Water treatment facility: final plans and specifications. 1986

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WATER TREATMENT FACILITY

FINAL PLANS AND SPECIFICATIONS

SEPTEMBER 1986

EXXON COAL AND MINERALS COMPANY
CRANDON PROJECT
CRANDON, WISCONSIN

CH2M HILL

WATER TREATMENT FACILITY

FINAL PLANS AND SPECIFICATIONS

PREPARED FOR:
EXXON COAL AND MINERALS COMPANY
CRANDON PROJECT
CRANDON, WISCONSIN

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September 1986

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SECTION 1
Introduction

Section 1
INTRODUCTION

1.1. PURPOSE OF DOCUMENT

This document presents the design of the water treatment system planned for Exxon's Crandon Project. The Water Treatment Facility Final Plans and Specifications is intended to support Exxon's application for a WPDES permit for the project pursuant to Wisconsin Statute 144.04 and NR108.04.

The following information is presented:

- Summary of applicable federal and state effluent regulations.
- A description of the treatment processes selected for the Crandon Project.
- Detailed documentation of the proposed configuration of the water treatment system and the sizing of major components in the system.
- Summary of projected influent and effluent water qualities.
- Preliminary construction schedule.
- Estimated sludge production.
- Operating manpower requirements.

1.2 BACKGROUND

The water treatment system design presented in this document is supported by several years of effort by CH2M HILL, Exxon, and other contractors working under Exxon's direction.

The process and mechanical design of the water treatment systems have evolved over the last 5 years. The final design has been prompted by receipt of effluent limitations from the Wisconsin Department of Natural Resources (DNR), treatment process pilot studies by Exxon, Exxon's desire to build redundancy and operating flexibility into the the water treatment system, and Exxon's recent changes to the configuration of the mine and milling facilities.

It should be noted that refinements will be made during final engineering to the design as presented in this document.

SECTION 2
Effluent Requirements

Section 2
EFFLUENT REQUIREMENTS

2.1 NEW SOURCE PERFORMANCE STANDARDS FOR MINES AND MILLS (APPLICABLE TO THE CRANDON PROJECT)

The EPA has promulgated New Source Performance Standards (NSPS) for copper, lead, and zinc mines and mills. The categorical standards applicable to effluent discharged from the Crandon project (40 CFR 440.104) are summarized as follows:

Effluent Characteristic	Effluent Limitations: Maximum for Any 1 Day	Effluent Limitations: Average of Daily Values for 30 Consecutive Days
	Milligrams Per Liter	
Cu	0.30	0.15
Zn	1.5	0.75
Pb	0.6	0.3
Hg	0.002	0.001
Cd	0.10	0.05
pH	*	*
TSS	30.0	20.0

* Within the range 6.0 to 9.0

NSPS applicable to the Crandon project further requires that:

1. The volume of water which can be treated and discharged is equal to the volume of water pumped from the mine plus the annual excess of rainfall over evaporation in the tailings and reclaim ponds and any other water which enters the process water system due to precipitation.

2. Water discharged from the effluent water treatment system must meet the standards set forth in paragraph 440.104(a) above.

3. Process water from the mill water circuit must be treated for recycle unless Exxon demonstrates that such recycle interferes with the ore recovery process and that such interference cannot be eliminated through appropriate treatment processes.

NSPS effluent limitations for treated mine water are technology based limitations based on treatment of mine water with lime precipitation, clarification, and neutralization.

2.2 WISCONSIN DNR EFFLUENT LIMITATIONS

The Wisconsin Department of Natural Resources (DNR) has established effluent limitations to be included in the WPDES permit for the Crandon Project. These limitations are more stringent than NSPS and are water quality based effluent limitations as established by the DNR to protect aquatic life in Swamp Creek.

Table 2-1 shows effluent limitations currently projected by the DNR for the Crandon Project.

2.3 PROCESS WATER RECYCLE REQUIREMENTS

As described in the previous section, New Source Performance Standards require that the project be designed for and operated with complete recycle of process water. Process water can be discharged in those instances where it is required to keep the project in operation and where no treatment process will correct the problem. To achieve complete reuse of process water in the mill, it is necessary to control the concentration of certain organic and inorganic constituents in the water that is recycled in the mill.

The concentration of certain organic compounds, particularly the frother compounds, will be controlled by the use of tailings and reclaim ponds. Naturally occurring processes such as evaporation and oxidation will control the concentration of these compounds. Oxidative processes will also control the concentration of thiosalts by conversion to sulfate.

One factor that imposes a limit on the amount of water that can be recycled to a mill is the presence of calcium and sulfate in the water. In a completely closed loop system, the concentration of calcium and sulfate in the water would continue to increase until the solubility product of calcium sulfate was exceeded. If this were to occur, severe gypsum scaling would occur in the mill piping system. To prevent scaling conditions, sufficient calcium and sulfate must be removed from the mill water circuit to control the buildup of these compounds. This will be the function of that portion of the water treatment plant devoted to recycle water treatment.

