	CS[b]	0.73 (1.80)					0.73 (1.80)	2.80 (6.91)	6.14 (15.19)	101
	W2	CS	1.82 (4.50)			0.25 (0.61)		2.07 (5.11)		16.76 (41.42)	102
Alternative E	R3	SM[c]					0.01 (0.02)	0.01 (0.02)	0.40 (0.98)	8.68 (21.44)	116
	R7	DS[d]		0.28 (0.68)				0.28 (0.68)		0.50 (1.26)	62
	Z20	SM					0.07 (0.18)	0.07 (0.18)		16.60 (41.03)	99
	Z22	SM					0.04 (0.10)	0.04 (0.10)		7.47 (18.48)	102
Haul Road/Tailings Transport Pipeline Corridor											
Proposed			0.26 (0.63)						0.26 (0.63)		
Alternative 1	F11	CS	0.12 (0.30)					0.18 (0.44)	0.18 (0.44)	7.26 (17.99)	78
	F116	CS				0.06 (0.14)				0.24 (0.59)	58
Alternative 3	F11	CS	0.26 (0.63)					0.26 (0.63)	0.26 (0.63)		
Alternative 4	F11	CS	0.17 (0.41)					0.17 (0.41)	0.17 (0.41)		
Alternative 5	F11	CS	0.03 (0.07)					0.03 (0.07)	0.03 (0.07)		

TABLE 4.4-4 (continued)

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE	AREA OF WETLAND TYPES REMOVED ha (Acres): CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL	ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[a]
Railroad Spur											
Proposed			0.73 (1.80)		0.34 (0.85)	0.18 (0.44)			1.25 (3.09)		
Alternative A	01	CS	0.28 (0.68)					0.28 (0.68)	2.58 (6.34)	46.79 (115.54)	89
	T2	B[e]			0.19 (0.46)			0.19 (0.46)		0.67 (1.65)	93
	T4	CS	1.20 (2.96)			0.91 (2.24)		2.11 (5.20)		18.09 (44.78)	118
Alternative B	01	CS	0.79 (1.95)					0.79 (1.95)	1.94 (4.78)		
	T2	B			0.23 (0.56)			0.23 (0.56)			
	T4	CS	0.81 (1.99)			0.11 (0.28)		0.92 (2.27)			
Alternative C	HC[f]		0.85 (2.10)			0.44 (1.08)	0.18 (0.45)	1.47 (3.63)	2.87 (7.09)		
	F12	SM					0.30 (0.74)	0.30 (0.74)		6.41 (15.83)	107
	F15	DS		0.79 (1.96)			0.31 (0.76)	1.10 (2.72)		13.81 (34.09)	96
Alternative E	01	CS	0.92 (2.27)					0.92 (2.27)	2.25 (5.56)	46.79 (115.54)	89
	P2	CS	0.15 (0.38)					0.15 (0.38)		8.42 (20.78)	85
	T1	B			0.16 (0.40)			0.16 (0.40)		0.77 (1.91)	72
	T2	B			0.18 (0.45)			0.18 (0.45)		0.67 (1.65)	93
	T4	CS	0.65 (1.60)			0.18 (0.44)		0.83 (2.04)		18.09 (44.78)	118
	T5	CS	0.01 (0.02)					0.01 (0.02)		0.57 (1.41)	78

TABLE 4.4-4 (continued)

PROJECT FACILITIES	WETLAND NO.	DOMINANT WETLAND TYPE	AREA OF WETLAND TYPES REMOVED ha (Acres) CONIFEROUS SWAMP	DECIDUOUS SWAMP	BOG	SHRUB SWAMP	SHALLOW MARSH	WETLAND TOTAL	ALTERNATIVE TOTAL	WETLAND SIZE ha (Acres)	BIOLOGICAL FUNCTION MODEL SCORE[a]
Alternative F	P2	CS	0.15 (0.38)					0.15 (0.38)	2.18 (5.39)	8.42 (20.78)	85
	I1	B			0.16 (0.40)			0.16 (0.40)		0.77 (1.91)	72
	I2	B			0.18 (0.45)			0.18 (0.45)		0.67 (1.65)	93
	I4	CS	0.66 (1.63)					0.66 (1.63)		18.09 (44.78)	118
	W1	CS	0.14 (0.34)			0.07 (0.17)		0.21 (0.51)		6.14 (15.19)	101
	Z14	CS	0.57 (1.40)			0.21 (0.51)		0.78 (1.91)		29.88 (73.78)	109
	Z15	CS	0.04 (0.11)					0.04 (0.11)		3.82 (9.42)	90
<u>Water Discharge Pipeline</u>											
Proposed			1.54 (3.82)	0.35 (0.86)	0.29 (0.72)	0.23 (0.57)	0.35 (0.86)		2.72 (6.73)		
Alternative B	W1	CS	0.23 (0.58)			0.02 (0.05)		0.25 (0.63)	0.25 (0.63)	6.14 (15.19)	101

[a]Model and actual ranges and means are shown in Table 4.4-1.

[b]Coniferous Swamp; [c]Shallow Marsh; [d]Deciduous Swamp; [e]Bog.

[f]Unnumbered wetlands located in vicinity of Hemlock Creek.

includes the wetland area within each corridor from the mine/mill site to the previously proposed reclaim pond location (Figure 3.4-8). The proposed route will extend an additional 750 m (2,460 feet) from the previously proposed reclaim pond area to the southwest corner of the current reclaim pond location (Figure 3.4-8).

The losses in carrying capacity of the five indicator species resulting from habitat reduction attendant with the four pipeline alternatives are compared in Table 4.4-3. Alternatives 1, 4 and 5 would result in somewhat greater losses than those incurred with the proposed alignment and Alternative 3. Nonetheless, all of these losses of wildlife habitat are relatively small and are not considered critical from a regional perspective.

Alternative 4 has an additional traffic impact in that it parallels, for a short distance, the existing Sand Lake Road. During certain phases of the Project life, heavy duty off-road haul trucks will be making several trips to and from the mine/mill facility and the MWDF and could pose a safety hazard. Also, Alternative 5 would require relocation of a 300-350 m (985-1,150 feet) segment of Sand Lake Road. The existing road corridor would have to be widened to accommodate the Project facilities and a new area cleared for Sand Lake Road.

4.4.1.4 Railroad Spur

The wetland and wildlife impacts of the various alternative railroad spur routes are summarized below. Alternative routes are shown on Figure 4.1-7. Wetlands affected by each alternative are identified in Table 4.4-4. Because of the number of wetlands affected and the small wetland areas disturbed, none of the alternatives represent a major decrease in wetland area or biological function resulting from Project construction and operation.

Railroad Alternative A would be 3.9 km (2.4 miles) long from the Soo Railroad mainline to the mine/mill perimeter, some 0.5 km (0.3 mile) shorter than Route D, the proposed route (see Chapter 3, subsection 3.4.3.1), yet Alternative A would require the filling of approximately 2.5 ha (6.3 acres) of wetlands, which is twice that required by Route D (Figure 4.1-7). Alternative A would cross Swamp Creek three times, thereby requiring much more land disturbance in and around Swamp Creek.

Alternative A would cross wetlands 01, T2 and T4. Wetland T4 is one of the most valuable wetlands in the study area (NAI and IEP, Inc., 1982). Alternative A would cross this wetland twice and would parallel Swamp Creek in some areas and be perpendicular to it in others; this would require a more extensive system of bridges and culverts to maintain existing surface water flow characteristics in the wetlands. Alternative A would cross two wide sections of wetland T4, whereas the proposed route would cross three narrower sections of wetland T4.

Alternative B would be approximately 3.9 km (2.4 miles) long from the Soo Railroad mainline to the mine/mill site perimeter, which is 0.5 km (0.3 miles) shorter than the proposed route; however, Alternative B would require the filling of approximately 1.9 ha (4.8 acres) of wetlands, 0.7 ha (1.7 acres) more than the proposed route (Table 4.4-2). This additional filling would be in wetland 01.

Route C avoids the Swamp Creek wetlands but would cross several perched wetlands, including wetland F12, a shallow marsh surrounded by bur oak. Route C would be located within 220 m (722 feet) of Skunk Lake and would require crossing Hemlock Creek and cutting through a high ridge, an engineering disadvantage. This route would pass along the south edge of the wetland-spring pond complex located west of the intersection with the Soo Railroad. Although the wetlands in this area were not mapped in detail, this alternative route would follow the higher ground south of the wetland and would infringe on the boundary of the wetland-spring pond complex bordering Hemlock Creek.

Routes E and F share a common corridor between the Soo Railroad mainline and a point appoximately 100 m (328 feet) south of the Swamp Creek crossing (Figure 4.1-7). Route E would parallel Swamp Creek for approximately 1.6 km (1 mile) from the interface point with Route D to the southwest portion of Section 19 prior to changing alignment in a southerly direction to the mine/mill site. Route E would have a greater effect on the Swamp Creek deeryard and wetlands than all other alternatives except Route A (see Table 3.4-2). This route would also pass within 0.56 km (0.35 mile) of the osprey nest.

Route F would connect to the Soo Railroad mainline at the same point as Route D and would be routed west approximately 1.8 km (1.1 miles) before turning south toward the mine/mill site. Route F would be approximately 225 m (740 feet) longer than the proposed route and would cross both Outlet and Swamp creeks.

Losses in wildlife habitat carrying capacity for the five indicator species for the five railroad spur alternatives are shown in Table 4.4-3. Three alternatives (A, B and C) would result in smaller habitat losses than those incurred with the proposed alignment, whereas losses would be greater for Alternatives E and F.

Both the proposed alignment and the alternatives would remove coniferous swamp habitat from the Swamp Creek deeryard. Most of the coniferous swamp wetland type that would be affected by construction of the proposed or alternative railroad spur routes is within or immediately adjacent to this deeryard. These losses represent only 1 percent or less of the total area of the deeryard.

4.4.1.5 Access Road

The environmental consequences to wetlands, wildlife, habitat and safety for the various alternative access road routes (Figure 4.1-6) are summarized below.

Access road Alternative A-1 would be 3.9 km (2.5 miles) in length, 0.8 km (0.4 miles) shorter than the proposed route, resulting in a slight decrease in runoff from the pavement to Swamp Creek. However, Alternative A-1 would require filling approximately 2.8 ha (6.9 acres) of wetlands compared to 1.3 ha (3.2 acres) for the proposed route (Figure 4.1-6). Alternative A-1 crosses only wetlands W1 and W2, whereas the proposed route crosses narrow sections of W2, Z6, Z7 and Z9. Wetland W2 had high scores for functional values (NAI and IEP, Inc., 1982), whereas wetlands Z6, Z7, and Z9 have lower scores (IEP, Inc., 1983). Crossing a large section of wetland area (Alternative A-1) would have a greater potential hydrologic impact to the watershed functions (NAI and IEP, Inc., 1982) than would crossing small sections (proposed route).

Alternative E would follow the existing route of Sand Lake Road from State Highway 55 to the mine/mill site. As a result it would not disturb any new wetlands. The road would require upgrading, consisting of some widening and paving and thus would cause minor additional disturbance to the wetlands adjacent to the existing road (Table 4.4-4). The paving will increase runoff over that of the existing gravel sections of the road. This increase will be small, however, when compared with the construction of a new road, such as the proposed route or Alterative A-1. No new crossing of Swamp Creek would be required and there would, therefore, be no hydrologic alterations of associated wetlands.

With Alternative A-1, 2.6 ha (6.3 acres) of coniferous swamp habitat would be removed from the Swamp Creek deeryard. This represents only 0.3 percent of the approximately 784-ha (1,940-acre) yard. In comparison, the proposed alignment will take 1.1 ha (2.7 acres) or 0.1 percent of the total yard. This deeryard would not be impacted with Alternative E. The losses of deeryard acreage, because of either the proposed alignment or Alternative A-1, are not considered critical, given that five deeryards are located within an 8.9-km (5.5-mile) radius of the Project site.

The losses of habitat carrying capacity for the five indicator species for the two alternatives are summarized in Table 4.4-3. Overall, the proposed alignment will have a greater impact than the alternatives. Of the two alternatives, Alternative E would result in a smaller loss in total wildlife carrying capacity than Alternative A-1. However, none of these losses is considered major from a regional perspective.

Route E would increase traffic over 60 percent in a residential area which includes the Mole Lake Sokaogon Chippewa Reservation, as compared to the traffic flow generated by Route A-1.

4.4.1.6 Surface Water Discharge

Two potential surface water discharge locations are identified in Chapter 3. Both locations are on Swamp Creek (Figure 4.1-5). The impacts projected for the proposed site, Alternative A, are discussed in Sections 4.1 and 4.2.

Alternative Route B represents essentially the shortest, most direct and least expensive route available for a surface water discharge to Swamp Creek. The route is less than 1.6 km (1 mile) long and could be constructed in the proposed Project access road corridor, which would minimize the land disturbed. Wetland W1, a coniferous swamp, would be the only wetland community affected by Alternative B (Table 4.4-4). However, the Alternative B discharge location is upstream of Rice Lake in a section of Swamp Creek designated by the DNR as a Class II trout stream. The losses in carrying capacity for the five indicator species are compared for the discharge pipeline alternative and the proposed alignment in Table 4.4-3. The total loss of wildlife habitat with Alternative B is substantially less than that of the proposed alignment.

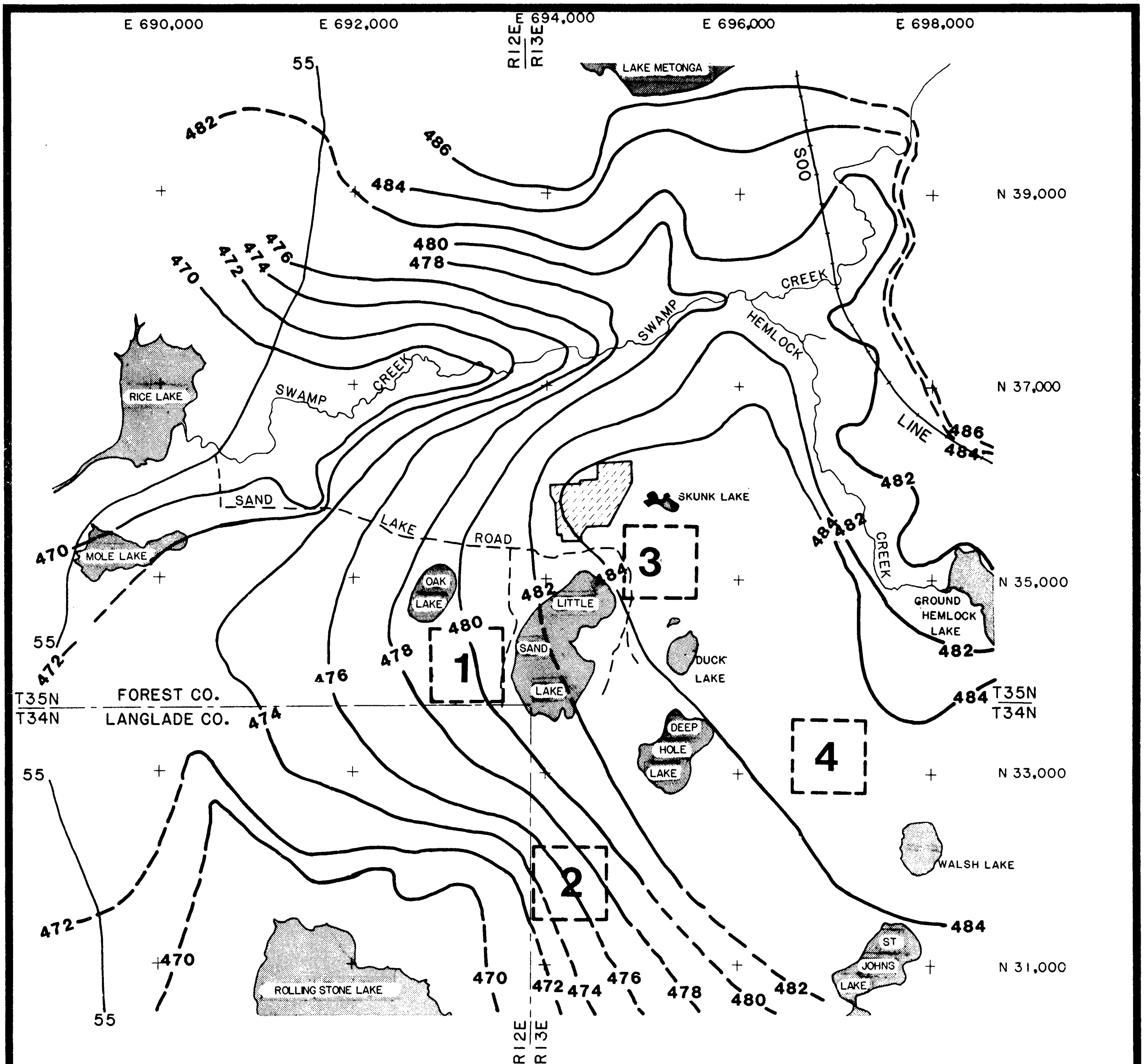
The discharge structure would be essentially the same at either location. Construction access would be facilitated with Alternative B because the route could be built in the Project access road corridor. However, the actual construction impacts, although anticipated to be minor as stated in Section 4.1, could be more negative at Alternative B than the proposed route because of the lower flow in Swamp Creek at the discharge site for Alternative B and because a Class II trout stream would be affected.

Compared to the proposed alignment, the wetland losses associated with Alternative B represent decreases of 1.21 ha (3.0 acres) in the amount of coniferous swamp removed; 0.35 ha (0.86 acre) of deciduous swamp, 0.29 ha (0.72 acre) of bog, 0.21 ha (0.52 acre) of shrub swamp and 0.35 ha (0.86 acre) of shallow marsh (Table 4.4-2). Overall, Alternative B would affect 2.51 ha (6.2 acres) less of wetland vegetation than the proposed route.

Because of the sensitive areas potentially affected by a discharge at Alternative B (i.e., Rice Lake and Class II trout waters), Alternative A, the proposed location, is the alternative with the least potential overall environmental impact.

4.4.1.7 Ground Water Discharge

In Chapter 3, subsection 3.4.3.5 four locations are identified and evaluated for discharge of excess treated water via a seepage lagoon. Of these four locations only Areas 2 and 3 (Figure 4.4-3) have subsoil materials with permeabilities high enough to be practical locations for seepage lagoon construction. During the operational period of these lagoons, the glacial soil material beneath them would become saturated and a ground water mound would form. A lagoon in Area 2 would alter the configuration of the ground water potentiometric surface below and immediately surrounding the pond but should not have any detrimental effect on the hydrogeologic regime. In Area 3 a ground water recharge mound would tend to mitigate the effect of mine dewatering on the hydrogeologic regime. In all cases the water in the lagoons for infiltration would be of the quality required to meet



LEGEND

——— GROUND WATER ISOPLETHS (contours) IN METERS ABOVE MSL

– – – GROUND WATER ISOPLETHS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA

[ ] GROUND WATER RECHARGE AREAS

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

GROUND WATER RECHARGE AREAS

SCALE METRIC	STATE WISCONSIN	COUNTY FOREST
DRAWN BY C.A. HACKER	DATE 8/82	CHECKED BY H.S. Lucas DATE 12/8/82
APPROVED BY	DATE	APPROVED BY C.C. Schroeder DATE 12/82
APPROVED BY	DATE	EXXON
DRAWING NO **FIGURE 4.4-3**	SHEET 1 OF 1	REVISION NO 0

appropriate discharge permit standards and would also have to meet ground water quality standards at the compliance boundary.

The impacts associated with ground water discharge are primarily surface disturbance with reduction of ecological habitat. The surface area required for pond construction will vary directly with the hydraulic conductivity of the soil. With a pond 9.0 m (30 feet) deep, an effluent discharge of 0.126 m^3/s (2,000 gallons per minute) could be seeped from a pond or ponds with a combined seep area of 16 to 18 ha (40 to 44 acres).

Area 3 is closer to the water treatment facility than any other site and would, therefore, require less surface disturbance for the construction of the discharge pipeline than would the other areas. However, Area 2 probably has better surface soil characteristics than Area 3 and would require less surface disturbance.

4.4.2 Structural/Operational Alternatives

4.4.2.1 Waste Rock Transport

Chapter 3 contains a discussion of the use of an overland conveyor instead of trucks to transport waste rock from the mine/mill facilities to the preproduction ore storage pad. Its use would substantially reduce haul road fugitive dust. However, this difference is minor and would be offset by the reduced operating flexibility and increased initial capital cost of the conveyor system.

4.4.2.2 Tailings Transport System

The proposed tailings transport system consists of three buried pipelines from the mine/mill facilities to the MWDF. The alternative is to install the pipelines on the surface. Although the costs of the two systems would be similar, an above ground system would not be as aesthetically acceptable as the proposed system even though either would be placed within the waste rock transport system corridor.

Engineering design for the above ground system would need to consider the possible addition of dump stations at low points in the line to accommodate emergency shutdowns during freezing weather. More land may be disturbed with the above ground system if additional facilities were needed such as dump stations and containers to drain tailings from the pipeline. Surface lines, unlike the proposed system, are also subject to vandalism and accidental damage from moving vehicles.

4.4.2.3 Tailing Disposal Methods

Three alternative disposal methods were evaluated for the Project: dry, subaerial, and modified subaqueous. The modified subaqueous method has been proposed as the waste disposal method. General descriptions of the advantages and disadvantages of the dry and subaerial methods are presented below and are followed by a more specific discussion of potential impacts to wetlands, surface water, ground water, and air quality.

The impact comparisons presented below are based on the previous subaerial and dry disposal facility designs reflecting the previous larger ore reserve. If these facilities were redesigned for the reduced ore reserve, they would be reduced in size proportion to the size reduction for the proposed facility.

Both the subaerial and dry methods offer similar advantages and disadvantages in their environmental effects. The major environmental advantages of these two methods of tailing disposal are the reduction in surface land area required and the potential decrease in water available in the tailings for seepage. The major environmental disadvantage is found in the subaerial method where, because of its continuous operating mode, reclamation is delayed until the completion of tailing disposal.

The reported environmental advantages of the subaerial method result from thin layer deposition of the tailings with estimated increased densities of approximately 25 to 30 percent. This consolidation reduces the tailings permeability so that more water is removed by surface decantation and less water is available for seeping to the ground water. Another reported advantage is the increased density and material strength which requires less surface area for disposal. For example, a subaerial facility would require 115 ha (284 acres) or approximately 79 percent of the proposed method (146 ha [360 acres]). The reduction in surface area required for disposal also would reduce the potential impacts to wetlands and other aquatic and terrestrial ecosystems.

The dry method of tailings disposal potentially has the advantages of reduced surface area and less water for percolation as stated above. However, it has additional advantages; specifically, reclamation can begin immediately and the soil material for the cover would not have to be stockpiled and, thus, would not be subject to nutrient leaching.

A discussion of the potential impacts of the subaerial and dry disposal methods on wetlands, surface water, ground water, and air quality, in comparison to the proposed modified subaqueous method, is presented below.

Subaerial Disposal Method - Potential impacts which could occur during the construction, operation and reclamation phases of the Project as a result of tailings disposal by the subaerial method are generally similar but on a somewhat reduced scale to those associated with the proposed wet method. Although most of these reduced activities would indicate fewer environmental effects, application of the subaerial technology has been limited in a climatic region such as northeastern Wisconsin. Because of that, there is a higher uncertainty associated with the performance of this system.

The major features of the subaerial method are primarily related to water removal from the tailings. Similar features will be incorporated in the proposed subaqueous method to the extent that they are possible. The underdrain is the main feature in this respect.

One of the most significant differences between the subaerial method and the proposed wet system is the method of deposition of the tailings. In the subaerial method, the tailings are deposited in thin (102-mm [4-inch]) layers and are allowed to partially dry before another layer is deposited. Partial drying causes the formation of a dense layer of tailings. In this manner, an overall higher density of tailings may be achieved.

The operation of this process requires that two deposition areas be available at any one time for the alternating flooding and drying process. This requires that the entire subaerial facility be constructed and operated for most of the mine life. The impacts of this method relative to the proposed wet method are expected to be as follows:

<ins>Wetlands</ins> - Overall, wetlands impacts are expected to be about the same. Although the proposed facility has a bigger size (146 ha [360 acres]), its development is phased, allowing material stockpiles and construction work areas to be located within the confines of the facility. While the subaerial facility is smaller (115 ha [284 acres]), it must be operated in a fully developed or completed configuration, meaning reclamation material stockpiles, borrow areas, work areas and other construction support areas must be located outside the confines of the subaerial facility. When these factors are taken into account, the total area impacted (either by the facility or to support its construction) is higher (220 ha

[543 acres]). However, the impacts at any one time for the subaerial facility will be slightly higher because the phased nature of the proposed system will require only approximately 40 ha (100 acres) to be in operation at any one time.

Surface Water - Potential surface water impacts from development of the subaerial disposal system should be similar to those associated with the proposed wet system. Erosion control measures, similar to those described in Chapter 1, subsection 1.3.1.7 for the proposed wet system, also would be applied for the subaerial method. These erosion control measures would control surface water runoff from the active construction and operation area and would ensure that surface water quality outside the confines of the facility would not be adversely affected.

When reclamation is complete, the subaerial disposal facility should have a reduced effect to surrounding surface waters because of its projected smaller overall size in contrast to the proposed wet facility. The reclamation system for the proposed facility, including the seal and the surface water management work in the 366-m (1200-foot) perimeter area, will minimize the potential for impacts to surface water bodies. However, because it does encompass a larger area than the subaerial facility, there would be a greater potential for impacts since the reclamation seal and work in the 366-m (1200-foot) zone would be comparable for either facility.

Ground Water - Overall, the impacts to ground water should be lower for the subaerial method due to the lesser area involved. However, during the operating life they may be equal or higher because of the greater active area involved with the subaerial system. The unit seepage rate for the two systems should be the same because the liner/underdrain systems would be the same.

Air Quality - Construction/Reclamation - Emissions will be generated from the excavation and deployment of soil materials and the associated construction equipment activity at the MWDF. Potential impacts associated with the subaerial method are expected to be less than those related to the proposed wet system because of less earthwork required for MWDF construction and the shorter time and fewer pieces of equipment required to develop the facility. The proposed facility has an estimated total excavation of approximately 11 M m^3 (15 million cubic yards), whereas the subaerial facility is estimated at approximately 5 M m^3 (6.6 million cubic yards).

Air Quality - Operation - Because of the smaller area required for the subaerial system, wind blown air emissions could be lower. However, the smaller area will be offset by a longer time of exposure to wind for the subaerial system because of the phased reclamation of the proposed system. The exact amount will depend upon the nature of the deposited tailings, area exposed, efficiency of dust control measures, and the wind velocity and direction. However, the minimum moisture content of the tailings (i.e., 10 percent) will preclude dusting as can be estimated by the EPA emission factors.

Because of the similarities in design between the two systems (i.e., underdrain), the proposed system may achieve higher than projected densities. In that case, the ultimate facility size may be reduced. Conversely, if the subaerial facility did not fully achieve the tailings density increases and other expected benefits, then its final stage of development would be increased in size. As a result, the expected differences between the environmental impacts associated with the two systems could be less than indicated above.

The greatest drawback to the subaerial system is the uncertainty of its performance in northern Wisconsin where precipitation exceeds evaporation and long periods of below-freezing temperatures are experienced. Additional operating experience is necessary to confirm the projected performance of this system which is now based on laboratory and engineering studies.

Dry Disposal Alternatives - The differences in concept between the dry disposal alternatives (cut and cover and landfill) and the proposed wet method are much greater. The technology to dewater the tailings is the most uncertain element of the dry disposal concept. The cost and performance unknowns for dewatering preclude a commitment to the dry disposal method at this time. In addition, the physical properties of the dewatered tailings are not sufficiently well known to assure that either of the conceptual designs (cut and cover or the landfill system) will work.

Based on the above information, it is possible to comment on the potential impacts as follows:

Cut and Cover Method - It is estimated that the cut and cover method would require a total excavation of approximately 16 M m^3 (21.0 million cubic yards). This is approximately 4.6 M m^3 (6.0 million cubic yards) greater than the proposed wet method. Earth moving equipment usage would be much less, consisting of a dragline and a dozer for grading the covered tailings. This equipment would, however, operate continuously throughout the life of the mine as compared with the periodic pond construction of the proposed wet method. Reclamation for the cut and cover system would be ongoing and would be completed in final form in a much shorter time.

A comparison of the potential impacts is as follows:

Wetlands - Overall, the wetlands impacts are expected to be equivalent or somewhat greater due to the aerial extent of the cut and cover operation compared to the proposed wet method area requirement of approximately 146 ha (360 acres). However, if the angle of the repose of the filtered tailings is less than that predicted in the analysis, the cut and cover operation could require more land area.

Surface Water - If the cut and cover alternative worked as proposed, there would be little change in existing surface water quality. Infiltration and ground water recharge, which presently occur throughout the area, would continue during operation and reclamation of the facility through the windows between the disposal trenches. The relatively low surface runoff now occurring in the area could be accomplished with the final detailed reclamation grading plans. There would be flexibility in the layout and grading of the trench and tailings cover layer to achieve a desired balance of runoff versus infiltration.

Ground Water - In the cut and cover method, ground water protection depends upon the impermeability of the tailings mass and the angle of repose to prevent infiltration of precipitation through the tailings. The method of construction does not permit the installation of a liner or a top cover. Recent investigations have indicated that the top cover is most important in the prevention of long-term facility seepage which could cause ground water impacts (Appendix 4.1A). Ground water impacts will probably be greater without the positive control afforded by the liner and top cover systems.

Air Quality - Emissions generated from the deployment of soil materials and the associated construction activities are expected to be less than that for the proposed wet system. Windblown emissions from the tailings themselves are also expected to be less due to the short time interval before reclamation.

Landfill Method - In the landfill method, a total excavation of approximately 8 M m^3 (10.5 million cubic yards) is required. This is less than the 11 M m^3 (15.0 million cubic yards) required by the proposed system. As in the cut and cover method, equipment usage is continuous throughout the life of the mine but at a lower level of utilization than the proposed wet method. Reclamation would also be ongoing and would be completed sooner than the proposed method.

A major uncertainty associated with the landfill method, in addition to the dewatering process, is the physical characteristics of the dewatered tailings. For this method to be successful, the tailings must be workable by means of earth moving equipment. The filtered tailings should be able to withstand equipment bearing pressures, and should not be excessively plastic, sticky, nor difficult to move. It will be necessary to work the tailings during periods of heavy rain, snow and freezing temperatures. This lack of confidence in a knowledge of the workability of the dewatered tailings is a serious impediment to the application of this method.

As in the case of the cut and cover method, the potential impacts of this method are as follows:

Wetlands - Overall, the wetlands impacts are expected to be equivalent or somewhat less than the proposed system due to the lesser amount of earth work estimated to be required. This, of course, depends greatly on the strength and flow properties of the filtered tailings. If the tailings are strong and non-plastic, then they can be stacked higher and thus occupy less area. The reverse is, of course, also true. If the tailings are weak and plastic, then the land requirements will be substantially greater.

Surface Water - A reclamation seal would be employed for the landfill method which would have the same "umbrella effect" as for the proposed wet facility or the subaerial facility. The ultimate size of the facility would depend upon the success of the tailings dewatering and handling steps. Assuming favorable results, the landfill dry disposal facility would be smaller than the proposed facility and the potential for surface water impacts would be reduced.

Ground Water - The landfill method lends itself to the installation of both a liner/underdrain system and a top cover/overdrain system. These systems, in combination with the reduced area requirements, theoretically provide the maximum ground water protection. Thus, ground water impacts with a successful landfill-type dry disposal system should be the least.

Air Quality - Total air emissions from the landfill method are also expected to be less than that from the proposed wet method. This conclusion results from the lesser amount of earth work estimated to be required and the rapid reclamation of exposed tailings.

The landfill-type dry disposal method has a number of conceptual advantages that make it appear to be environmentally desirable. When equipped with liner and top seal systems, it offers theoretically the maximum ground water protection. However, it has the most risk of all of the methods studied for the Project. The costs and the effectiveness of the technology related to the filtering of the tailings are highly uncertain. Likewise, the strength and flow properties of the dewatered tailings remain largely unknown. When taking into consideration the climatic conditions under which the system must successfully operate and the potential for liquefaction and flow of the tailings under load, the possibility of environmental impacts is many times greater than those that might be attributed to the proposed wet method. It is the potential severity of environmental impact and the uncertainty associated with the successful operation of the dry disposal system that rules out its application.

Although the potential environmental effects from the use of either the subaerial or dry method are largely beneficial, their current use is limited and there is no assurance that their potential benefits could be realized for the Project. Test results for the subaerial (Knight & Piesold, 1982) and dry (Scheiner, 1982) methods have been encouraging. However, further development or operating experience would be necessary to fully evaluate these systems before implementation of either for the Project tailings disposal. The ability to filter the fine tailings to produce the "dry" product for disposal is questionable.

4.4.2.4 Tailing Ponds Leachate Management

Four alternatives to the proposed leachate management system are described in Chapter 3. The most important feature of the system is the combination liner and underdrain system. The proposed facility includes an underdrain system which reduces the head on the liner to such a small depth that the hydraulic gradient across the liner approaches unity. Therefore, flow across the liner, or seepage, is then dependent upon the permeability of the liner, not its thickness.

Native clays having a permeability of 1×10^{-9} m/s are generally recommended for consideration as liner materials for solid waste disposal facilities in Wisconsin. The proposed bentonite modified soil admixture liner will be constructed using a permeability of 5 x

10^{-10} m/s standard in accordance with strict quality control procedures. This permeability is one-fifth that of the native clays. Therefore, seepage across a native clay liner is expected to be five times that across the proposed system.

In addition, native soil materials, meeting the material guidelines for liners, have not been found in required quantities within an economical haul range of the MWDF. The closest known potential sources are in the area of Goodman in Marinette County, about a 64-km (40-mile) one-way haul, and Fence in Florence County, about a 84-km (52-mile) one-way haul. Hauling costs alone would be near $30 million for the 1.7 M m^3 (2.2 million cubic yards) of material required for a traditional thickness lining of 1.5 m (4.9 feet). This total cost is many times that of the proposed liner material. In conclusion, native material offers no major benefits over the proposed system and requires borrowing and hauling large volumes of material.

Polymeric materials, in general, have low permeabilities and, therefore, make good liners. In practical terms, however, pond seepage depends on liner integrity, which in turn is dependent primarily upon fabrication techniques and accidental and unknown damage. These liners typically have a manufacturer's guaranteed life in excess of 30 years, making them suitable for a reclaim pond application or other locations, such as the top cover, that are accessible for repair or replacement.

Surface sealants like polymeric materials have low permeabilities; however, since seepage depends on liner integrity, these systems which are brittle and subject to fracture and relatively high construction cost may not be practical for long-term seepage control.

4.4.2.5 Water Treatment

In Chapter 3, subsection 3.5.7.1 two treatment processes are described that are considered viable for treatment of process (recycle) water from the Project. These two systems, designated as system 9 (carbonate precipitation, pH adjustment, filtration, reverse osmosis/vapor compression evaporation) and system 10 (lime precipitation, pH adjustment, filtration, vapor compression evaporation) can meet process requirements and water quality discharge criteria. System 9 was selected for use in treating process water as being the most economic and would also produce a marketable by-product (sodium sulfate).

Four systems are identified in Chapter 3 that are considered viable for the treatment of both contaminated mine water and intercepted ground water for discharge. All of these systems can, depending on the quality of the influent, meet water quality discharge criteria. They are all refinements of System 1 and are listed below:

1) System 1 - Lime precipitation, filtration, pH adjustment.

2) System 11 - Lime precipitation, sulfide precipitation, filtration, pH adjustment. Low levels of sodium sulfide are added to the clarifier.

3) System 12 - Lime precipitation, starch xanthate treatment, filtration, pH adjustment. This system is similar to system 11 with the exception that starch xanthate is added to the clarifier. This system is as effective on contaminated mine water or intercepted ground water as system 11, but has a higher operating cost.

4) System 13 - Carbonate precipitation, sulfide precipitation, filtration, pH adjustment. This system utilizes some soda ash in the

clarifier to enhance sludge formation. It might be helpful in treating water for discharge when the influent has relatively low contaminant levels and the addition of lime alone would produce insufficient sludge for recycle.

System 11 is the process system proposed for use in treating water for discharge and is described in Chapter 1. All of the alternative systems (systems 1, 12 and 13) are different from the proposed system only in reagent addition. With the exception of system 12, the current plant design allows for the immediate implementation of the other alternatives.

4.4.2.6 Surface Water Discharge

Two surface water discharge alternatives to the proposed Swamp Creek discharge are discussed in Chapter 3. These are lake and wetland discharges.

Lake Discharge - The effluent standards and mixing zone requirements that would be imposed for lake discharge will ensure protection of the lake ecosystem. If the water quality standards are met, the only incremental impacts associated with lake discharge would be a possible increase in the lake water surface elevation or discharge flow out of the lake. However, the selected lake would have to be relatively large (i.e., Little Sand Lake or larger) in comparison to the quantity of discharged effluent to meet the mixing zone requirements (limited to 10 percent of the lake's surface area). The water quality standards for discharge water to a lake would be specific to the receiving lake.

Although both lake and stream discharge alternatives are viable, there would be a larger change in surface flow from existing conditions with a lake discharge than the proposed discharge to Swamp Creek. As stated above, the lake would have to be relatively large, or the discharge split and discharged to several lakes so the existing hydrologic conditions in the lake and down gradient streams are not drastically changed.

The base flow immediately below Little Sand Lake, for example, is estimated to be less than 0.028 m^3/s (1 cubic feet per second) (see Table 2.4-19), whereas the estimated Project discharge is approximately 0.11 m^3/s (4 cubic feet per second), resulting in a four-fold increase in base flow rate. However, the base flow at the proposed discharge site on Swamp Creek is approximately 0.54 m^3/s (19 cubic feet per second) and the increase in flow caused by the Project discharge can easily be absorbed in the existing stream capacity.

Also, potential discharge lakes all have adjoining wetlands which could be impacted by the proposed discharge. Discharge to Swamp Creek in accordance with NR 1.95 would provide less potential for adverse impacts on wetlands, and this combined with the greater physical hydrologic effects on lakes and down gradient streams from a lake discharge make discharge to Swamp Creek the alternative with the least overall adverse environmental impact.

Wetland Discharge - Surface discharge of excess water to wetlands would result in some impacts to the hydrology and water quality of the selected wetlands. Water quality should not be significantly reduced because the water quality discharge standards established as part of the WPDES permit program would have to be met. Several large wetland systems capable of handling the projected volume of discharge water are located within close proximity to the Project site. Through further study of wetland hydrology, a wetland system could be selected which would not be adversely impacted by the addition of discharge water over the life of the Project.

A wetland discharge also offers an opportunity to mitigate local hydrological impacts to the ground water and surface water systems. The slow movement of water through wetlands provides increased retention time and more potential for infiltration and replacement of ground water drawdown by mine dewatering. Moreover, wetlands offer greater potential for physical and biochemical removal of constituents remaining in the discharge before the water flows to surface water bodies.

Before a potential water discharge to wetlands could be proposed as the desired alternative, a considerable amount of information/data would be required. As part of the analytical process, potential wetlands would have to be selected to receive the proposed water discharge and seasonal environmental data obtained and evaluated. Concurrent with this analytical process, the DNR would have to develop water quality standards as a basis for the WPDES permit. The standards would probably vary depending on the type of wetland selected (i.e., shrub swamp, conifer swamp, marsh).

Although a wetlands discharge might theoretically have potential, particularly as it may relate to mitigation of Project operational effects, design and year-round operational problems could preclude the use of this alternative. Operational difficulties could be quite variable, depending on the type of discharge water distribution system selected, the hydrological regime of the wetland and the wetland vegetative type selected. During the winter period, frozen ground could prevent the discharge water from penetrating the wetland substrate and channels could form. Water passing through these channels would not have the benefit of the "living filter" function of the wetland ecosystem and could eventually reach a surface water body unattenuated. Without adequate attenuation of some chemical parameters, difficulties could arise in meeting the WPDES permit limits year-round. Overall it remains to be determined whether or not a particular wetland site in northern Wisconsin could be operated effectively throughout the year.

Generically, hydrologic impacts from a wetland discharge would result from an increase in the surface water flow. Initially, this could cause local scouring at the discharge site and possibly produce or increase channeling through the wetland. This may be particularly true during the winter.

Assuming the discharge water would meet DNR water quality standards, there should be no adverse impact to wetland plant and animal communities. Also, because most of the wetlands near the mine/mill site are perched overlying poorly drained low permeability soils, impacts to ground water quality should be negligible.

Realizing that water table wetlands in the site area are discharge points for ground water, it should follow that the discharge of mine intercept water (uncontaminated ambient ground water) at a flow rate commensurate with the size of the wetland should not have adverse impacts to the overall functions of the wetland. However, based on our monitoring of stream flow rates in wetlands, there are no wetland systems in the site area for which a discharge of 0.126 m^3/s (2,000 gallons per minute) would not be a major increase in the estimated base flow rate. Consequently, such an increase could result in some impacts on the watershed functions of the wetland.

4.4.2.7 Ground Water Discharge

Three possible alternatives to surface water discharge are discussed in Chapter 3. These are the use of infiltration basins, injection wells, and drain fields. The impact to the ground water hydrologic regime from any of the three alternatives would be similar. In each case a ground water mound could be expected to form after saturation of the glacial soil material under the ponds or drain fields and around each injection well. Formation of the ground water mounds would not be a permanent feature of the hydrogeologic regime. After mining operations ceased, the ground water mounds would dissipate and the potentiometric surface would return to premining conditions.

The required quality of the water to be discharged in all three alternatives would meet appropriate discharge permit standards and would also have to meet ground water quality standards at the compliance boundary. There would not be any detrimental effects to the ground water quality. The major differences in environmental impacts are non-hydrologic in nature and are discussed below.

Infiltration Basins - Infiltration basins must be located where the hydraulic conductivity of the underlying soils are high enough to allow seepage of the discharge water volume first into the underlying strata and then to the water table or to surface streams. Depending on the soil characteristics, an infiltration basin could require several acres to develop a sufficient infiltration rate. An access road would also be required for maintenance and inspection. Depending on the proximity of the basin to the mine/mill site, because of the need for access, use of infiltration basins would require long-term disturbance of considerably more land than any of the surface discharge alternatives.

Infiltration basins also are subject to clogging from accumulation of sediment or other fine materials on the bottom and sides of the basins. Drying the basin and scouring the bottom material may be required to restore the infiltration rate to its original level. It may be necessary to construct two basins to permit one to be used while the other is being cleaned. This would, however, result in additional land disturbance.

Injection Wells - Injection wells can be used to discharge water directly into the ground water aquifer. Like infiltration basins, the capital and operating cost of the injection system may be higher than any of the alternative discharge systems. Injection wells also are subject to clogging from processes similar to those that occur in recharge basins. This would require cleaning or the development of additional wells. Flexibility does exist so that injection wells can be located to minimize the potential surface water impacts from ground water inflow into the mine.

Drain Field - A drain field would operate in a manner similar to a sanitary septic system. The drain field would be subject to the same hydrologic design restrictions and impacts as the infiltration basin. However, the drain field would result in only temporary surface disturbance while the field was being constructed. Once constructed, there would be no surface manifestation of the facility, although it also would require an access road. Like the infiltration basin, it is subject to clogging and could require subsequent surface disturbance to mitigate malfunctions.

4.4.3 References

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APPENDIX 4.1A

HYDROLOGIC IMPACT ASSESSMENT

(REFER TO EIR VOLUME X FOR THIS APPENDIX.)

APPENDIX 4.1B

INFORMATION USED IN EVALUATING NOISE IMPACTS
IN THE CRANDON PROJECT AREA

APPENDIX 4.1B

4.1B.1 Noise

The range of sound pressures that can be heard by humans varies from sounds that are barely audible to those that are so loud as to be painful. The decibel (dB) notation system uses logarithms to compress this wide range of sound pressures to convenient quantities called sound pressure levels (Beranek, 1971).

$$\text{Sound pressure levels (dB)} = 20 \log_{10} \frac{P}{P_o}$$

P = the measured sound pressure in Pascals or Atmospheres; and

where: P_o = sound pressure required for a threshold sensation of hearing; equal to 20 uPa (microPascals, where 1 microPascal = 10^{-6} newton per square meter) or 0.0002 u Atmosphere.

On the decibel scale, 0 dB is assigned to P_o. Approximately 125 dB is the sound level at the threshold of pain (U.S. Department of Labor, 1980).

The human ear does not perceive sounds at low frequencies in the same manner as those at higher frequencies. Sounds of equal pressure level at low frequency do not seem as loud as those at higher frequencies. To simulate the human ear in evaluations of hearing damage risk or community annoyance impacts (Peterson and Gross, 1967), sound analysis systems incorporate an A-weighting network (American National Standards Institute, 1971a). A-weighted sound levels are expressed in decibels (dB). Typical A-weighted sound levels at a given distance from a sound source and in the environment are shown in Table 4.1B-1.

Because sound is not constant with time, statistical analysis is used to describe the temporal distribution of a sound and to compute single-number descriptions for that sound when actual measurements are

TABLE 4.1B-1

TYPICAL A-WEIGHTED SOUND LEVELS

DECIBELS (dB)	SOUND LEVELS
140	
	50 HP Siren, 30.5 m (100 feet) Jet Takeoff, 61.0 m (200 feet)
120	
	Riveting Machine
100	
	Subway Train, 6.1 m (20 feet)
80	
	Pneumatic Drill, 15.2 m (50 feet) Freight Train, 30.5 m (100 feet) Vacuum Cleaner, 3.0 m (10 feet)
60	
	Speech, 0.3 m (1 foot) Near Freeway Light Traffic, 30.5 m (100 feet)
40	Minimum Levels - Residential Areas in Chicago at Night
	Soft Whisper, 1.5 m (5 feet)
20	Studio for Sound Pictures Threshold of Hearing/Youths 1000-4000 Hz
0	

available from different times (see Appendix 2.8A). The following single-number statistical A-weighted sound levels (National Academy of Science, 1977; Bureau of National Affairs, 1978) from the predictive modeling are used in this analysis to assess sound quality effects:

L_{eq} - The equivalent steady sound level that provides an equal amount of acoustic energy* as the time-varying sound.

L_d - Day sound level, L_{eq} for the daytime period (0700-2200) only.

L_n - Night sound level, L_{eq} for the nighttime period (2200-0700) only.

L_{dn} - Day-night sound level, defined as (U.S. EPA, 1974):

$$L_{dn} = 10 \log_{10} \left(\frac{15 \times 10^{(L_d/10)} + 9 \times 10^{[(L_n+10)/10]}}{24} \right)$$

Note: The U.S. EPA adds a 10 dB correction factor to the night sound level as a weighting to compensate for the greater annoyance of nighttime noise (U.S. EPA, 1974).

4.1B.2 Noise Estimation Model

The noise emanations from the described sources (see sections 4.1B.3 and 4.1B.4) were extrapolated to noise-sensitive areas using a hemispherical divergence model. As the distance from the noise source increases, the sound level** decreases in accordance with an inverse

---

*Acoustic energy can be defined as follows: "Acoustic" means of or relating to sound; therefore, the sound energy of the given part of a medium is the total energy in this part of the medium minus the energy which would exist in the same part of the medium with no sound waves present (American National Standards Institute, 1971b).

**All non-octave band sound levels used in this report are A-weighted unless noted otherwise. Octave band sound levels are all unweighted.

square law. The following mathematical model for estimating sound levels at receiver locations distant from a noise source has been used (consistent with Beranek, 1971):

$$L_p(f) = L_w(f) - 10 \log(2 \pi r^2) - A_1(f,r,t,h) - A_2(f) - A_3(f) - A_4(f) - A_5(f)$$

where:

L_p = sound pressure level, dB re 20 uPa, at receiver location.

f = frequency, Hz

π = 3.14159

L_w = source sound power level, dB re 10^{-12} W. If the source is other than omnidirectional, the sound power may be adjusted to account for source directivity.

r = distance between source and receiver, m.

A_1 = molecular air absorption attenuation, dB as a function of air temperature, t, and relative humidity, h. Values were obtained from CONCAWE (1977).

For noise calculations presented in Chapter 4, subsections 4.1.8 and 4.2.8 and Appendix 4.1B, subsections 4.1B.8 and 4.1B.9, the values used were t = 0°C and h = 55%. For t = 0°C and h = 55%, atmospheric molecular absorption in dB/100 m is:

Frequency band (Hz)	63	125	250	500	1000	2000	4000	8000
Attenuation (dB/100 m)	.01	.04	.08	.18	.53	1.86	6.17	15.6

A_2 = shielding attenuation from manmade structures. Except where specified otherwise, A_2 has been set to 0 for this study.

A_3 = shielding attenuation from land contours, manmade or existing. Except where specified otherwise, A_3 has been set to 0 for this study.

A_4 = shielding attenuation from trees and other vegetative ground cover = 10 dB for distances of more than 150 m (492 feet) for both winter and summer. See discussion below.

A_5 = meteorological effects, can be positive or negative. A_5 has been set to 0 for this study.

Several studies contain documentation on the excess attenuation effects (A_4 in the previous equation) of forests. Typical forest floors of either decaying leaves or needles are "excellent acoustic absorbers" (Reethof et al., 1976) when the width of the forested area is a minimum of 60 m (200 feet). Reethof also stated in his conclusions that:

> "Low frequencies, typical of low-speed truck noise, are attenuated to a far lesser degree than the higher frequencies characteristic of high-speed traffic and industrial noise sources. However, low frequency truck noise is in a frequency range in which the human ear is quite insensitive to sound. A thick litter layer is an important element in the sound absorption process of forests."
>
> "Natural forests should be 200 to 300 feet wide to provide significant noise reduction from traffic."
>
> Cook and Van Haverbeke (1971) stated that:
>
> "Diesel truck noise was reduced to the acceptable level (60 dBa) at 350 feet from a highway with a strip of trees 100 feet wide and 45 feet tall between the highway and the receiver. Without the trees and the sound passing over a field, the noise would have been above the acceptable level out to 450 feet from the highway."

Heisler (1977) stated that "...trees are useful for noise control primarily because they scatter sound waves, which are then absorbed by the ground..." and that "...trees used for noise abatement also influence climate." The following statements (cited in Heisler [1977]) support the concept of forests acting as attenuators. They also indicate that the attenuation effect is occuring in summer and winter.

> "Trees themselves apparently do not absorb much sound. Most investigators now agree that trees are effective in reducing

noise transmission primarily by reflecting and scattering sound waves (Aylor 1975; Reethof et al. 1975). . . Tree bark absorbs only a small amount of sound--usually less than 10 percent (Reethof et al. 1976). . . Foliage is also effective primarily by scattering sound rather than by absorption (Aylor 1972a, 1972b, 1975). . . The most effective sound absorber is the ground beneath trees (Reethof et al. 1975). . . Herrington and Brock (1975) studied the variation of sound reduction in relation to height in a forest and found that by far the greatest reduction was near ground level, apparently because of the strong absorption of sound by the forest floor following scattering by foliage, branches, and boles. Hence, it is the combination of all forest elements that makes forests effective in sound absorption."

The attenuation effects associated with forests reduce the sound level variations associated with thermal plumes which are characteristic of an open field environment (Roth, 1983). Roth attributed the suppression of acoustical variations to the micrometeorological climate of forests produced by the shading from tree foliage and limbs and their interaction as windbreaks which serve to diffuse thermal air currents within the forest.

Quantitative results of the attenuation effects of forests are cited in Giesbers (1984) and include:

"Hess [54] compared the attenuation of the sound level of a diesel engine over open terrain with its attenuation through a mixed forest. He found that the forest attenuated 7 dB more over 100 m. This attenuation includes both ground and vegetational absorption....

The Dutch Government has also investigated the influence of forests on the absorption of traffic noise [125]. The results are expressed in an absorption factor of 0.05 - 0.08 dB(A)/m....

Mitscherlich and Scholzke [89] found that at 120 m from the road a pine forest attenuated 7 dB(A), a deciduous forest 5 dB(A) and a field 3 dB(A) more than a meadow."

Other work by Harrison (1975) for the United States Department of Agriculture (USDA) indicates that maximum acoustic attenuation provided by trees and rocks occurs in the first 150 m (500 feet). The resulting octave band attenuation ranged from 14 dB at 250 Hz to 9 dB at 1,000 Hz and 0 dB above 1,000 Hz. Overall attenuation levels reported by Harrison (1975) for foliage and ground cover were 14 dB for conifers and hardwoods at distances greater than 110 m (350 feet). Also, the Federal Highway Administration (Barry, 1978) allows 10 dB reduction if dense woods are at least 60 m (200 feet) in width between the road source and the receiver.

To account for the effects of the forest surrounding the mine/mill site, A_4 in the above equation has been conservatively set to 10 dB for distances of more than 150 m (492 feet) from the site in summer and winter. Model calculations for distances less than 150 m (492 feet) are not provided in this analysis because no sensitive receptors were located within that proximity to the Project noise sources. As indicated by the literature, the primary noise attenuation factors in the winter are associated with the acoustic reflections/absorption from the tree trunks, branches, pine needles, and ground cover. Although the leaves of hardwood species augment these factors during the summer, the conservative level of 10 dB was still used for A_4.

4.1B.3 Construction Phase Noise Sources

To compute the contribution of construction phase noise sources to the noise sensitive land use areas (Table 4.1B-2) required the sound power level spectrum of individual construction equipment operating at each site or, if the individual equipment inventory was not

TABLE 4.1B-2

APPROXIMATE DISTANCES FROM NOISE SOURCES TO NOISE SENSITIVE AREAS

LOCATION	DESCRIPTION	MINE/MILL DISTANCE (ft)	MWDF DISTANCE (ft)	ACCESS ROAD DISTANCE (ft)	RAILROAD SPUR DISTANCE (ft)	HAUL ROAD/SLURRY PIPELINE DISTANCE (ft)	WATER DISCHARGE STRUCTURE DISTANCE (ft)	EXHAUST FAN WER DISTANCE (ft)	EXHAUST FAN EER DISTANCE (ft)
1	Mole Lake School	18,500	24,000	15,700	28,000	21,000	9,300	15,500	19,000
2	Community Center	12,000	17,500	10,000	22,000	15,000	15,500	8,600	12,800
3	Mihalko Residence	13,000	17,000	3,500	14,000	15,500	26,500	12,600	14,000
4	Residence 3712	19,200	15,500	19,000	9,000	17,500	46,000	21,500	19,300
5	Exxon Field Office	2,900	7,000	4,000	15,000	3,000	24,900	1,750	2,750
6	Webb Residence	6,150	8,000	8,000	18,500	6,500	24,000	4,500	5,500
7	Lake Metonga, South Shore	13,700	16,500	7,100	8,000	15,000	34,000	15,000	15,500
8	Rolling Stone Lake, North Shore	15,000	15,500	16,900	27,500	15,500	21,500	13,500	15,000
9	Ground Hemlock Lake, West Shore	12,500	3,500	14,500	12,500	9,500	38,500	15,500	11,500
10	St. John's Lake	17,700	11,000	20,500	23,500	14,800	39,000	19,500	16,500

available, an estimate of the sound power level emission of the activities. The octave band sound pressure level resulting from each source and activity was logarithmically summed at each receiver location and then A-weighted using a computer model developed by Rice (1980).

The computer model was used to calculate the sound pressure level at each receiver location from the individual equipment or activity sound power level spectrum using the following equation (Beranek, 1971):

$$L_{eq}(f) = L_w(f) - 10 \, Log(2\pi r_o^2) + 10 \, Log \, (UF) - A_t(f)$$

where:

$L_{eq}(f)$ = The equivalent sound pressure level at frequency, (f), at the distance, r_o in meters;

$L_w(f)$ = The source sound power level at frequency, (f);

π = 3.14159;

UF = Usage Factor, the percentage (i.e., expressed as a decimel) of time the construction equipment is in its noisiest mode; and

A_t = The sum of the attenuation factors, A_1 to A_5, discussed in subsection 4.1B.2.

Using a computer allowed a multiplicity of calculations for a general grid in addition to the computations at the noise sensitive receiver locations. Plots of equi-A-weighted sound level contours were prepared from these computer calculations (see Chapter 4, Figures 4.1-13, 4.1-14, 4.2-9 and 4.2-10). To account for the varying noise emanations from each source when estimating impacts, equivalent sound levels (L_{eq}) were used to weight all component noise emanations. The computer model summed the L_{eq} contribution from individual noise sources or activity using the logarithmic addition described in subsection 1.3.5.1.

TABLE 4.1B-3

EQUIPMENT TO BE USED IN MINE WASTE DISPOSAL FACILITY AREA EXCAVATION - CONSTRUCTION PHASE

SOUND POWER LEVEL SPECTRUM, dB

EQUIPMENT*	NO. OF UNITS	UF	OCTAVE BAND CENTER FREQUENCIES (Hz) 63	125	250	500	1K	2K	4K	8K
Scraper Cat 631	10	.13	120	119	118	117	116	110	104	99
Dozer Cat D9	2	.15	115	114	113	112	110	105	99	94
Dozer Cat D8	4	.15	118	117	116	115	114	108	102	97
Dozer Cat D6	2	.15	114	113	112	111	110	104	98	93
Front End Loader Cat 988	2	.30	115	114	113	112	111	110	104	99
Front End Loader Cat 966	1	.30	115	114	113	112	111	105	99	95
Motor Grader Cat 16G	1	.30	112	111	110	109	108	102	96	91
Motor Grader Cat 14G	4	.30	112	111	110	109	108	102	96	91
Excavator Cat 235	2	.70	116	115	114	113	112	111	105	100
Backhoe JD 410	1	.15	105	104	103	102	101	95	89	84
Dump Truck Ford LT-9000	9	.50	130	129	128	127	126	120	114	109
Belly Dump Truck and Trailer	5	.50	128	127	126	125	124	118	112	107
Compactor CAT 825	3	.1	106	105	104	103	102	96	90	85
Compactor Raygo 400A	3	.1	106	105	104	103	102	96	90	85

*While this list is representative, it is only intended to show the types and numbers of equipment. The actual manufacturers and model numbers could change depending on final engineering and product availability.

Notes:

1. The basis for the equivalent sound power (eL_W) data for the equipment shown above is from literature sound pressure levels (L_p data at 15 m (50 feet) (Kessler, 1978; Pygin, 1982). The procedure summarized below shows the specific calculation for the above Scraper Cat 631 for which the A-weighted pressure level (L_p) is 87 dB at 50 feet. This same procedure has been used for other equipment throughout this report where noise emission was available as sound pressure level data at a specified distance.

   From the equation on page 4.1B-7 and the definitions for L_{eq} and eL_w

   $$L_{eq}(f) = L_p(f) + 10 \log UF$$

   $$L_w(f) = eL_w(f) - 10 \log UF:$$

   $$eL_w(f) = L_p\ (f) + 10 \log (2 \pi r_o{}^2) + 10 \log UF + A_t(f)$$

   Since measurement distances, r_o, are typically less than 30 m (100 feet), A_t is set to 0.

Scraper CAT 631 - 1 Unit	(A-weighted)	OCTAVE BAND CENTER FREQUENCIES (Hz) 63	125	250	500	1K	2K	4K	8K
Sound pressure level at (L_p) at 50 feet A-weighted	87	87	86	85	84	83	77	71	66
10 log UF = 10 log (0.13)		-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9
10 log 2 $\pi r_o{}^2$ = 10 log(6.28 x 15.22)		+31.6	+31.6	+31.6	+31.6	+31.6	+31.6	+31.6	+31.6
10 log No. of Units = 10 log 10		+10	+10	+10	+10	+10	+10	+10	+10
Equivalent sound power, eLw		120	119	118	117	116	110	104	99

   Therefore, the sound power data listed above and in the table include usage factors. The octave band sound pressure levels at 50 feet are based upon typical diesel spectra(U.S. EPA, 1971) and are consistent with the 87 dBA value, L_p, for 1 unit.

TABLE 4.1B-3 (continued)

2. The MWDF sound sources were modeled at 4 periphery and 1 central location. The equivalent sound power level at each of these five locations is determined according to the following calculation procedure:

	OCTAVE BAND CENTER FREQUENCIES (hz)							
	63	125	250	500	1K	2K	4K	8K
Total equivalent $\mathcal{L}_W$ from MWDF including usage factors	133	132	131	130	129	123	117	112
-10 log(5)	-7	-7	-7	-7	-7	-7	-7	-7
1/5 of total MWDF equivalent $\mathcal{L}_w$	126	125	124	123	122	116	110	105

Using the equation of Note 1: $L_p(f) = \mathcal{L}_w(f) - 10 \log (2 \pi r_o^2)$

For r_o = 15 m (50 feet)

A-weighted L_{eq} at 50 feet = 94 dB for 1/5 total MWDF $\mathcal{L}_w$

A-weighted L_{eq} at 50 feet = 101 dB for the total MWDF $\mathcal{L}_w$

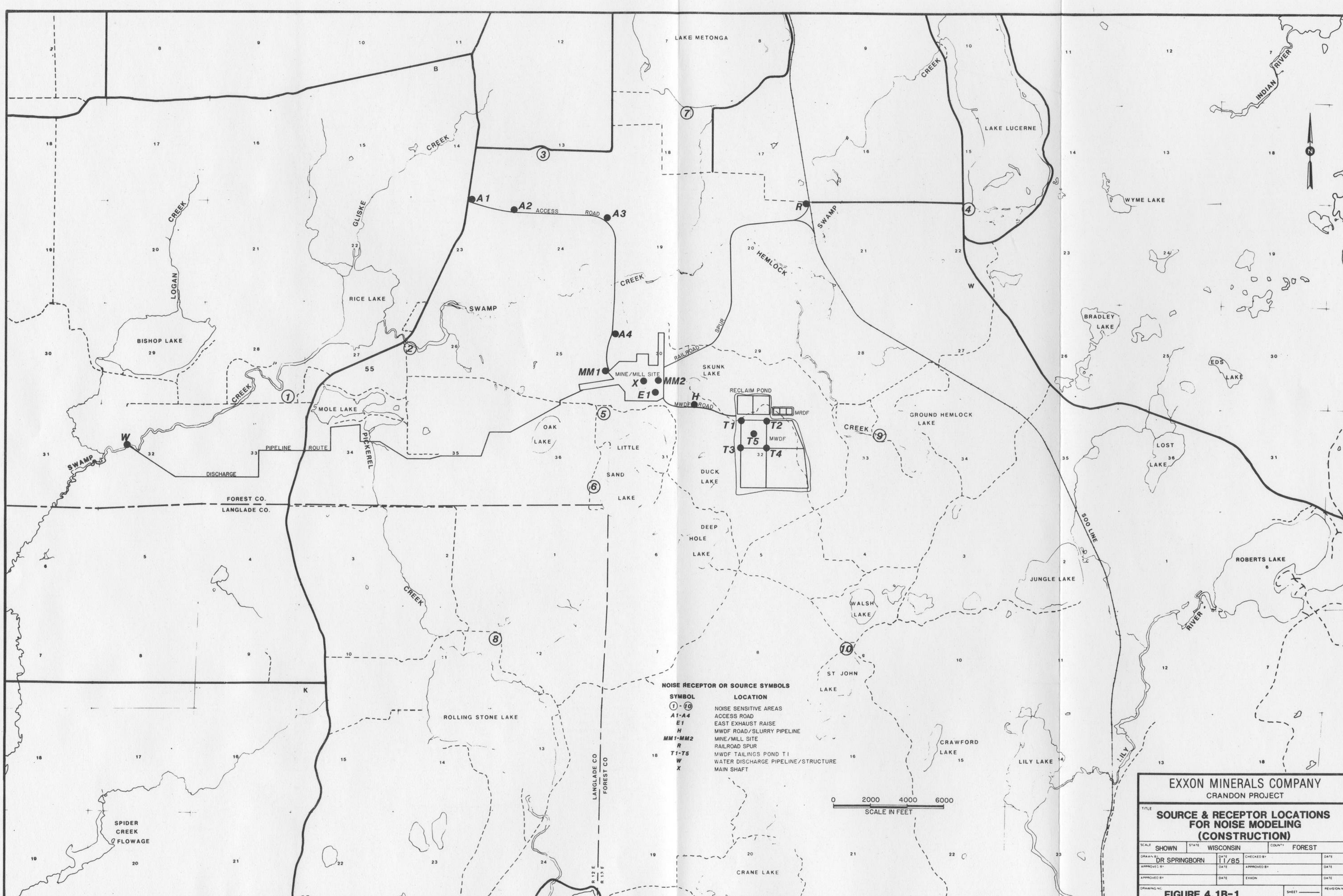
where $\mathcal{L}_w$ includes Usage Factors making L_{eq} an equivalent sound pressure level.

The mine/mill site construction day-night sound level contours were provided for all construction activity sources including development of the main mine shaft and east exhaust raise (Pygin, 1982). Since most construction activity will occur only during daytime hours, these contours were used to develop the daytime construction activity noise contributions for the mine/mill site (MM1 and MM2 on Figure 4.1B-1). Because shaft sinking will occur on a 24-hour basis, these noise source contributions were also used to conservatively model nighttime mine/mill site construction activity. The sound power level spectra (including usage factors [UF]) developed from these construction activity noise contours are shown below:

Sound Power Level Spectrum, dB

	Octave Band Center Frequency (Hz)							
	63	125	250	500	1K	2K	4K	8K
Mine/Mill West of Access Road (MM1)	121	120	119	118	117	111	105	100
Mine/Mill Adjacent to Timber and Steel Storage Area (MM2)	117	116	115	114	113	107	103	98

The MWDF excavation equipment (from Chapter 1, Table 1.3-11) and associated sound power level spectra, with usage factors included, are presented in Table 4.1B-3. The usage factors represent the percent of time during the total workday that a piece of equipment will be operating in its noisiest mode. It is not the percent of time a piece of equipment will be operating during the day. Most equipment will operate throughout the working shifts but will not be doing so in its noisiest mode.


LAKE METONGA
LAKE LUCERNE
INDIAN RIVER
WYME LAKE
CREEK
GLISKE
LOGAN
RICE LAKE
SWAMP
BISHOP LAKE
MOLE LAKE
PICKEREL
PIPELINE ROUTE
DISCHARGE
ACCESS ROAD
A1
A2
A3
A4
MM1
MM2
MINE/MILL SITE
X
E1
H
MWDF ROAD
RAILROAD SPUR
R
SKUNK LAKE
RECLAIM POND
MRDF
T1
T2
T3
T4
T5
MWDF
HEMLOCK
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
GROUND HEMLOCK LAKE
BRADLEY LAKE
EDS LAKE
LOST LAKE
SOO LINE
ROBERTS LAKE
JUNGLE LAKE
WALSH LAKE
ST JOHN LAKE
CRAWFORD LAKE
LILY LAKE
LILY
RIVER
ROLLING STONE LAKE
SPIDER CREEK FLOWAGE
CRANE LAKE
FOREST CO.
LANGLADE CO.
LANGLADE CO
FOREST CO
R12E
R13E
55
B
K
W
NOISE RECEPTOR OR SOURCE SYMBOLS
SYMBOL LOCATION
1 - 10 NOISE SENSITIVE AREAS
A1-A4 ACCESS ROAD
E1 EAST EXHAUST RAISE
H MWDF ROAD/SLURRY PIPELINE
MM1-MM2 MINE/MILL SITE
R RAILROAD SPUR
T1-T5 MWDF TAILINGS POND T I
W WATER DISCHARGE PIPELINE/STRUCTURE
X MAIN SHAFT
0 2000 4000 6000
SCALE IN FEET
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
SOURCE & RECEPTOR LOCATIONS FOR NOISE MODELING (CONSTRUCTION)
SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 11/85
CHECKED BY
DATE
APPROVED BY
DATE
APPROVED BY
DATE
APPROVED BY
DATE
EXXON
DATE
DRAWING NO
FIGURE 4.1B-1
SHEET
OF
REVISION NO

To assess the sound level contribution during the construction phase to off-site receptor locations, the MWDF construction activity was assumed to be located at five locations (T1 - T5 on Figure 4.1B-1). One-fifth of the total equipment sound power was assigned to each of the five locations.

The sound power level spectra for the equipment used in the construction of the (1) tailings transport pipeline, (2) water discharge pipeline and structure, (3) railroad spur, (4) access road, and (5) haul road are presented in Table 4.1B-4. Figure 4.1B-1 shows the location of these sources as well as the identified noise sensitive area receptors used in the noise modeling. The construction equipment for building the access road was assumed for the model calculations to be located at four locations (A1 through A4). The railroad spur construction activities were assumed to be located at the northeastern end of the railroad spur (R). The construction activities associated with development of the haul road and tailings transport pipeline were assumed to be located halfway between the mine/mill site and MWDF areas (H). Construction activities for the water discharge pipeline/structure were assumed to occur at the discharge location on Swamp Creek approximately 1.6 km (1.0 mile) downstream from County Trunk Highway M (W).

4.1B.4 Operation Phase Noise Sources

The major sources of noise during the Project operation phase will be associated with the following facilities:

TABLE 4.1B-4

EQUIPMENT USED IN CONSTRUCTION OF TAILINGS TRANSPORT AND WATER DISCHARGE PIPELINES, RAILROAD SPUR, AND ACCESS ROAD AND HAUL ROAD

SOUND POWER LEVEL SPECTRUM, dB

			OCTAVE BAND CENTER FREQUENCIES (Hz)[a]							
EQUIPMENT TYPE[b]	NO. OF UNITS	UF	63	125	250	500	1K	2K	4K	8K
TAILINGS TRANSPORT AND WATER DISCHARGE PIPELINE/STRUCTURE AREAS										
Dozer Cat D7	1	.15	111	110	109	108	107	101	95	90
Backhoe Cat 235	1	.15	106	105	104	103	102	96	90	85
Front End Loader Cat 9888	1	.15	109	108	107	106	105	99	93	88
Dump Truck 5 CYD	1	.10	114	113	112	111	110	104	98	93
Flatbed Truck 8T	1	.10	105	104	103	102	101	95	89	84
Trencher	1	.70	115	114	113	112	111	105	99	94
RAILROAD SPUR AREA										
Chainsaw	5	.20	123	122	121	120	119	113	107	102
Front End Loader Cat 9888	1	.15	109	108	107	106	105	99	93	88
Front End Load Cat 9920	1	.15	109	108	107	106	105	99	93	88
Dozer Cat D9	1	.15	112	111	110	109	108	102	96	91
Dozer Cat D6	2	.15	114	113	112	111	110	104	98	93
Backhoe (Comb)	2	.10	108	107	106	105	104	98	92	87
Motor Grader 16G	1	.10	108	107	106	105	104	98	92	87
Dump Truck 5 CYD	8	.10	123	122	121	120	119	113	107	102
Compactor	4	.10	108	107	106	105	104	98	92	87

TABLE 4.1B-4 (continued)

EQUIPMENT TYPE	NO. OF UNITS	UF	63	125	250	500	1K	2K	4K	8K
			OCTAVE BAND CENTER FREQUENCIES (dB)							
			ACCESS ROAD AND HAUL ROAD AREAS[c]							
Chainsaw	5	.20	123	122	121	120	119	113	107	102
Front End Loader Cat 9888	1	.15	109	108	107	106	105	99	93	88
Front End Loader Cat 977L	1	.15	112	111	110	109	108	102	96	91
Motor Grader 16G	2	.10	111	110	109	108	107	101	95	90
Gradall G1200	1	.10	108	107	106	105	104	98	92	87
Dozer Cat D9	1	.15	112	111	110	109	108	102	96	91
Dozer Cat D6	2	.15	114	113	112	111	110	104	98	93
Backhoe (Comb)	2	.10	108	107	106	105	104	98	92	87
Dump Truck 5 CYD	12	.10	125	124	123	122	121	115	109	104
Compactor	5	.10	109	108	107	106	105	99	93	88
Crane	2	.05	107	106	105	104	103	97	91	86

Source: Pygin (1982).

[a]Sound power levels shown above include the indicated usage factor (UF).

[b]While this equipment list is representative, it is only intended to show the types and numbers of equipment. The actual manufacturers and model numbers could change depending on final engineering and product availability.

[c]When calculating the contours shown on Chapter 4, Figure 4.1-13, these sources were used twice to model the "worst-case" situation of both activities occurring simultaneously. Typical public works industrial construction data (U.S. EPA, 1975) were used for the water discharge structure analysis.

1) Mine/Mill Site

Mine/mill site noise sources and associated sound levels* were developed and are presented on the Surface Plant Operations noise contours map (Pygin, 1982). The octave band sound power level spectra of the major noise sources at the mine/mill site are presented in Table 4.1B-5.

The mine/mill site operation phase noise was assumed, for assessment purposes, to be located at the center (MM3) of the site (Figure 4.1B-2).

Two vent fan locations -- East Exhaust Raise (E1) and West Exhaust Raise (E2) -- are also considered (Figure 4.1B-2).

2) Mine Waste Disposal Facility

The MWDF construction activity noise during the operation phase was assumed to be produced by the equipment listed in Table 4.1B-5 at four perimeter locations (T3, T6, T7, and T8) and one central location (T4) in the MWDF area (Figure 4.1B-2). These five locations were also used for the contour calculations for development of the other tailing ponds during the operation phase. One-fifth of the total equipment sound power was assigned to each of the five locations. The sound power level spectrum for the MWDF is also presented in Table 4.1B-5. No sound levels from the operation of a tailing pond (i.e., slurry disposal of tailings) were included for the operation phase. The sound from tailing pond operations are minor, and when construction activity for another pond is ocurring, would be negligible to the development equipment noise.

3) Access Road

The noise levels associated with the access road (A1, A2, A3, and A4) were calculated from the number and types of vehicles that will be traveling along the road (estimates from Chapter 1, subsection 1.4.7) during the morning, afternoon, and nighttime periods. The sound power level spectrum emitted from the access road activity is presented in Table 4.1B-5. The noise source locations for the access road were chosen at four points along the road (Figure 4.1B-2). These four locations were used as constant sources in the contour computations.

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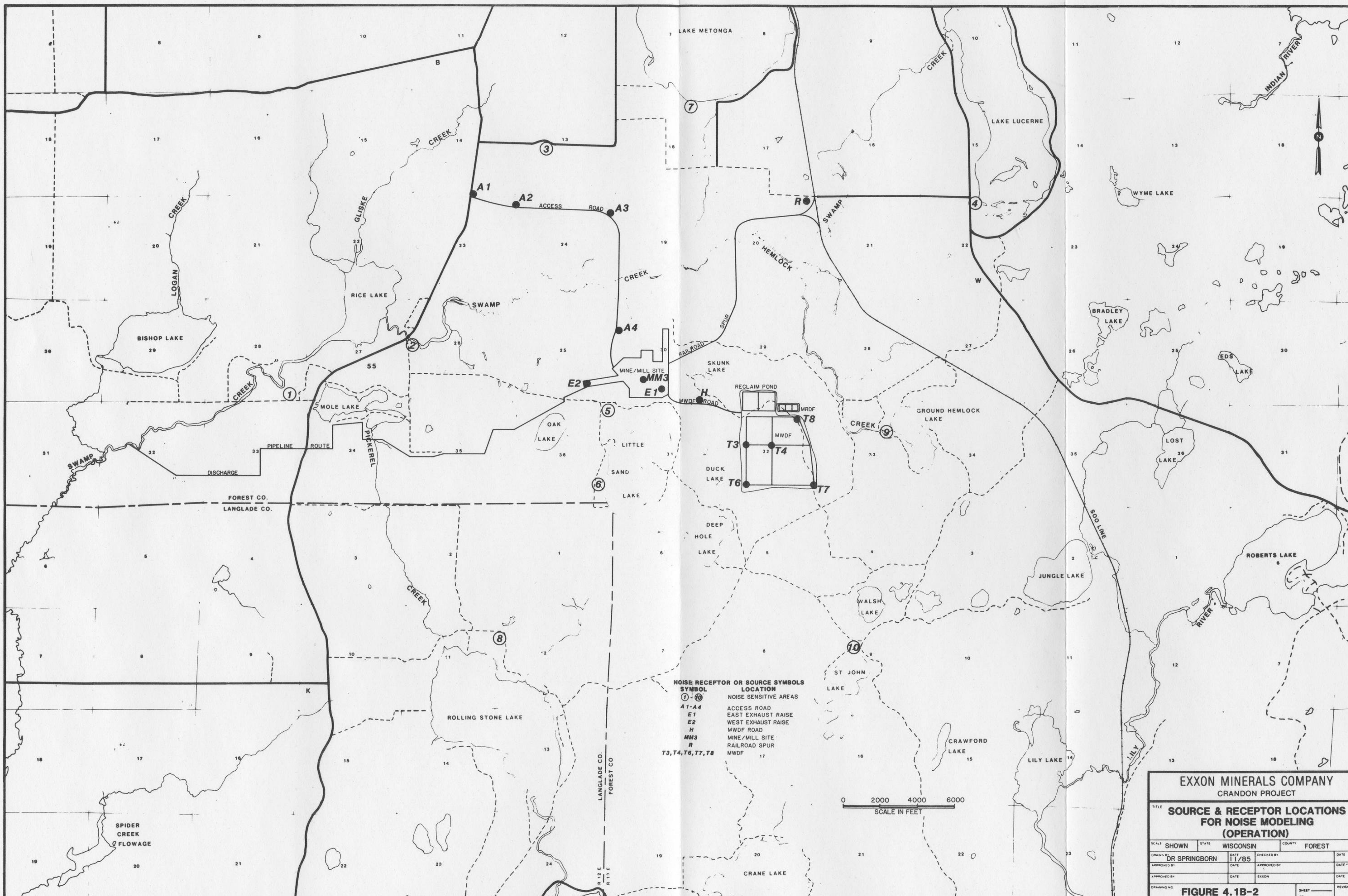
*All non-octave band sound levels used in this report are A-weighted unless noted otherwise. Octave band sound levels are all unweighted.



EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **SOURCE & RECEPTOR LOCATIONS FOR NOISE MODELING (OPERATION)**

SCALE SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 11/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO **FIGURE 4.1B-2**		SHEET ___ OF ___	REVISION NO

TABLE 4.1B-5

OPERATION PHASE NOISE SOURCES

SOUND POWER LEVEL SPECTRUM, dB

EQUIPMENT*	OCTAVE BAND CENTER FREQUENCIES (Hz)							
	63	125	250	500	1K	2K	4K	8K
Mine/Mill								
Train/Concentrator	111	130	119	124	120	117	110	104
Transformer		93	96	100	100	97	90	
Crusher	116	98	85	73	66	62	58	55
Batch Plant		88	91	95	95	92	85	
Air Heaters[a] (2 units)	113	109	105	100	95	90	89	89
Compressor	104	104	84	77	77	74	69	69
Generator		105	104	105	105	102	94	88
East Exhaust Raise[b] (3 fans)	113	118	124	120	115	109	104	97
West Exhaust Raise[b] (2 fans)	111	116	122	118	113	107	102	95
Mine Waste Disposal Facility (one-fifth of total L_{eq})[c]	118	117	116	115	114	108	102	97
Access Road (one-fourth of total L_{eq})[d]	81	83	86	80	77	73	65	56
Railroad Spur	104	123	112	114	113	110	103	97
Haul Road	122	121	120	119	118	112	106	101

[a]Air heater noise contribution modeled at two locations.
[b]Exhaust raise noise contribution modeled at two locations. Exhaust fan noise emanations are based on data from Joy Industrial Equipment Company for model No. M96-58-880 RPM and include a factor to account for a nonuniform sound pattern.
[c]MWDF noise contributions modeled at five locations - see next page for specific equipment list.
[d]Access road noise contribution modeled at four locations.

TABLE 4.1B-5 (continued)

(EQUIPMENT TO BE USED IN MINE WASTE DISPOSAL FACILITY AREA EXCAVATION)

SOUND POWER LEVEL SPECTRUM, dB

EQUIPMENT*	NO. OF UNITS	UF	OCTAVE BAND CENTER FREQUENCIES (Hz) 63	125	250	500	1K	2K	4K	8K
Scraper Cat 631	5	.13	117	116	115	114	113	107	101	96
Dozer Cat D9	3	.15	117	116	115	114	113	117	101	96
Dozer Cat D8	4	.15	118	117	116	115	114	108	102	97
Dozer Cat D6	3	.15	116	115	114	113	112	106	100	95
Front End Loader Cat 988	2	.30	115	114	113	112	111	110	104	99
Front End Loader Cat 966	1	.30	115	114	113	112	111	105	99	95
Motor Grader Cat 16G	1	.30	112	111	110	109	108	102	96	91
Motor Grader Cat 14G	4	.30	112	111	110	109	108	102	96	91
Excavator Cat 235	1	.70	113	112	111	110	109	108	102	97
Dump Truck Ford LT-9000	6	.50	128	127	126	125	124	118	112	107
Belly Dump Truck and Trailer	5	.50	128	127	126	125	124	118	112	107
Compactor CAT 825	6	.1	109	108	107	106	105	99	93	88
Compactor Raygo 400A	3	.1	106	105	104	103	102	96	90	85
Total MWDF Equivalent Sound Power Level	-	-	132	131	130	129	128	122	116	111

*While this list is representative, it is only intended to show the types and numbers of equipment. The actual manufacturers and model numbers could change depending on final engineering and product availability.

4) Railroad Spur

The noise level from railroad spur operation phase activities was obtained from the mine/mill site noise contours. The locomotive and freight cars produce a sound power level spectrum as shown in Table 4.1B-5. The noise source was located at the northeastern end (R) of the spur (Figure 4.1B-2).

5) Haul Road

The haul road was assumed to have three heavy trucks traveling at the midpoint (H) of the road (Figure 4.1B-2). The sound power level spectrum for this source is shown in Table 4.1B-5.

6) Pipelines (Tailings Transport and Water) and Discharge Structure

The tailings transport pipeline, water discharge pipeline, and water discharge structure were assumed to have no operating noise associated with them because they are located underground or in an enclosure.

4.1B.5 Construction Phase Automobile Traffic Noise

Construction phase employee and delivery truck traffic on State Highway 55 can be considered a noise source emitted to nearby communities. Traffic noise can be estimated using a Federal Highway Administration noise model (FHWA, 1978). This model was used to estimate the noise levels on Highway 55 north and south of the intersection with the proposed access road to the mine/mill site from current and Project-related traffic during the construction phase. A summary of present and future traffic on State Highway 55 is tabulated below:

Location/Vehicles	Vehicles Per Day Existing	Vehicles Per Day Estimated
North of Access Road		
Cars	846	1620
Trucks	94	106
Buses	0	24
South of Access Road		
Cars	477	493
Trucks	53	65
Buses	0	8

Sources: RPC, 1983 and EIR Chapter 1, Sections 1.3 and 1.4.

Use of the model provides a one hour equivalent sound level at 15 m (50 feet) from the center of each traffic lane. The resulting A-weighted sound level projections for existing and estimated conditions during the construction phase are listed below:

Location/Vehicles	Equivalent Sound Levels, dB at 15 m (50 feet) Existing	Estimated	Change
North of Access Road			
Cars	54.8	57.6	2.8
Trucks	59.2	59.8	0.6
Buses		49.3	
Sum of vehicle sources	60.6	62.1	1.5
South of Access Road			
Cars	52.3	52.4	0.1
Trucks	56.8	57.6	0.8
Buses		44.5	
Sum of vehicle sources	58.1	58.9	0.8

The A-weighted sound level contours presented in Chapter 4, Figures 4.1-13 and 4.1-14 and the assessment of construction phase noise impact in Chapter 4, subsection 4.1.8 do not include the effect from traffic on State Highway 55. As indicated above, the noise effect associated with construction phase traffic is calculated by the model to be small.

4.1B.6 Operation Phase Automobile Traffic Noise

Project-related traffic on State Highway 55 can be considered a noise source emitted to nearby communities. Traffic noise can be estimated using a Federal Highway Administration noise model (FHWA, 1978). This model was used to estimate the noise levels from current and Project-related traffic on Highway 55 north and south of the intersection with the proposed access road to the mine/mill site during the Project operation phase. A summary of present and future traffic on State Highway 55 is tabulated below:

	Vehicles per Day	
Location/Vehicles	Existing	Estimated
North of Access Road		
Cars	846	1096
Trucks	94	100
Buses	0	10
South of Access Road		
Cars	477	577
Trucks	53	59
Buses	0	4

Sources: RPC, 1983 and EIR Chapter 1, Sections 1.3 and 1.4

Use of the model provides a 1 hour equivalent sound level at 15 m (50 feet) from the center of each traffic lane. The resulting A-weighted sound level projections for existing and estimated conditions are listed below:

	Equivalent Sound Levels, dB at 15 m (50 feet)		
Location/Vehicles	Existing	Estimated	Change
North of Access Road			
Cars	54.8	55.9	1.1
Trucks	59.2	59.5	0.3
Buses		45.5	
Sum of vehicle sources	60.6	61.2	0.6
South of Access Road			
Cars	52.3	53.1	0.8
Trucks	56.8	57.2	0.4
Buses		41.5	
Sum of vehicle sources	58.1	58.7	0.6

4.1B.7 Construction and Operation Phase Blasting

Surface blasting is not planned as part of the construction phase of the Project. However, large boulders may be encountered in the glacial till during construction activities which may have to be reduced in size by blasting.

However, when bedrock is encountered during shaft sinking, blasting will be required. The sound overpressure levels associated with blasting will be highly variable and directly related to the amount of explosives and the delay time used which in turn is related to the geometry and type of material which must be blasted. Charge weight and delays will be designed to minimize emitted overpressure levels.

As the shaft progresses downward, the overpressure levels will decrease for a given charge weight per delay. The formula for overpressure is

$$P = 82 \left(\frac{R}{W^{1/3}} \right)^{-1.2}$$

where:

P = Overpressure in psi (at 50 feet),
R = Distance (shaft depth plus 50 feet) in feet, and
W = Charge weight per delay in pounds.

The overpressure (and overpressure level) for various depths of shaft as measured on the surface 15.2 m (50 feet) from the opening are given below:

Shaft Depth (feet)	Overpressure (psi) at 50 feet	Sound Level (dB) at 50 feet	A-weighted Sound Level (dB) at 50 feet
110	.73	168	118
1425	.051	145	95
2745	.024	139	89

4.1B.8 Construction Phase Noise Level Changes

The International Organization for Standardization (ISO) (1971) has adopted guidelines for assessing community response to noise. Their Recommendation No. R1996, "Noise Assessment with Respect to Community Noise," contains a procedure for assessing community response to noise based upon the change the community will experience by a change in ambient sound. The following ISO procedure is recommended as a guide for impact assessment:

Change in L_{eq} at the Receptor from Criterion (dB)	Category	Response
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very Strong	Vigorous community action

The ISO prescribes two methods for establishing a criterion for assessing the complaint potential from a noise. One method uses an absolute criterion level (recommended for zoning purposes) and the other uses existing background noise as the criterion (in cases where there are already specific complaints). For the current land use of the environmental study area, the ISO method of using background noise as a criterion would be inappropriate because no complaints have been lodged against any noise sources in the area. The absolute criterion is a value established by some form of regulatory action.

In addition, the Federal Highway Administration (FHWA) and the Department of Housing and Urban Development (HUD) have adopted criteria for assessing noise impact and to minimize the effect of noise on people. These criteria from U.S. EPA, FHWA, and HUD are summarized in Table 4.1B-6. Table 4.1B-7 contains a summary of these effects for day-night sound level values from 55 dB and higher (Federal Interagency Committee, 1982).

TABLE 4.1B-6

NOISE ZONE CLASSIFICATION

Noise Zone	Noise Exposure Class	Noise Descriptor			HUD Noise Standards
		DNL[1] Day-Night Average Sound Level	L_{eq}(hour)[3] Equivalent Sound Level	NEF[4] Noise Exposure Forecast	
A	Minimal Exposure	Not Exceeding 55	Not Exceeding 55	Not Exceeding 20	"Acceptable"
B	Moderate Exposure	Above 55[2] But Not Exceeding 65	Above 55 But Not Exceeding 65	Above 25 But Not Exceeding 30	
C-1	Significant Exposure	Above 65 Not Exceeding 70	Above 65 Not Exceeding 70	Above 30 But Not Exceeding 35	"Normally Unacceptable"[5]
C-2		Above 70 But Not Exceeding 75	Above 70 But Not Exceeding 75	Above 35 But Not Exceeding 40	
D-1	Severe Exposure	Above 75 But Not Exceeding 80	Above 40 But Not Exceeding 80	Not Exceeding 45	"Unacceptable"
D-2		Above 80 But Not Exceeding 85	Above 80 But Not Exceeding 85	Above 45 But Not Exceeding 50	
D-3		Above 85	Above 85	Above 50	

[1]CNEL — Community Noise Equivalent Level (California only) uses the same values.

[2]HUD, DOT and EPA recognize L_{dn} = 55 dB as a goal for outdoors in residential areas in protecting the public health and welfare with an adequate margin of safety (Reference: EPA "Levels" Document.) However, it is not a *regulatory* goal. It is a level defined by a negotiated scientific consensus without concern for economic and technological feasibility or the needs and desires of any particular community.

[3]The Federal Highway Administration (FHWA) noise policy uses this descriptor as an alternative to L_{10} (noise level exceeded ten percent of the time) in connection with its policy for highway noise mitigation. The L_{eq} (design hour) is equivalent to DNL for planning purposes under the following conditions: 1) heavy trucks equal ten percent of total traffic flow in vehicles per 24 hours; 2) traffic between 10 p.m. and 7 a.m. does not exceed fifteen percent of the average daily traffic flow in vehicles per 24 hours. Under these conditions DNL equals L_{10} - 3 decibels.

[4]For use in airport environs only; is now being superceded by DNL.

[5]The HUD Noise Regulation allows a certain amount of flexibility for non-acoustic benefits in zone C-1. Attenuation requirements can be waived for projects meeting special requirements.

TABLE 4.1B-7

EFFECTS OF NOISE ON PEOPLE

(RESIDENTIAL LAND USES ONLY)

Effects[1] / Day-Night Average Sound Level in Decibels	Hearing Loss	Speech Interference		Annoyance[2]	Average Community Reaction[4]	General Community Attitude Towards Area
		Indoor	Outdoor			
	Qualitative Description	% Sentence Intelligibility	Distance in Meters for 95% Sentence Intelligibility	% of Population Highly Annoyed[3]		
75 and above	May Begin to Occur	98%	0.5	37%	Very Severe	Noise is likely to be the most important of all adverse aspects of the community environment
70	Will Not Likely Occur	99%	0.9	25%	Severe	Noise is one of the most important adverse aspects of the community environment.
65	Will Not Occur	100%	1.5	15%	Significant	Noise is one of the important adverse aspects of the community environment.
60	Will Not Occur	100%	2.0	9%	Moderate to Slight	Noise may be considered an adverse aspect of the community environment.
55 and below	Will Not Occur	100%	3.5	4%		Noise considered no more important than various other environmental factors.

1. "Speech Interference" data are drawn from the following tables in EPA's "Levels Document": Table 3, Fig. D-1, Fig. D-2, Fig. D-3. All other data from National Academy of Science 1977 report "Guidelines for Preparing Environmental Impact Statements on Noise, Report of Working Group 69 on Evaluation of Environmental Impact of Noise."
2. Depends on attitudes and other factors.
3. The percentages of people reporting annoyance to lesser extents are higher in each case. An unknown small percentage of people will report being "highly annoyed" even in the quietest surroundings. One reason is the difficulty all people have in integrating annoyance over a very long time.
4. Attitudes or other non-acoustic factors can modify this. Noise at low levels can still be an important problem, particularly when it intrudes into a quiet environment.

NOTE: Research implicates noise as a factor producing stress-related health effects such as heart disease, high-blood pressure and stroke, ulcers and other digestive disorders. The relationships between noise and these effects, however, have not as yet been quantified.

The estimated winter ambient L_{dn} sound level during the construction phase exceeds 45 dB from only one location (Location 6) for which the background measured L_{dn} did not exceed 45 dB (Table 4.1B-8). At Location 6, the estimated ambient L_{dn} is 46 dB. However, the estimated change in ambient sound levels, L_d and L_n, may exceed 5 dB at four locations (Locations 3, 5, 9, 10) during daytime conditions and two locations (Locations 5, 6) at night. Only one of these locations, Location 5, has estimated L_d and L_n over 45 dB during the construction phase. This location is the Exxon field office on Sand Lake Road.

The major estimated changes in winter ambient sound levels from construction activities are near Locations 5, 6 and 9 (Table 4.1B-8). Daytime (L_d) equivalent sound levels will change by 7.5 and 11.3 dB at Locations 5 and 9, respectively, whereas nighttime (L_n) equivalent sound levels will change by an estimated 8.2 and 15.7 dB at Locations 5 and 6, respectively (Table 4.1B-8). At other locations, such as Locations 3 and 10, daytime winter ambient sound levels will change slightly more than 5 dB because of construction phase activities. However, the total expected winter ambient daytime sound levels remain low at 44.8 and 38.6 dB, respectively. With the exceptions of Locations 5 and 6, changes to ambient nighttime sound levels at all other locations are estimated to be less than 4 dB.

Only three locations (Locations 5, 6, 7) are estimated to have total daytime ambient sound louder than 45 dB with just the current Exxon field office (Location 5) having a change from background of more than 5 dB (Table 4.1B-8). The largest estimated nighttime (L_n) sound change of 15.7 dB at Location 6, although a low estimated ambient sound level of only 34.7 dB, is attributed to the very low nighttime background sound of 19 dB measured in 1977. This was the only location

TABLE 4.1B-8

CONSTRUCTION PHASE EFFECT ON BACKGROUND SOUND LEVELS[a]

LOCATION	BACKGROUND			CONSTRUCTION NOISE		TOTAL[b] NOISE DURING CONSTRUCTION			CHANGE		
	L_d	L_n	L_{dn}	L_A DAY	L_A NIGHT	L_d	L_n	L_{dn}	L_d	L_n	L_{dn}
WINTER											
1	42.8	29.8	41.9	32.0	20.1	43.1	30.2	42.3	0.3	0.4	0.4
2	37.9	28.5	38.1	36.6	25.7	40.3	30.3	40.3	2.4	1.8	2.2
3	39.3	23.9	38.0	43.3	24.2	44.8	27.1	43.1	5.5	3.2	5.2
4	43.7 (43.4)[c]	35.1	44.2 (44.1)[c]	36.6	18.0	44.5 (44.2)[d]	35.2	44.8 (44.6)[d]	0.8 (0.8)[d]	0.1	0.5 (0.5)[d]
5	42.4	50.5 (37.7)[c]	56.4 (45.2)[c]	49.0	45.2	49.9	51.6 (45.9)[d]	57.8 (53.2)[d]	7.5	1.1 (8.2)[d]	1.5 (8.0)[d]
6	51.6 (42.1)[c]	19.0	49.5 (40.2)[c]	44.7	34.6	52.4 (46.6)[d]	34.7	50.8 (46.0)[d]	0.8 (4.5)[d]	15.7	1.2 (5.8)[d]
7	44.8	41.8	48.8	37.5	22.1	45.5	41.8	49.0	0.7	0.0	0.2
8	34.2	30.8	37.9	35.9	22.6	38.1	31.4	39.7	3.9	0.6	1.8
9	33.4	30.0	37.1	44.4	23.6	44.7	30.9	43.7	11.3	0.9	6.6
10	33.4	31.0	37.8	37.1	18.7	38.6	31.2	39.8	5.2	0.2	2.0
SUMMER											
1	46.6	42.7	49.9	32.0	20.1	46.7	42.7	50.0	0.1	0.0	0.1
2	42.1	39.7	46.5	36.6	25.7	43.2	39.9	46.9	1.1	0.2	0.4
3	47.1 (44.4)[c]	44.1	51.1 (50.5)[c]	43.3	24.2	48.6 (46.8)[d]	44.1	51.5 (51.0)[d]	1.5 (2.5)[d]	0.0	0.5 (0.5)[d]
4	63.8	47.0	62.3	36.6	18.0	63.8	47.0	62.3	0.0	0.0	0.0
5	58.6	26.5	56.6	49.0	45.2	59.1	45.3	58.0	0.5	18.8	1.4
6	38.0	38.6	44.9	44.7	34.6	45.5	40.1	47.8	7.5	1.5	2.9
7	47.5	41.3	49.3	37.5	22.1	47.9	41.4	49.5	0.4	0.1	0.2
8	40.7	39.6	46.2	35.9	22.6	41.9	39.7	46.5	1.2	0.1	0.3
9	42.7	27.4	41.4	44.4	23.6	46.6	28.9	45.0	3.9	1.5	3.7
10	38.6	28.1	38.4	37.1	18.7	40.9	28.6	40.2	2.3	0.5	1.8

[a] All sound levels are A-weighted in dB.

[b] Background plus construction phase noise.

[c] Measured background values were adjusted to reduce the contribution from short duration, high sound pressure level sources (Tans, 1984).

[d] Construction phase change in values based on adjusted background data.

where nighttime sounds were this low, suggesting these measurements may be atypical or in error. In only one case is estimated nighttime sound above 45 dB (45.9) and that is again at the current Exxon field office (Location 5).

The only location where the estimated ambient L_{dn} exceeds 45 dB (47.8) during the summer construction phase activity, where the background L_{dn} was measured at less than 45 dB, is Location 6. However, with the measured background sound pressure level for L_{dn} of 44.9 dB at Location 6, the effective change is only 2.9 dB (Table 4.1B-8). Summer construction phase activity will increase ambient sound levels by more than 5 dB only at Location 6 (45.5 dB L_d) and Location 5 (45.3 dB L_n). Other estimated changes in ambient sound levels, either daytime or nighttime, are mainly less than 2 and all are below 4 dB (Table 4.1B-8).

4.1B.9 Operation Phase Noise Level Changes

The estimated winter ambient L_{dn} sound levels during the operation phase activities exceed 45 dB at two locations (Locations 6 and 9) where the existing background L_{dn} is lower than 45 dB (Table 4.1B-9). The actual Location 6 noise level is expected to be lower than these estimates because of the conservative modelling assumptions used for the east and west exhaust raise fans and the train/concentrator source, which the model indicates are the primary Project contributors to the estimated sound levels at Location 6. The modelling assumed that the train/concentrator source would operate continuously when in actuality train movements will be less than a total of five hours per day. Further, fewer than the modeled five exhaust raise fans will operate simultaneously at the exhaust raises. Even with this

TABLE 4.1B-9

OPERATION PHASE EFFECT ON BACKGROUND SOUND LEVELS[a]

LOCATION	BACKGROUND L_d	BACKGROUND L_n	BACKGROUND L_{dn}	OPERATION[b] NOISE L_A DAY	OPERATION[b] NOISE L_A NIGHT[d]	TOTAL[c] NOISE DURING OPERATIONS L_d	TOTAL[c] NOISE DURING OPERATIONS L_n	TOTAL[c] NOISE DURING OPERATIONS L_{dn}	CHANGE L_d	CHANGE L_n	CHANGE L_{dn}
WINTER											
1	42.8	29.8	41.9	29.4	28.0	43.0	32.0	42.6	0.2	2.2	0.7
2	37.9	28.5	38.1	34.2	33.2	39.4	34.5	42.0	1.5	6.0	3.9
3	39.3	23.9	38.0	32.7	31.5	40.2	32.2	41.0	0.9	8.3	3.1
4	43.7 (43.4)[e]	35.1	44.3 (44.1)[e]	32.5	28.8	44.0 (43.7)[f]	36.0	44.9 (44.7)[f]	0.3 (0.3)[f]	0.9	0.6 (0.6)[f]
5	42.4	50.5 (37.7)[e]	56.4 (45.2)[e]	51.5	51.3	52.0	53.9 (51.5)[f]	60.1 (58.0)[f]	9.6	3.4 (13.8)[f]	3.8 (12.8)[f]
6	51.6 (42.1)[e]	19.0	49.6 (40.2)[e]	43.9	42.6	52.3 (46.1)[f]	42.6	52.4 (49.7)[f]	0.7 (4.0)[f]	23.6	2.8 (9.5)[f]
7	44.8	41.8	48.8	32.8	31.0	45.1	42.1	49.1	0.3	0.3	0.3
8	34.2	30.8	37.9	33.7	30.8	37.0	33.8	40.8	2.8	3.0	2.9
9	33.4	30.0	37.1	45.8	32.2	46.0	34.2	45.5	12.6	4.2	8.4
10	33.4	31.0	37.8	36.9	27.3	38.5	32.5	40.5	5.1	1.5	2.6
SUMMER											
1	46.6	42.7	49.9	29.4	28.0	46.7	42.8	50.1	0.1	0.1	0.1
2	42.1	39.7	46.5	34.2	33.2	42.8	40.6	47.4	0.7	0.9	0.8
3	47.1 (44.4)[e]	44.1	51.1 (50.6)[e]	32.7	31.5	47.3 (44.7)[f]	44.3	51.3 (50.8)[f]	0.2 (0.3)[f]	0.2	0.2 (0.2)[f]
4	63.8	47.0	62.3	32.5	28.8	63.8	47.1	62.3	0.0	0.1	0.0
5	58.6	26.5	56.6	51.5	51.3	59.4	51.3	60.2	0.8	24.8	3.6
6	38.0	38.6	44.9	43.9	42.6	44.9	44.1	50.6	6.9	5.5	5.7
7	47.5	41.3	49.3	32.8	31.0	47.6	41.7	49.6	0.1	0.4	0.3
8	40.7	39.6	46.2	33.7	30.8	41.5	40.1	46.8	0.8	0.5	0.6
9	42.7	27.4	41.4	45.8	32.2	47.5	33.4	46.4	4.8	6.0	5.0
10	38.6	28.1	38.4	36.9	27.3	40.8	30.7	40.8	2.2	2.6	2.4

[a] All sound levels are A-weighted in dB.

[b] Day and night operation phase sound levels include three mine fans in the east exhaust raise (EER) and two in the west exhaust raise (WER).

[c] Background plus operation phase noise.

[d] Night operation phase sound levels exclude MWDF activities.

[e] Measured background values were adjusted to reduce the contribution from short duration, high sound pressure level sources (Tans, 1984).

[f] Operation phase change in values based on adjusted background data.

conservative bias, the estimated L_{dn} at Location 6 is only 49.7 dB. The estimated Location 9 L_{dn} is only 0.5 dB above 45 dB.

The conservatively estimated winter ambient nighttime (L_n) equivalent sound levels may increase more than 5 dB at Locations 2 and 3, and 10 dB at Locations 5 and 6 (Table 4.1B-9). Although the winter nighttime (L_n) change exceeds 5 dB at Locations 2 and 3, the total ambient noise is estimated to remain low at 34.5 and 32.2 dB, respectively. Location 5 is the current Exxon field office and is not used for residential purposes. The large estimated change at Location 6 is a result of the very low background sound level measured in 1977 (19 dB). This was the only location where nighttime sounds were this low, suggesting that these measurements may be atypical or in error. In spite of this large estimated change, the ambient sound is only 42.6 dB.

The winter daytime (L_d) sound level is estimated to increase more than 5 dB at Locations 5, 9 and 10. Location 5 is the current Exxon field office and is not used for residential purposes. At Locations 9 and 10, the estimated total winter daytime (L_d) sound levels of 46.0 and 38.5 dB are low.

In summer, the resulting operation phase ambient sound levels are estimated to change less than in winter because of the higher summer background levels. The only locations where the estimated ambient L_{dn} exceeds 45 dB, where the background L_{dn} is less than 45 dB, are Locations 6 and 9 (Table 4.1B-9). If the 10 dB forest attenuation were increased to include summer foliage attenuation (Aylor, 1972a,b; 1975), the estimated ambient sound levels would be even lower. At

Location 6, the summer background L_{dn} is currently close to 45 dB (44.9 dB), and even with the conservative modeling assumptions described above, only results in an estimated noise level of 50.6 dB. The estimated Location 9 L_{dn} is less than 2 dB above 45 dB (Table 4.1B-9).

Increases of 5 dB or higher in estimated summer nighttime (L_n) equivalent sound levels may occur at Locations 5, 6, and 9 (Table 4.1B-9). The estimated summer nighttime (L_n) equivalent sound levels increase at Location 5, the current Exxon field office, is of no concern since it is not a residential receptor. At Location 6, even with the conservative assumptions in the modelling, the summer nighttime L_n of 44.1 dB is only 5.5 dB higher than background. Background summer nighttime sound is very low (27.4 dB) at the area represented by Location 9. Although a 6 dB increase to summer nighttime sound is estimated from operation phase activities, the total noise is estimated to remain low at 33.4 dB. When compared to other summer background data, the Location 9 summer background sound level of 27.4 dB may be uncharacteristically low making the estimated change of 6 dB a probable worst-case.

The only estimated daytime summer increase exceeding 5 dB occurs at Location 6. However, the increase of approximately 7 dB results in an estimated daytime noise level that is not expected to exceed 45 dB.

4.1B.10 References

See Chapter 4, subsections 4.1.11 and 4.2.11 for a complete list of references cited.

APPENDIX 4.2A

INFORMATION USED IN EVALUATING IMPACTS ON AQUATIC BIOTA IN SITE AREA STREAMS AND LAKES

1.0 Introduction

During Project operation, ground water seepage into the mine will be collected, pumped to the surface, treated, and discharged to Swamp Creek downstream of Rice Lake. Inflow of ground water into the mine will result in a lowering of the ground water table in the site area. The methodology and background information used in evaluating impacts on aquatic biota in site area streams and lakes are described below.

2.0 Streams

The impacts that reductions in flow will have on site area streams will depend on the morphometry and morphology of each stream, the inherent sensitivity of the species present, and the amount of flow reduction.

2.1 Stream Morphometry and Morphology

The degree to which a given stream will be affected by reductions in flow will depend to some extent on its morphometry and morphology. Streams discharging similar quantities of water will not necessarily be affected to the same degree by identical reductions in flow if they differ considerably in substrate type and bottom topography. For example, streams with cobble or gravel substrates generally need higher velocities to maintain relatively clean substrates. Similarly, streams that are broad and shallow will more likely be affected by reductions in flow than those that are narrow and deep.

The amount of shallow water habitat (e.g., riffles, shoals, and bars) is also an important factor. Such areas often provide cover and are essential for the maintenance and survival of certain aquatic organisms. Because of their shallow nature, areas of this type are among the first to be dewatered when flow reductions occur. Conversely, a stream that has a relatively flat bottom will not have much of its bottom exposed unless flow reductions are severe. Because of low gradients, most streams within the study area are of the latter type; Hemlock Creek is a good example of such a stream. It has a low gradient (9.5 m/km), with predominantly muck and sand substrates; natural riffle areas are absent. Pickerel Creek, particularly upstream of Rolling Stone Lake, is another example of a low-gradient, depositional stream. Such streams typically possess aquatic organisms adapted to low current velocities and soft (fine) substrates. A habitat survey of Hemlock Creek in August 1984 revealed that it possessed such a community (EA Science and Technology, 1984b).

Although there are no streams in the study area of the classic pool-riffle type, Swamp Creek upstream of Rice Lake (particularly the segment between Hemlock Creek and the proposed access road crossing) contains a considerable amount of hard substrates and riffles. This portion of Swamp Creek contains aquatic organisms that are uncommon or absent in other area streams.

The above information indicates that a riffle-run stream like Swamp Creek upstream of Rice Lake would be more severely affected by the same percentage reduction in flow than would a low gradient, depositional stream like Hemlock Creek.

2.2 Species Sensitivity

Because of differing habitat requirements, all aquatic organisms do not respond similarly to reductions in stream flow. Species requiring fast currents, (i.e., rheophilic species), erosional substrates, and/or riffle habitats would be more likely to be affected by reductions in flow than would species preferring slack water or depositional substrates. The instream flow incremental methodology (Stalnaker, 1979; Bovee, 1981) assumes that there is a positive, linear relationship between weighted usable area and fish standing stock. Orth and Maughan (1982) found that this assumption held true for three riffle-dwelling fishes (freckled madtom [*Noturus nocturus*], central stoneroller [*Campostoma anomalum*], and orangebelly darter [*Etheostoma radiosum*]), particularly during the summer, but this relationship was not evident in any season for smallmouth bass (*Micropterus dolomieui*), a species adapted to both stream and lake environments. They described the three riffle-dwelling species as obligate stream fishes (i.e., they depend on flowing water to survive). Based on the work of Orth and Maughan (1982), fishes in the site area most likely to be affected by reduced flows are those that can be described as obligate stream (lotic) fishes. Conversely, species that prefer lentic (lake) habitats (e.g., pumpkinseed, largemouth bass) are less likely to be affected.

As with fish, macroinvertebrates that are associated with high velocity and/or riffle areas are those more likely to be affected by reduced stream flows. The effect of reduced flows on stream macroinvertebrates is discussed in more detail later in this section.

Based on the species present (see Chapter 2, Section 2.5) and their habitat requirements according to Becker (1983), obligate stream fishes in the study area would be:

Swamp Creek	Hemlock Creek	Pickerel Creek	Creek 12-9
Brook trout	Brook trout	Brook trout	Brook trout
Hornyhead chub	Hornyhead chub		
Blacknose dace	Blacknose dace		
Longnose dace			
Pearl dace			

Creek 11-4	Hoffman Creek
Pearl dace	Blacknose dace
	Brook trout

The characterization of brook trout as an obligate stream fish is debatable because some beaver ponds and small lakes offer excellent trout fishing in northern Wisconsin, provided water temperatures do not become excessive. Of the above five species, only longnose dace is a true riffle-dweller. Becker (1983) states that "the longnose dace occurs in riffles or torrential water over a bottom of boulders and gravel; it generally avoids pools and quiet runs." Because riffles are the areas that will be affected most by reductions in flow, longnose dace is the species most likely to be affected. Of the six streams evaluated, longnose dace are confined to Swamp Creek, where they are abundant in the riffle areas (Chapter 2, Section 2.5). Because flows in Swamp Creek will only be reduced by approximately 8 percent (Chapter 4, Table 4.2-6), major impacts to this species appear unlikely. However, the key factor in assessing the degree of impact to this species is whether the amount of riffle habitat on which it depends will be reduced appreciably. This information is not available at this time.

A reduction in brook trout habitat should not be detrimental to this species because it is uncommon in all these streams, except Hoffman Creek. Swamp Creek, Hoffman Creek, and Hemlock Creek are classified as Class II trout streams (which by definition have more habitat than is utilized by the trout; Kmiotek, 1980). Even though the total amount of habitat available for basic activities (e.g., feeding and resting) is more than adequate for their needs, impacts may still occur if the amount of spawning habitat is reduced significantly. Among the six streams only Swamp Creek, Hoffman Creek, and Hemlock Creek are classified by the DNR as trout streams (Kmiotek, 1980). Potential spawning areas in Swamp and Hemlock creeks are small and isolated (see Chapter 2, Section 2.5). The most extensive known spawning area within the site area occurs in Hoffman Creek (Chapter 2, Section 2.5; Simon, 1984). This area has sand and gravel substrates and appears to be a ground water discharge area. It is shallow, with depths under normal flow conditions averaging only about 0.1 m (0.3 foot). Given its shallowness and its importance as a brook trout spawning area, Hoffman Creek is one of the streams in the site area most sensitive to flow alterations.

The other fishes in the study area that are primarily lotic species (i.e., hornyhead chub, blacknose dace, and pearl dace) are not as dependent on riffle areas as longnose dace or as stringent in their spawning requirements as brook trout. For example, hornyhead chubs are common in Swamp Creek downstream of Rice Lake (Ecological Analysts, Inc., 1983; EA Science and Technology, 1984a) even though riffles and hard substrates (i.e., gravel or rubble) are uncommon in the lower reaches of Swamp Creek.

Fish and macroinvertebrate species and/or populations can overcome reductions in flow. Cairns et al. (1971) showed that a riffle area, which was purposely acidified to destroy most of the resident macroinvertebrates, completely recovered both in terms of density and diversity within only 28 days. Larimore et al. (1959) studied Smiths Branch, a small warmwater stream in central Illinois, following a severe drought that "virtually destroyed the fish and invertebrate populations" in 1953 and 1954. They reported that repopulation began as soon as the stream resumed its flow and that by the first summer following the elimination of all fish species, 25 of the 29 species originally found in the stream had returned. Further, they reported that most of the species that had repopulated the stream reproduced successfully soon after re-entering the stream. With regard to macroinvertebrates, Larimore et al. (1959) stated that "invertebrates displayed remarkable adaptations to drought conditions and repopulated Smiths Branch soon after the flow was resumed."

Aquatic populations are not necessarily controlled by flow and attendant changes in velocity and depth, but often are limited by other factors (Lewis, 1969; Gorman and Karr, 1978). Thus, several investigators have not found a good relationship between flow and numbers or biomass of certain fishes. For example, Orth and Maughan (1982) found that the biomass of smallmouth bass was not correlated with weighted usable area (a flow dependent variable). White et al. (1976) reported that trout biomass, primarily brook trout, was related to seasonal stream flows in one central Wisconsin trout stream, the Roche-a-Cri, but not in a second central Wisconsin trout stream, Lawrence Creek. Kraft (1972) reported that flow reductions of 90 percent did not affect the number of underyearling brook trout but did reduce the number of older brook trout. Reductions of 75 percent did not affect brook trout of any age.

Brook trout eggs reside in the streambed during the winter low flow period. In this regard, survivability of salmonid eggs to redd dewatering is quite pronounced (Reiser and White, 1983; Becker et al., 1984). Reiser and White (1983) reported that "salmonid eggs can tolerate 1-5 weeks of dewatering with essentially no effects on hatching success . . . provided sediment moisture content is at least 4 percent by weight and the sediments neither freeze nor reach temperatures that exceed incubation tolerances." In contrast to the tolerance of salmonid eggs, many authors have pointed out that the tolerance of newly hatched fry to lack of water is much less, generally <8 hours.

3.0 Assessment of Flow Reductions by Stream

Another important factor in determining the impact of flow reductions on area streams is the amount of reduction in each stream. To evaluate stream-specific reductions, a community approach is necessary. Therefore, the so-called "Montana Method" described by Tennant (1976) was used to evaluate the overall impacts of flow reductions on the six streams in the study area. The only site-specific data needed for the Montana Method are average annual stream discharge and estimates of the expected flow reductions. The Montana Method, though somewhat simplistic, can yield flow recommendations comparable to those generated by other methods, such as wetted perimeter (single cross-section) method or the more complex incremental flow method (Hilgert, 1982; Orth and Maughan, 1982). The Montana Method is based on comparison of the estimated flow reductions with the mean annual flow on a percentage basis. The categories developed by Tennant (1976) are presented in Table A-1. A detailed explanation of each category is provided by Tennant.

Evaluation of the site-specific data and its inherent limitations is important because the accuracy of any predictions generated by the Montana Method is dependent on the accuracy of the estimates for average annual flow and for reductions in flow.

Average annual flow for Swamp Creek was taken directly from USGS records (USGS, 1984). The USGS does not maintain gaging stations on any of the other five streams being considered, however, and data gathered during the baseline studies (Chapter 2, Section 2.4) are not sufficient to allow them to simply be averaged. Because the best available data are those for Swamp Creek, it was determined that the most appropriate method for deriving average annual flow would be one that used the relationships among Swamp Creek data to derive comparable relationships for other study area streams. This was accomplished by using the percent exceedance value for Swamp Creek that corresponded to its average annual flow. Based on data calculated by Krug (1984), the average annual flow of 31.7 cubic feet per second for Swamp Creek corresponded to a 38 percent exceedance value (i.e., flows in Swamp Creek equalled or exceeded 31.7 cubic feet per second 38 percent of the

TABLE A-1

IN-STREAM FLOW CHARACTERIZATIONS (TENNANT, 1976)

NARRATIVE DESCRIPTION OF FLOWS	RECOMMENDED BASE FLOW REGIMES	
	OCT-MAR	APR-SEP
Flushing or maximum	200% of the average flow	
Optimum range	60-100% of the average flow	
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe degradation	10% of average flow to zero flow	

time). It was assumed that other streams in the study area would show the same relationship so estimates of average annual flow for Hemlock Creek, Creek 12-9, and Pickerel Creek were determined from flow versus exceedance curves presented by Krug (1984). The average annual flow for these streams was assumed to be the flow corresponding to 38 percent exceedance.

In assessing impacts associated with the predicted reductions in flow two low flow scenarios were considered, $Q_{7,2}$ and $Q_{7,10}$. These are defined as the average low flow rate over a 7-day period that will have and average occurrence of once in 2 and once in 10 years, respectively. To estimate average annual flow for Hoffman Creek and Creek 11-4, it was assumed that he ratios between average annual flow and $Q_{7,2}$ and $Q_{7,10}$ flows in Swamp Creek were applicable to Hoffman Creek and Creek 11-4. For Hoffman Creek, the estimate for average annual flow was 0.576 cubic feet per second when the $Q_{7,2}$ ratio (2.88) was used and 0.594 cubic feet per second when the $Q_{7,10}$ ratio (3.96) was used. The mean of these two estimates (rounded to the nearest hundredth), 0.59 cubic feet per second, was used as the estimate of average annual flow for Hoffman Creek.

For Creek 11-4, an estimate of average annual flow was derived by multiplying the estimated base flow (0.2 cubic feet per second) by the $Q_{7,2}$ ratio (2.88). This yielded an estimate of 0.58 cubic feet per second.

In the site area, two low flow periods typically occur: winter (December through March) when little or no surface runoff occurs and late summer (August and September) when evapotranspiration is high.

The $Q_{7,2}$ value approximates base flow, which is that portion of total flow originating from ground water discharge. The $Q_{7,10}$ flow rate is, by definition, an extremely low flow regime and represents worst-case conditions. As such, $Q_{7,10}$ flow rates may adversely affect the biota of streams in the site area without any effect from the Project. The $Q_{7,2}$ and $Q_{7,10}$ values for Swamp, Pickerel, and Hemlock creeks, and Creek 12-9 are presented in Chapter 2, Table 2.4-19 and were taken from Krug (1984). For Creek 11-4 it was assumed that the base flow ($Q_{7,2}$) was approximately one-third the flow (0.61 cubic feet per second) measured by Simon (1984) under what were considered normal conditions. No attempt was made to estimate $Q_{7,10}$ for this stream.

The low flow estimates for each stream were compared to average annual flow both before and after the predicted flow reductions described in subsection 4.2.4 and Appendix 4.1A for steady-state mine inflow under the middle recharge case. The accuracy of using the Montana Method to predict stream-specific impacts will be affected by accuracy of (1) the annual average flow estimates, (2) the low flow estimates, and (3) the predicted reductions. With regard to the first two points, the relative accuracy of any predictions for each stream can be categorized as follows:

Stream	Category	Reason For Placement In Category
Swamp Creek	Good	6 years of USGS monitoring data available; therefore, the estimates of average and low flows should be good.
Hemlock Creek Pickerel Creek Creek 12-9	Fair Fair Fair	These streams were gaged during baseline studies at the site; however, the amount of data for determining average flow are less than recommended by Tennant (1976).
Hoffman Creek Creek 11-4	Poor Poor	No routine gaging data available; low flow estimates are only approximations; each stream dominated by a single spring.

An assessment of the impacts associated with flow reductions for each of the streams in the study area follows.

3.1 Swamp Creek

Data reported by USGS (1979-1984) and that presented in Krug (1984) were used in this assessment. USGS (1984) reported that the average annual flow in Swamp Creek at the Highway 55 gage is 31.7 cubic feet per second. Annual, monthly, and daily flow data are summarized in Table A-2. The monthly flow data presented are the lowest mean monthly flows for the periods in question, either October through March or April through September. The daily flow values represent the lowest daily flow on any date during the period. Table A-2 indicates that lowest monthly flows typically occur during the winter, whereas the lowest daily flows usually occur during the summer. The 6-year average monthly and daily flow values presented in Table A-2 were compared to the 6-year average annual flow of 31.7 cubic feet per second. To assess the possibility of impacts during other low flow periods, $Q_{7,2}$ and

TABLE A-2

SUMMARY OF STREAM FLOWS MEASURED BY USGS AT HIGHWAY 55 ON SWAMP CREEK

WATER YEAR	MEAN ANNUAL FLOW (CFS)	LOWEST MONTHLY (DAILY) FLOW IN (CFS)	
		OCTOBER-MARCH	APRIL-SEPTEMBER
1978	33.5	17.1 (16)	34.2 (20)
1979	36.4	19.0 (17)	23.1 (13)
1980	29.1	18.9 (14)	24.8 (16)
1981	28.8	18.3 (15)	13.2 (9.4)
1982	24.8	14.3 (11)	15.0 (8.9)
1983	37.4	24 (21)	19.8 (12)
6-Year Average	31.7	18.6 (15.7)	21.7 (13.2)

$Q_{7,10}$ values were included in the comparisons (Table A-3). The "before" figures were then each reduced by 1.5 cubic feet per second to represent the amount of reduction in base flow predicted as a result of mine dewatering for the middle recharge case (see Chapter 4, Table 4.2-7).

For the October-March period, percentages based on monthly and daily flows place Swamp Creek in the outstanding category (Table A-1), both before and after flow reduction. Under $Q_{7,2}$ conditions, Swamp Creek remains in the excellent category before and after flow reduction. Under $Q_{7,10}$ conditions, it remains in the good category both before and after flow reductions.

During the April-September period, Swamp Creek is in the outstanding category under monthly flow conditions, regardless of whether or not reductions occur (Table A-3). With regard to daily flows, a decline from the good to fair category would occur for the before and after conditions, respectively. Under $Q_{7,2}$ conditions, Swamp Creek would remain in the fair category regardless of whether or not reductions in flow of the expected magnitude occurred. Only under $Q_{7,10}$ conditions would the rating fall below the fair category. However, the rating would be the same before and after flow reductions. Thus, the only time the Montana Method indicates that degradation of Swamp Creek might occur would be during $Q_{7,10}$ conditions.
Because these conditions will occur only infrequently and because the rating remains unchanged after accounting for the expected reductions in flow, it is concluded that significant impacts to the aquatic

TABLE A-3

PERCENTAGE THAT THE DESCRIBED FLOW CONTRIBUTES TO AVERAGE ANNUAL FLOW IN SWAMP CREEK

	OCTOBER-MARCH				APRIL-SEPTEMBER			
	MONTHLY	DAILY	$Q_{7,2}$	$Q_{7,10}$	MONTHLY	DAILY	$Q_{7,2}$	$Q_{7,10}$
Before flow reduction	59	50	35	25	68	42	35	25
After flow reduction of 1.5 cfs	54	45	30	21	64	37	30	21

communities of Swamp Creek are not likely to occur as a result of the predicted reductions in flow.

3.2 Hemlock Creek

No USGS or other long-term flow data are available for Hemlock Creek. Therefore data presented by Krug (1984) were used. These data show that the values for mean annual flow, $Q_{7,2}$ and $Q_{7,10}$ are 5.9, 2, and 1.4 cubic feet per second, respectively. The percentages of the average annual flow based on these values before and after the reduction of 0.4 cubic feet per second for the middle recharge case during steady-state mine inflow (Chapter 4, Table 4.2-5) are as follows:

	$Q_{7,2}$	$Q_{7,10}$
Before Reduction	34%	24%
After Reduction	27%	17%

These calculations show that under $Q_{7,2}$ conditions during the October-March period, the rating of the stream would decline from excellent to good, suggesting that few, if any, impacts would be expected. If $Q_{7,10}$ conditions developed during this period, the rating would decline from good to fair after accounting for the predicted reductions. Thus, some impacts may occur during periods of low flow. During the April-September period, the flows would generally fall between the cutoff points for the poor (10 percent) and fair (30 percent) categories regardless of whether or not the predicted reductions occur. Collectively, these data suggest that some degradation might result if the predicted reductions occur, but the amount of change would be small.

Evaluation of the morphometric and biological characeristics of Hemlock Creek supports the prediction that impacts should be minimal. For example, the lack of riffles and other shallow areas on Hemlock Creek (EA Science and Technology, 1984b) suggests that few sensitive areas would actually be dewatered. Similarly, Hemlock Creek is a depositional stream that would be less sensitive to reduced stream flows than an erosional stream would be. The fish and benthic communities of Hemlock Creek are dominated by species adapted to lentic rather than lotic conditions (Chapter 2, Section 2.5; EA Science and Technology, 1984b). Such species would not be affected by flow reductions of the magnitude currently predicted. Species needing hard substrates for breeding purposes (e.g., hornyhead chub and pearl dace) would only be affected if sedimentation were so severe as to bury gravel substrates or if deposition on active nests affected hatching. Also, the potential brook trout spawning area in Hemlock Creek (Chapter 2, Section 2.5) no longer appears to be suitable for this purpose, apparently because of siltation caused by the extensive number of beaver dams in the area (EA Science and Technology, 1984b).

3.3 Pickerel Creek

Long-term flow data are not available for Pickerel Creek. Data presented by Krug (1984) indicate that the values for mean annual flow, $Q_{7,2}$ and $Q_{7,10}$ are 1.75, 0.6 and 0.4 cubic feet per second, respectively. Based on these values, the percentages of the average annual flow before and after the reduction of 0.2 cubic feet per second for steady-state conditions under the middle recharge case (Chapter 4, Table 4.2-9) are as follows:

	$Q_{7,2}$	$Q_{7,10}$
Before Reduction	34%	23%
After Reduction	23%	11%

These comparisons suggest that reductions occurring during $Q_{7,2}$ conditions would not significantly affect the aquatic biota of Pickerel Creek. For example, during the October-March period, the rating, even after the predicted flow reduction, would be good (Table A-1). Under $Q_{7,10}$ conditions, however, flows in Pickerel Creek would be reduced to only 11 percent of the average annual flow if the predicted 0.2 cubic feet per second reduction occurs. This value approaches the poor classification, especially during the April to September period, and suggests that some adverse impacts to the aquatic biota may occur. However, these theoretical impacts must be considered in light of (1) the fish community of Pickerel Creek (only six species present, see Chapter 2, Section 2.5), (2) its depositional nature (no hard substrates are present), (3) the presence of few sensitive species, and (4) not being classified as a trout stream by the DNR.

3.4 Creek 12-9

Stream flow data presented by Krug (1984) were used to develop estimates of 4.7, 1.5, and 1.1 cubic feet per second for average annual flow, $Q_{7,2}$ and $Q_{7,10}$, respectively. Flow reductions of approximately approximately 25 percent may occur in Creek 12-9 (Appendix 4.1A).

Thus, percentages of the average annual flow calculated before and after a 25 percent reduction are as follows:

	$Q_{7,2}$	$Q_{7,10}$
Before Reduction	32%	23%
After Reduction	23%	18%

These comparisons suggest that little or no impact would occur as a result of reductions in flow during $Q_{7,2}$ conditions (Table A-1). Under $Q_{7,10}$ conditions during the October to March period, the rating of the stream would decline from good before flow reductions to fair after flow reductions. During the April to September period, the rating of the stream would be poor both before and after flow reductions. Thus, under $Q_{7,10}$ conditions some adverse impacts might occur, especially during the summer. However, the depositional nature of Creek 12-9 throughout most of its length, the poor existing fishery, and the lack of sensitive species suggest that the possibility of significant impacts is small. Creek 12-9 is not classified as a trout stream and only a single brook trout was collected in the stream during baseline studies (Chapter 2, Section 2.5).

3.5 Creek 11-4

Creek 11-4 was not included as part of the stream gaging network during the baseline studies, so limited flow data are available. The DNR (Simon, 1984) reported a 0.61 cubic feet per second flow value under normal flow conditions.

Using this datum and the estimating procedures described earlier, estimated flow rates of 0.58 and 0.3 cubic feet per second were derived for average annual and $Q_{7,2}$ flows, respectively. These data, in conjunction with an estimated 15 percent reduction in flow (Appendix 4.1A), indicate that the $Q_{7,2}$ represents 52 percent of the average annual stream flow before any flow reductions and 44 percent after the predicted reduction is taken into account. This suggests that little or no impact to the biota of Creek 11-4 would be expected. This contention is supported by the depositional nature of the stream and its lack of sensitive species. For example, the only obligate stream fish that has been reported is the pearl dace.

3.6 Hoffman Creek/Spring

Hoffman Creek was not extensively gaged during the baseline studies. Simon (1984) measured a flow rate of 0.59 cubic feet per second in the lower portion of Hoffman Creek on November 16, 1984 under what were considered to be normal flow conditions. Using these and other limited data, Krug (1984) suggests that the $Q_{7,2}$ might be between 0.1 and 0.3 cubic feet per second and the $Q_{7,10}$ is probably less than 0.2 cubic feet per second.

For the purposes of this assessment, the $Q_{7,2}$ and $Q_{7,10}$ values were assumed to be 0.3 cubic feet per second and 0.15 cubic feet per second, respectively. An average annual flow of 0.59 cubic feet per second was derived using the ratios described earlier. These data, in conjunction with the projected 30 percent reduction in flow (Appendix 4.1A), were used to calculate the percentages of the average annual flow before and after the reduction:

	$Q_{7,2}$	$Q_{7,10}$
Before Reduction	51%	25%
After Reduction	36%	18%

These comparisons suggest that impacts are unlikely during $Q_{7,2}$ conditions but are possible during $Q_{7,10}$ conditions.

Three factors need to be considered in evaluating the possibility of impacts to this stream. First, the available flow data are limited and, therefore, the percentages calculated above may be erroneously high or low, thereby over- or underestimating the likelihood of impacts. Second, in contrast to most of the streams considered, Hoffman Creek is inherently sensitive to reductions in flow because of its morphometry and biological communities. Hoffman Creek is sensitive morphometrically because reductions in flow could dewater riffles and reduce the amount of undercut bank cover. Hoffman Creek is sensitive biologically because it is a spawning and nursery area for brook trout. The shallow gravel substrates in the spawning area must remain covered by water and free of silt to allow brook trout to spawn successfully. Brook trout spawn in late October and November when flows should not be excessively low. Thus, spawning may not be affected. However, the eggs deposited in the redo will incubate in the stream bed throughout the winter low flow period. Significant increases in sedimentation during this period could suffocate eggs thereby reducing hatching success.

4.0 Lakes

To evaluate the potential for impacts to the five site area lakes (Skunk, Duck, Deep Hole, Little Sand, and Oak) that could be affected by reductions in water levels, literature pertaining to water level fluctuations and reductions (drawdowns) was reviewed. Two annotated bibliographies (Triplett et al., 1980; Polskey, 1982) were reviewed. Many of the same papers were discussed in the two reviews; however, the review by Polskey (1982) emphasized fisheries, whereas Triplett et al. (1980) contained more citations on macrophytes. The discussions that follow are based primarily on the annotations provided by either Polskey (1982) or Triplett et al. (1980).

Two important facts should be considered in order to relate the findings reported in the literature to the lakes in the site area. First, most of the studies that have been published were conducted on impoundments (reservoirs), particularly those in the south, the Great Plains, and the southwest. These impoundments are typically an order of magnitude deeper and several orders of magnitude larger than the lakes in the site area. Because of their size and geographical location, most are dominated by forage and rough fishes (principally clupeids, carp, buffalos, and drum), with the principal sport species being centrarchids (usually largemouth bass, crappie, and bluegill) and catfish. Thus, their species compositon is different from that found in site area lakes.

Secondly, these impoundments are generally used for either flood control or hydroelectric generation, and, as a result, significant cyclic fluctuations are common. Water level fluctuations of 3-9 m (10-30 feet) are typical, but fluctuations exceeding 30 m (100 feet) occur in some of the southwestern reservoirs. Thus, wide annual fluctuations are common in most of the reservoirs that have been studied. This contrasts greatly with the lake level fluctuations expected to occur in site area lakes, i.e., a gradual drawdown followed by establishment of a fairly constant water level at a reduced elevation.

4.1 Fish

The effects of lake level fluctuations and drawdowns on fishes can be grouped into four basic categories: (1) habitat loss or alteration, (2) effects on reproduction, (3) effects at the population level, and (4) management implications.

Reducing the water level will reduce the volume of water in a lake, which, in turn, usually reduces the amount of habitat available to fish. The degree of impact caused by such reductions depends on the magnitude and timing of the reductions, rate of drawdown, composition of the fish community, degree to which the littoral zone is affected, and the type and amount of the various substrates in the lake (Ploskey, 1983).

These factors are discussed in greater detail below. Because the littoral zone is the most productive area in most lakes, reductions in its extent will reduce the standing crop of fishes in a lake, assuming the existing populations consist of species dependent on the littoral zone and are not limited by other factors (e.g., water chemistry, substrate, temperature). In assessing how drawdowns affect aquatic organisms, Ploskey (1983) reported that an expert panel convened to assess the impacts of water-level changes concluded that "the capability to quantitatively predict the physical extent of water-level changes was adequate but that the capability to predict biological consequences was not." He also reported that the panel concluded that "the capability to predict the effects of water-level changes on aquatic biota in lower trophic levels was poor, and ecologists have not quantified the effects of water-level changes on fish, except to determine optimum or minimum requirements for spawning." Most of the investigations conducted to date have dealt primarily with situations where the reduction in habitat has been temporary (e.g., as part of annual drawdowns). Also, low water levels do not always reduce fish populations. For example, Starrett and Fritz (1965) reported stable low water levels increased macrophyte development and macroinvertebrate abundance and decreased turbidity. These changes at the lower trophic levels allowed the carrying capacity of fish to be higher in low water years than in high water years.

Reduced reproductive (spawning) success is commonly associated with reduced or fluctuating water levels. Nest building species (e.g., sunfishes) and species that depend on seasonal flooding of wetlands (e.g., northern pike and carp) are the species affected most (numerous citations in Ploskey [1982] and Triplett et al. [1980]). Conversely, pelagic species such as freshwater drum (Aplodinotus grunniens) are usually unaffected by reduced or fluctuating water levels (Benson, 1973).

The spawning requirements and characteristics of 10 species of fish found in the four site area lakes most likely to undergo lake-level reductions are summarized in Table A-4. Northern pike is the only species in these lakes that depends on flooded vegetation to spawn

TABLE A-4

SPAWNING CHARACTERISTICS AND REQUIREMENTS OF 10 COMMON OR IMPORTANT FISH SPECIES IN THE FOUR SITE AREA LAKES MOST LIKELY TO UNDERGO WATER LEVEL REDUCTIONS

SPECIES	SPAWNING CHARACTERISTICS
Northern pike	Typically in flooded marshes with emergent vegetation.
Golden shiner	Over beds of submerged vegetation.
Black/Yellow bullhead	Builds nests in mud or sand, often beneath bank, logs, or tree roots, in water 0.6 to 1.2 m (2 to 4 feet) deep. Nesting in weed beds is common in lakes.
Walleye	Broadcasts eggs over gravel and rubble substrates. These can be gravelly tributary streams or along wave washed shallows.
Yellow perch	Random spawners which do not build nests nor guard their young. They usually spawn over aquatic vegetation or submerged brush in a sheltered area, but are very flexible in their spawning requirements.
Bluegill/Pumpkinseed	Builds nests over sand or fine gravel, usually in colonies. Bluegills apparently nest in slightly deeper water (0.3 to 1.5 m [1.0 to 4.9 feet]) than do pumpkinseeds (0.3 to 0.8 m [1.0 to 2.6 feet]). Mixed nesting colonies sometimes occur.
Black crappie	Builds nests, typically near vegetation, in sand or fine gravel. Nests have also been observed over mud and clay bottoms. Nests occur at depths from 0.6 to >2 m (2.0 to >6.6 feet).
Largemouth bass	Builds nests, typically over sand and gravel substrates, but can successfully nest on soft substrates. The average depth of nests is 0.6 m (2 feet) but it ranges from 0.2 to 1.8 m (0.7 to 5.9 feet).

successfully. Among the four lakes, it is found only in Little Sand Lake, where only two individuals were collected during baseline studies (see Chapter 2, Section 2.5). It is unknown whether the small northern pike population in Little Sand Lake is from stocking or natural reproduction. If natural reproduction is involved, lowering the level of Little Sand Lake such that pike could not utilize the adjacent wetlands could eliminate this species from the lake.

Walleye are present in Little Sand and Deep Hole lakes but do not reproduce naturally in either lake (Lloyd Andrews, DNR, personal communication). Thus, water level reductions in these lakes will not affect the spawning success of this species.

Golden shiner, yellow perch, black bullhead, and yellow bullhead have relatively unspecialized spawning requirements and their spawning success should not be affected, unless macrophyte abundance is greatly reduced. The group whose reproductive success is most likely to be affected by reduced or fluctuating water levels is the centrarchids (sunfishes). These species (bluegill, pumpkinseed, black crappie and largemouth bass) are essentially restricted to Oak and Little Sand lakes, the two lakes containing sand substrates preferred by these species. Centrarchids can be affected by water-level alterations (Ploskey, 1982). Most of the documented adverse impacts have resulted from rapid reductions in lake levels, thereby causing nest desertion or desiccation of the eggs (Stewart, 1967; Robbins and Mathur, 1976; Summerfelt and Shirley, 1978). However, the slow rate at which levels are expected to decline in the site area lakes suggests that reproductive failure because of nest desertion or egg desiccation is unlikely.

Substrate changes in littoral zones of Little Sand and Oak lakes would also affect centrarchids. All four of the above-mentioned centrarchids prefer sand/gravel substrates for their nest sites. Although all four species can nest on mud or clay bottoms (Scott and Crossman, 1973; Becker, 1983), their reproductive success probably would be reduced if the amount of sand/gravel substrates in Little Sand and Oak lakes is reduced appreciably. The majority of the sand/gravel substrates in Little Sand Lake are located at depths of $\leq$ 1.5 m ($\leq$5 feet), and sandy substrates extend beyond the 1.5-m (5-foot) contour along much of the west, east, and north shores of the lakes. This suggests that water level reductions of approximately 1.5 m (5 feet) would be necessary in order to substantially reduce the amount of potential spawning area. Furthermore, the bluegill and pumpkinseed populations of Little Sand Lake are stunted, suggesting that a lack of productivity in the lake is limiting the populations rather than reproductive success.

The above information indicates that fish populations in the site area lakes are unlikely to be affected by reductions in the lake level (because of the slow rate at which it will proceed) or by lower water levels per se. However, at a reduced size the lakes could be less productive. Reductions in the area or volume of lakes do not automatically cause reductions in total productivity.

Manipulation of water levels is a tool used in managing the fisheries of many impoundments. Hulsey (1958) suggests that the management (drawdown) pool of a reservoir should not exceed 20 percent of the area at normal pool. Drawdowns are frequently used to (1) control excessive aquatic vegetation (Hulsey, 1958; Lantz et al., 1964; Beard, 1973; Cooke, 1980), (2) control rough fish (Brasch, 1953; Jenkins, 1970), (3) increase predation on forage fishes (Hulsey, 1958; Davis, 1967; Jenkins, 1970; Keith, 1974) and (4) re-aerate bottom soils thereby increasing productivity (Bennett, 1962; Jenkins, 1970; Keith, 1974). Thus, it is apparent that periodic drawdowns can be beneficial to lakes and reservoirs. Many of these benefits are realized, however, only when the lakes are refilled to normal levels.

4.2 Macroinvertebrates

Lake level fluctuation and drawdown effects on benthic macroinvertebrates can be categorized into two general areas: (1) stranding of organisms because of reduced water levels and (2) alterations of the littoral habitat (i.e., substrates and aquatic macrophytes) followed by changes in the profundal zone.

Mortality of benthic macroinvertebrates stranded by rapidly reducing lake levels has been documented (Ioffe, 1966; Paterson and Fernando, 1969; Kaster and Jacobi, 1978). Reported densities of chironomid larvae stranded by reduced lake levels range from 2,825/m^2 (McLachlan, 1970) to 6,146/m^2 (Cowell and Hudson, 1967). Many organisms on silt and clay substrates are able to burrow into the substrate and survive lake drawdown (Frey, 1967; Paterson and Fernando, 1970). Fillion (1967) reported survival of chironomids in areas dewatered up to 85 days. Lake drawdown during the winter also exposes stranded organisms to freezing temperatures (Aass, 1960; Kaster and Jacobi, 1978). For all organisms observed, Paterson and Fernando (1969) reported the lowest reductions (54-88 percent) for the chironomid *Glyptotendipes barbipes* during winter drawdown. They noted greater survival for organisms located more than 20 cm (7.9 inches) below the substrate surface. They also reported the pupation and emergence of three benthic species (one caddisfly and two chironomids) from exposed substrates. Although many organisms are killed by reductions in lake levels, Chironomidae (Cowell and Hudson, 1967), the mayfly *Hexagenia* (Swanson, 1967) and probably many other organisms (Davis and Hughes, 1965) survive drawdowns by migrating with the water level.

The above cited reports contain documentation on the effects of relatively fast water level reductions on benthic macroinvertebrates in littoral habitats of lakes and reservoirs. The drawdown in site area lakes, however, is predicted to occur over a relatively long period. Consequently, because of the ability of many littoral organisms to migrate, expected drawdown mortalities probably will be minimal.

The second major effect of fluctuating water levels and drawdowns is the alteration of the littoral habitat, which is important to many aquatic macroinvertebrates. Several researchers have documented the loss of the established littoral zone during lake drawdowns and the establishment of a new littoral zone in what was formerly the profundal zone (Swanson, 1967; Markosyan, 1969; Hunt and Jones, 1972a). Markosyan (1969) noted a decrease in benthic biomass in the littoral zone during the change from a rocky to muddy shoreline during drawdown. Swanson (1967) reported reduced *Hexagenia* nymph densities in the muddy profundal zone exposed to increased wave action during a drawdown. Conversely, several researchers have reported increased benthic densities in the profundal zones of lakes after water-level drawdown (David and Hughes, 1965; Markosyan, 1969; Hunt and Jones, 1972b). Davis and Hughes (1965) attributed the greater densities to the crowding of organisms in the reduced bottom area of the reservoir. Markosyan (1969) and Hunt and Jones (1972b) reported increased numbers of oligochaetes and chironomids in the profundal zone which they attributed to increased organic matter suspension in the unstable littoral zones and consequently increased production in the profundal zones.

The most obvious impact of fluctuating water levels is the loss of a permanent, established shoreline for development of a stable benthic community (Aass, 1960). Hunt and Jones (1972a) noted an increase in total benthos but a decrease in diversity in the fluctuating portion of the littoral zone. They reported species of the amphipod Gammarus and the isopod Asellus as the invertebrates most sensitive to water-level fluctuations.

Aass (1960) noted severe reductions of gastropods and Gammarus by fluctuating water levels. Hynes (1961) reported the loss or nearly complete loss of sponges, flatworms, leeches, gastropods, amphipods, mites, stoneflies, mayflies, some bugs, and caddisflies because of water-level fluctuations in the littoral zone of a reservoir; however, the densities of the benthos actually increased because of a great abundance of oligochaetes. Cowell and Hudson (1967) found reduced Hexagenia mayfly densities, but three-fold greater chironomid densities, in the littoral area of a fluctuating reservoir when compared with a more stable reservoir.

As summarized above, conflicting results (probably because of the variety of lentic habitats studied) have been reported in the literature but reports of altered benthic communities in the littoral zone of a fluctuating reservoir or lake are common. The resultant fauna generally has reduced diversity and biomass, but sometimes greater density of organisms. The greater density is attributed to the increased abundance of the opportunistic organisms (oligochaetes and chironomids) that colonize this rigorous habitat.

If the density or composition of aquatic macrophytes in the littoral habitat is significantly affected by lake level fluctuations or drawdown, major changes in the macroinvertebrate community of the littoral zone usually result. Large water-level changes in lakes and reservoirs generally destroy aquatic macrophytes (Markosyan, 1969; McLachlan, 1974) which, in turn, significantly reduces populations of macroinvertebrates by eliminating refuge and food.

Macrophytes - During periods of low lake levels, aquatic macrophytes can be substantially reduced by exposure, and subsequent desiccation and/or freezing (Aass, 1968; Beard, 1973; Nichols, 1974). Lake drawdown is a common management technique for controlling macrophytes in eutrophic lakes (Bonner, 1978; Cooke, 1980). Macrophyte growth is retarded by destroying seeds and vegetative structures during aerial exposure. The impact of such drawdowns depends upon the macrophyte species present and when the drawdown occurs. The common Wisconsin species *Ceratophyllum demersum*, *Myriophyllum* spp., *Potamogeton* *robbinsii* and *Potamogeton amplifolius* are especially susceptible to reductions because of drawdown (Beard, 1973). The reduction of the water lily *Nuphar* spp. depends on the severity of the winter temperatures. The extended drawdown period in site area lakes may eliminate some of the shoreline vegetation in Duck, Little Sand and Skunk lakes.

Water level fluctuations and drawdown will also result in aquatic macrophytes being affected by concomitant changes in substrates and water depth in the littoral zone. Markosyan (1969) noted a substantial reduction in *Chara* following a reduction in lake water levels. He attributed the reduction to suspension of newly exposed mud substrates and a subsequent increase in turbidity. In addition to the reduction of shoreline vegetation during drawdowns, Holcomb and Wegener (1971) noted the lakeward spread of some littoral macrophytes during reduced lake levels. Drawdown of site area lakes will not only result in changes in the littoral substrate and possibly increase turbidity, but will also expose some of the deeper vegetation to wave action. The effects of drawdown could affect the aquatic macrophytes in Skunk Lake and possibly Duck and Little Sand lakes, but any reduction probably would be temporary and the vegetation in these lakes would become reestablished after the lakes stabilize.

Plankton and Periphytic Algae - Information regarding the impact of water fluctuations and drawdowns on the lower trophic levels (plankton and periphytic algae) is limited. Plankton (zooplankton and phytoplankton) shows variable effects due to water-level fluctuations. Asch and Kingsbury (1972) found no correlation between water level and zooplankton abundance in an Iowa reservoir. In a comparison of six regulated and seven unregulated lakes, Lotmarker (1964) found that zooplankton densities were not significantly different, but water level regulation did reduce numbers of *Daphnia longispina hyalina* and *Bosmina coregoni*. Legovich et al. (1973) reported that the biomass of rotifers increased during falling lake levels but found no significant change in cladoceran and copepod biomass. In addition, diatoms became the dominant algal group and algal biomass nearly doubled. Legovich et al. (1973) attributed the community changes to increased nutrients from shoreline washed by waves during the drawdown period. Arner et al. (1971) noted no obvious effects on phytoplankton and zooplankton populations because of drawdown, but reported a strong spring algal bloom in a fluctuating lake. Vennie and Shaw (1979) also noted increased algal levels in a Wisconsin reservoir subjected to winter drawdown. They attributed this increase to resuspension of settled phosphorus by wave action during drawdown.

Cowell and Hudson (1967) reported that winter drawdown prevented the full development of littoral periphytic algal communities. In a study of the mechanical control of aquatic vegetation, Bonner (1978) noted that the filamentous blue-green alga *Lyngbya* was not controlled by drawdown.

The above studies indicate that nutrient levels increase in lakes and reservoirs subjected to drawdown and as a result, the plankton community is affected and often exhibits an increase in production. The periphytic algae along the shoreline may be reduced (at least initially) because of drawdown. The effect of drawdown on the plankton and periphytic algal communities in site area lakes will depend on the degree of the reduction and the limnological characteristics of the specific lake.

4.3 Individual Lake Assessment

An assessment of the potential impacts to each of the five site area lakes is summarized below. This assessment is based on the previously cited literature and the physical, chemical, and biological characteristics of each lake. Much of the data reported in the literature are conflicting, however, and even when consistent impacts have been demonstrated, the circumstances typically involved water level reductions much greater than those predicted to occur in the site area. Thus the resultant assessment is, of necessity, qualitative rather than quantitative and is based on professional judgement.

4.3.1 Oak Lake

Because Oak Lake is perched (i.e., it lies above the ground water table), no impacts from mine dewatering are expected.

4.3.2 Deep Hole Lake

In Deep Hole Lake, lake level reductions resulting from mine dewatering will not exceed those expected under preconstruction conditions (see Appendix 4.1A, Figure A.10-13). Therefore, no impacts are expected to occur in Deep Hole Lake.

4.3.3 Little Sand Lake

As a result of mine dewatering, the water level in Little Sand Lake is predicted to decline by 0.07 m (0.23 foot) under average conditions and approximately 0.2 m (0.7 foot) during dry climatic conditions (Appendix 4.1A). Based on hipsographic curves prepared by Exxon, these declines will cause a reduction in lake area of 2 percent and in volume of 4 percent under average conditions. Based on the preceding discussion of how lake level reductions affect aquatic organisms, it is unlikely that the small reductions predicted during average climatic conditions would impact the lake.

Among the fish species present in Little Sand Lake during 1977-78 (the last time period for which data are available), centrarchids (bluegill, pumpkinseed, black crappie and largemouth bass) and northern pike are the species most susceptible to reductions in water levels (Table A-5). Centrarchids are vulnerable because of their nest building habits. However, a gradual decline of 0.07 m (0.23 foot) should not be harmful to the reproductive success of these species, because the sandy substrates they prefer for spawning are abundant in the lake and their nests should be beyond the depth at which dewatering will occur.

Northern pike are uncommon in Little Sand Lake (Table A-5). This species requires marshes and wetlands for spawning (Table A-4), which are limited adjacent to Little Sand Lake. Because of a lack of suitable spawning habitat, Little Sand Lake will never support a large northern pike population without stocking. It is unlikely that a 0.07 m (0.23 foot) drop would appreciably affect pike spawning.

The small amount (0.07 m [0.23 foot]) of drawdown and the slow rate at which it will proceed suggest that impacts to aquatic macroinvertebrates and macrophytes should be negligible.

TABLE A-5

SUMMARY OF POTENTIAL FOR IMPACTS TO FIVE LAKES IN THE SITE AREA

Lake	Likelihood of Impacts	Reason(s) for Classification
Oak	None	Perched lake.
Deep Hole	Very low	Reductions will not exceed those that occur normally.
Little Sand	Low	Under average climatic conditions the lake level will drop only 0.06 m (0.2 foot), with another drop of approximately 0.15 m (0.5 foot) occurring under dry conditions (Appendix 4.1A).
Skunk	Moderate	Skunk Lake contains no fish. However, changes in its macrophyte community and especially in the associated wetland community are likely.
Duck	Moderate	No impacts are expected under average conditions; however, some impacts may occur under dry conditions. The most probable impacts will be dewatering of macrophytes and an increase in the likelihood of winterkills.

[a]Source: Chapter 2, Section 2.5.

[b]– Indicates none collected.

[c]Reported as present in DNR verification studies.

Under dry conditions, the area and volume of the lake may decrease by 3 and 9 percent, respectively. Thus, the possibility of adverse impacts increases, but only slightly. Centrarchids should be unaffected by a total decline of approximately 0.2 m (0.7 foot). Natural fluctuations of 0.65 m (2.14 feet) were recorded during the baseline monitoring period (1977-78) and the minimum lake level reported during that period (1590.82 feet) is 0.09 m (0.3 foot) lower than what is predicted under dry conditions.

A drop of approximately 0.2 m (0.7 foot) from the Ordinary High Water Mark (OHWM) would, however, be detrimental to northern pike as it would probably prevent access to the already limited wetland spawning areas. Because no stocking of northern pike has occurred in Little Sand Lake since 1978 (Lloyd Andrews, DNR, personal communication), the current status of this species in Little Sand Lake is unknown.

The magnitude of the predicted reductions under dry conditions is small and significant effects on the macroinverterate community seem unlikely. The 9 percent reduction in volume also seems unlikely to increase the likelihood of winterkills.

With the exception of northern pike, the group most likely to be affected during dry conditions is aquatic and/or wetland vegetation. Aquatic macrophytes, particularly emergents, may be affected in Little Sand Lake. However, large scale shifts in either abundance or species composition seem unlikely because of the small amount of reduction. Wetland vegetation is more likely to be affected than submerged macrophytes.

In summary, impacts to the aquatic biota of Little Sand Lake are unlikely during average climatic conditions. Under dry conditions, the possibility of impacts increases, with northern pike and wetland vegetation being the groups most likely to be affected. Major changes in the fish and benthos communities are unlikely, however, because they probably are affected more by the low pH and productivity of the lake than they are by water levels. More than half of the predicted total drop in lake level elevation during dry conditions would occur irrespective of mine operations.

4.3.4 Skunk Lake

Skunk Lake is the smallest and shallowest of the lakes under consideration. It is a winterkill lake which contains no fish and has a depauperate macroinvertebrate fauna (Chapter 2, Section 2.5). Water levels in Skunk Lake will decline 0.18 m (0.58 foot) as a result of mine dewatering during average climatic conditions (Appendix 4.1A). This will result in a decline in lake volume of about 20 percent and will dewater much of the adjacent wetlands (Appendix 4.1A). Although the sparse macroinvertebrate community is already composed of tolerant species, further declines are likely. Changes in macrophyte abundance and composition may occur. An additional 0.15 m (0.5 foot) decline is predicted to occur after one dry year (Appendix 4.1A), thereby further increasing the likelihood of winterkills in the lake.

4.3.5 Duck Lake

Duck Lake is predicted to undergo a decline of 0.06 (0.2 foot) during average climatic conditions and a total of approximately 0.6 m

(2.0 feet) under dry conditions (Appendix 4.1A). Eighty percent (0.5 m [1.6 feet]) of the predicted total decline is a result of climatic conditions and not mine operation. Based on hipsographic curves provided by Exxon, these reductions in elevation will result in a less than 2 percent reduction in lake area and a 4 to 5 percent reduction in volume under average conditions. Under dry conditions, the area will be reduced by 12 percent (compared to that at the OHWM) and the volume will decline by 38 percent (compared to that at the OHWM).

During baseline studies in 1977-78 and following verification studies by the DNR, only three species of fish--yellow perch, black bullhead, and central mudminnow--were collected from Duck Lake (Chapter 2, Section 2.5; Ramharter [1982]). Of these species, yellow perch were abundant, whereas the other two species were uncommon. The low number of species may be a result of the low average pH (5.0) in Duck Lake. Other investigators have reported that acid lakes have fewer fish species than lakes having a neutral pH (Harvey, 1980; Rahel and Magnuson, 1983; Wiener, 1983). However, other factors also may contribute to the paucity of fish species because Wiener (1983) found 5 to 11 species of fish in six naturally acidic small lakes in northern Wisconsin. Likely contributing factors are low alkalinity, orthophosphate, and dissolved oxygen values. Because of its shallow nature, Duck Lake approaches being a winterkill lake (Lloyd Andrews, DNR, personal communication) and dissolved oxygen values as low as 0.5 mg/l have been reported (Chapter 2, Section 2.4).

The predicted water level reductions under average climatic conditions should not significantly affect the aquatic biota of Duck Lake. Under dry climatic conditions, however, some dewatering of the adjacent wetlands is likely and Duck Lake will become more susceptible to winterkills. Both of these impacts could, in turn, affect the composition of the macrophyte, benthic, and fish communities. Because all three fish species in the lake have relatively unspecialized spawning requirements (Becker, 1983), each should be able to spawn under dry conditions. However, increased intra- and inter-specific competition may reduce survival and subsequent growth of larvae. The macroinvertebrate community may also be affected because of increased predation and competition. The increased likelihood of low dissolved oxygen concentrations in the winter would affect yellow perch more than they would black bullhead or central mudminnow.

5.0 References

See Chapter 4, subsection 4.2.11 for a complete list of references cited.

APPENDIX 4.2B

INFORMATION USED IN EVALUATING EFFECTS OF CHANGES IN SURFACE WATER HYDROLOGY ON WETLAND VEGETATION

INFORMATION USED IN EVALUATING EFFECTS OF CHANGES IN SURFACE WATER HYDROLOGY ON WETLAND VEGETATION

The hydrologic effects on wetland vegetative communities were assessed for the previous MWDF design on the basis of seasonal changes in outflow during preoperation (phase 1) and in each of the four tailing ponds operational stages (phases 2 through 5) (IEP, Inc., 1982). The results of IEP's assessment indicated minimal changes in the water balances of wetlands associated with the MWDF during phases 2 through 5. Therefore, it was assumed that changes in wetland inflow or outflow, described by IEP, Inc. (1982) for MWDF development phases 2 thorugh 5, would be representative, although greater in magnitude, for the current downsized MWDF design. The scores from the Storm and Floodwater Storage Function Model (the model) for each of the wetlands evaluated were also used to assess these effects (NAI and IEP, Inc., 1982). As in the Biological Function Model, this model utilized a semi-quantitative approach based on physical and biological factors (elements) which govern the storm and floodwater storage function. Each element and their conditions were weighted based on their contribution to the function (Table B-1). Although the numerical range of the model is 31-123 and the mean 77, the range of scores for the 158 wetlands in the study area was 56-109 and the mean 91.9 (Table B-2). The actual mean was 14.9 points higher than the model mean because of the abundance of wetlands in the study area having a high storm and floodwater storage function.

TABLE B-1

STORM AND FLOOD WATER STORAGE FUNCTION MODEL

ELEMENTS	ELEMENT WEIGHT	CONDITION WEIGHT	CONDITIONS
Dominant Wetland Class	2	1	Stream or brookside wetland
		1	Open fresh water
		2	Deep fresh marsh (aquatic bed)
		4	Shallow fresh marsh
		4	Yearly flooded floodplain
		3	Wet meadow.
		5	Shrub swamp
		4	Wooded swamp
		3	Bog
Percent Open Water	2	3	0-33%
		2	34-66%
		1	67-95%
		0	96-100%
Vegetative Density	4	3	High
		2	Moderate
		1	Low
Topographic Configuration	2	4	Closed basin
		3	Semi-closed basin
		2	Valley
		1	Hillside
Topographic Position in Watershed	3	3	Upper
		2	Intermediate
		1	Lower
Surficial Material of Watershed	2	4	Till
		1	Stratified sand and gravel
		3	Stratified fine sand and silt
		2	Alluvium
Surficial Geologic Materials of Wetland Banks	2	1	Till
		4	Stratified sand and gravel
		2	Stratified fine sand and silt
		3	Alluvium
Organic Material	1	2	High permeability
		1	Low permeability
		0	Absent
Dominant Hydrologic Type	5	1	Condition 1
		2	Condition 2
		3	Condition 3
		4	Condition 4
		5	Condition 5
		6	Condition 6
Hydrologic Connection	4	1	Not part of riparian system
		2	Part of riparian system
Water Level Fluctuation	3	2	High
		1	Low
Inlet	1	2	Perennial
		1	Ephemeral
		0	Absent
Outlet	1	1	Perennial
		2	Ephemeral
		0	Absent
Size	4	3	Large .6 acres
		2	Medium 1.1-4.5 acres
		1	Small .0 acre
		Range 31-123*	
		Mean 77	

*Total value for one inlet and one outlet only. Some wetlands may have more than one inlet or outlet, but the range presented above is for wetlands with only one inlet and one outlet.

TABLE B-2

STORM AND FLOODWATER STORAGE FUNCTION MODEL SCORES OF WETLANDS AFFECTED BY SURFACE WATER RUNOFF FROM THE RECLAIM POND AND MINE WASTE DISPOSAL FACILITY[a]

WETLAND NO.	DOMINANT WETLAND TYPE[b]	STORM AND FLOODWATER STORAGE FUNCTION MODEL SCORE[c]
F15	DS	98
F23	CS	106
F24	SS	69
F25	SM	97
F26	B	58
F28	B	103
F29	B	96
F57	DS	95
F60	CS	101
F61	DS	84
F62	DS	94
F63	CS	101
K1	SW	59
K2	DS	101
K3	CS	102
M1	SS	90
M2	SW	60
M3	DS	98

[a]Source: NAI and IEP, Inc. (1982).

[b]B = Bog; CS = Coniferous swamp; DS = Deciduous swamp; SM = Shallow marsh; SS = Shrub swamp; SW = Streamside wetland.

[c]Model range: 31-123; model mean: 77; actual range: 56-109; actual mean: 91.9.

To assess the potential influence of the projected changes in wetland water balances on the vegetation of these areas, a review of the literature was undertaken to determine the current understanding of how changes in wetland hydrologic regimes affect plant communities. It is recognized that hydrology is a principal factor influencing plant community composition and productivity (Jeglum, 1971; Carter et al., 1979), i.e., different types of wetland plant communities are associated with distinct water regimes in terms of the duration of flooding, average water table, and extent of water table fluctuation (Cowardin et al., 1979). This current analysis has provided information to (1) characterize the existing water regime of the wetlands in the areas disturbed during Project construction activities, (2) determine if the projected changes in water balances of these wetlands will result in water regimes outside the range (wetter or drier) considered normal for these communities, and (3) determine the likely results to the plant communities, particularly in terms of changes in dominance types but also with respect to productivity, if the changes are major. This analysis applies to the phase by phase changes in wetland water balances presented in IEP, Inc. (1982) for the earlier reclaim pond and MWDF design. It was assumed that the changes in wetland surface water hydrology (i.e., differences between water discharge [outflow] under existing conditions and outflow during construction and operation) will be similar but lesser in magnitude for the current reclaim pond and MWDF design for phases 1 through 4. Changes in wetland hydrology under phase 5 conditions (final reclamation) for the proposed reclaim pond and MWDF design (see Chapter 4, subsection 4.3.4.3) have also been considered in this analysis.

The change in water depth or degree of soil saturation in a wetland was of particular relevance in assessing effects on wetland vegetation. Assessment of the change in water depth in a given wetland was based on the assumption that a high score in the model reflected a high water storage function. Large changes in outflow in such a wetland would be less likely to result in corresponding water depth changes than in a wetland having a poor storage function and a short storage release cycle. Accordingly, it was assumed that the condition indicating a high impact potential because of a major change in water depth would be a large difference in outflow for a wetland with a low storm and floodwater storage function. A condition indicating low impact potential would be a small difference in outflow for a wetland with a high storm and floodwater storage function. In general, the 18 potentially affected wetlands around the perimeter of the reclaim pond/MWDF had high scores, with all but six (F24, F26, F61, K1, M1 and M3) exceeding the actual mean for the Storm and Floodwater Storage Function Model (Table B-2).

The wetland communities in the subject area include deciduous and coniferous wooded swamps, sapling, bushy and compact shrub swamps, marshes, streamside wetlands, and bogs. Coniferous forested wetland is by far the dominant class in areal extent. Organic soils ranging in texture from sapric to hemic are typically found in the swamps. These communities are characteristically seasonally flooded, that is, "surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years" (Cowardin et al., 1979). The drop in water table elevation during the growing season is generally attributed to evapotranspiration; thus, the vegetation itself strongly influences the water regime in these wetlands (Satterlund, 1960; Bay, 1967; Novitzki, 1980).

The impact of increases in water levels (i.e., flooding) to wetland vegetation has been examined considerably more than the impact of lowering the water levels (Teskey and Hinckley, 1978; Whitlow and Harris, 1979). There is little specific data on the effects of lowering water levels. Conceptually, such activity could lead to the invasion of more mesic species. In the coniferous forested wetlands, for example, conditions may be more suitable for species such as yellow birch (Betula lutea), sugar maple (Acer saccharum), and American elm (Ulmus americana).

The range in site conditions suitable for the dominant species in these swamps, however, suggests that only an extreme reduction in water level and duration of flooding would cause an appreciable change in species composition (Christensen et al., 1959; Curtis, 1959; Teskey and Hinckley, 1978). A major decrease in water level, approximately 1 m (3.3 feet) or more, would result in subsidence of the organic sediments and shock to the vegetation. The relatively small decreases in water budget assumed for these wetlands are not expected to result in any major changes; potential benefits may include increased species diversity and a temporary increase in growth rate due to increased mineralization of the surface organic soils.

An important factor in mitigating the effects of a decrease in wetland water budget is the absorptive or storage capacity of the organic soils; in well-decomposed (sapric) peat, lowering the water table has been shown to remove only about 10 percent of the water (Bay, 1967). Also, root systems are believed to react quickly to changes in water level by extending or dying back to achieve a similar relative position (Phipps et al., 1979).

In those wetlands where an increase in water budget is forecast, the degree of change is considered too small to result in important changes to the plant communities. In general, wetland trees cannot survive more than 2 years of continuous flooding; maintaining a duration of flooding during the growing season of more than 50 percent is considered potentially fatal to most deciduous trees (Hall and Smith, 1955; Teskey and Hinckley, 1977). Because the seasonal fluctuations in water table activity are not anticipated to change in the wetlands, during most years there will be a period when the water table drops below the surface of the soil in the wetlands providing an opportunity for aeration in the root zone. Since most of the tree species in these wetlands grow on elevated root crowns (hummocks), the ability to withstand prolonged flooding is achieved by avoiding the adverse impacts associated with anaerobiosis (Whitlow and Harris, 1978).

Teskey and Hinckley (1978) have rated the flood tolerance of the most common tree species found in these swamps (Table B-3). Most of the species are considered tolerant or very tolerant to flooding. Only hemlock (Tsuga canadensis) is listed as intolerant. Hook et al. (1970) have shown that species which are tolerant of flooding may show improved growth when flooded. This suggests that a substantial increase in duration of flooding would be required to cause a major change in plant community composition. Most wetlands discharge flood waters rapidly

TABLE B-3

FLOOD TOLERANCE LISTING FOR PRINCIPAL SPECIES IN FORESTED WETLANDS OF THE SITE AREA

SPECIES	TOLERANCE RATING*
Acer rubrum	Tolerant
Fraxinus pennsylvanica var. *subintegerrima*	Very tolerant
Thuja occidentalis	(not listed)
Tsuga canadensis	Intolerant
Abies balsamea	Tolerant
Betula lutea	Intermediately tolerant
Ulmus americana	Tolerant
Populus tremuloides	Intermediately tolerant
Larix laricina	Tolerant
Picea mariana	Very tolerant
Tilia americana	Tolerant

*Source: Teskey and Hinckley (1978).

Definitions for each rating are listed below:

Very tolerant. Trees which can withstand flooding for periods of two or more growing seasons. These species exhibit good adventitious or secondary root growth during this period.

Tolerant. Trees which can withstand flooding for most of one growing season. Some new root development can be expected during this period.

Intermediately tolerant. Species which are able to survive flooding for periods between 1 to 3 months during the growing season. The root systems of these plants will produce few new roots or will be dormant during the flooded period.

Intolerant. Species which cannot withstand flooding for short periods (1 month or less) during their growing season. The root systems die during this period.

from the shallow upper portion of the wetland ground water body (O'Brien, 1977), thus only a constriction or impounding at the wetland outlet will produce a lasting rise of the water table. Again, there is a potential for evapotranspiration to reduce higher than normal water levels during the growing season (Satterlund, 1960; Novitzki, 1980). Novitzki (1980) reported that as much as 85 percent of the outflow from swamps in Wisconsin may be from evapotranspiration.

The potential changes which might occur from an increase in wetland water levels can be described through an understanding of retrogressive succession. In the forested wetlands of the region a permanent rise in the water table beyond the level normally found in these habitats would result in reversion to an earlier successional stage, either shrub or herbaceous communities. Given the predominance of forested wetlands in the region at the present time, this change would add to habitat diversity and benefit wildlife. Snag development would further add to wildlife values.

References

See Chapter 4, subsection 4.2.11 for a complete list of references cited.