To summarize, according to Federal NSPS, water pumped out of the mine and the net gain from precipitation can be discharged provided certain effluent limitations will be met. This will be ensured by proper design and operation of the mine water treatment portion of the plant. Further, all process water must be recycled. The use of reclaim water ponds and the proposed recycle water treatment process will ensure successful water reuse in the mill.

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Table 2-1 (Page 1 of 2)

WATER QUALITY BASED EFFLUENT LIMITS FOR THE PROPOSED DISCHARGE TO SWAMP CREEK

		Monthly average limits[c] based on effluent flows (Q_e) of		
Parameters[a]	Daily Maximum[b]	<1,300 gpm	1,301-2,000 gpm	2,0001-3,000 gpm
Toxic Pollutants				
Arsenic	1.48[d]	0.626/0.663[d]	0.508/0.533[d]	0.436/0.452[d]
Cadmium	0.073	0.0045/0.0048	0.0037/0.0039	0.0032/0.0033
Chromium (VI)	0.058	0.051/0.053	0.042/0.043	0.036/0.037
Chromium (III)	11	0.27/0.28	0.22/0.23	0.19/0.19
Copper	0.025	0.025/0.025	0.021/0.022	0.019/0.019
Cyanide	0.093	0.010/0.011	0.010/0.011	0.010/0.011
Lead	0.6[e]	0.118/0.125	0.096/0.10	0.082/0.085
Mercury	0.0022	0.0002[f]	0.0002[f]	0.0002[f]
Selenium	1.0	0.165/0.174	0.134/0.140	0.115/0.119
Silver	0.007	no rec'd value	no rec'd value	no rec'd value
Zinc	0.44	0.14/0.14	0.11/0.12	0.10/0.10
Conventional Pollutants				
BOD		20 (summer)[g]	15 (summer)[g]	15 (summer)[g]
		40 (winter)[g]	30 (winter)[g]	30 (winter)[g]
Total Suspended Solids	30[e]	20[e]	20[e]	20[e]
pH (S.U.)	6 - 9			
Non-Conventional Pollutants				
Barium		10.8/11.4	8.8/9.2	7.5/7.8
Fluoride		14.6/15.5	11.9/12.4	10.2/10.6
Iron		1.8/1.9	1.5/1.6	1.4/1.4
Total Dissolved Solids[h]	1,210/1,000[i]			

---

[a] All values are in mg/l unless noted differently.

[b] For most of the toxic pollutants (except lead), the maximum limits were derived from the available acute toxicity information for resident Wisconsin aquatic species.

[c] The monthly average limits were calculated based on the following mass balance equation:

$$Ce = \frac{Qm\ Cm - Qs\ Cs}{Qe}$$

[d] The water quality criterion for arsenic to protect human health is being reviewed. The above limits are based on the acute and chronic toxicity affects to resident Wisconsin aquatic species.

Table 2-1 (Page 2 of 2)

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[e] Categorical limits (New Source Performance Standards) apply because they are more stringent than the water quality numbers.

[f] The monthly average water quality criterion necessary to prevent exceedance of FDA action limits in fish and thus protect human health is 0.0002 mg/l. This criterion value is near the detection limit of most current analytical techniques.

[g] BOD limits are applied as weekly rather than monthly averages.

[h] Limits for chlorides and sulfates are regulated as part of the TDS number.

[i] The maximum limit for TDS is 1,210 mg/l when Q_e <1,300 gpm and 1,000 mg/l when Q_e is between 1,301 and 2,000 gpm.

Note: Two scenarios were assumed in determining the monthly average effluent limits. The first set of numbers (before the slash) were calculated based on an upstream $Q_{7,10}$ of 13.5 cfs (assuming no flow mitigation for Upper Swamp Creek). The second set of numbers were calculated based on an upstream $Q_{7,10}$ of 15 cfs (assuming that there will be flow mitigation to Upper Swamp Creek).

Source of <1,300 and 1,301 to 2,000 gpm data: Letter from B. Baker, Bureau of Water Resources Management to B.J. Hansen, Crandon Permitting Manager, dated February 19, 1986.

Source of 2,001 to 3,000 gpm data: Provided by Mr. Ronald Martin, Department of Natural Resources, on August 27, 1986.

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SECTION 3
Water Management Program

Section 3
PROJECT WATER MANAGEMENT

The water management system for the Crandon Project has been designed recognizing the nature of the orebody, the hydrologic and climatic conditions in the area, applicable federal NSPS regulations, and effluent limitations recently received from the DNR. All or a portion of the water pumped from the mine will be treated for discharge as allowed by the federal NSPS regulations. The project has been designed for 100 percent recycle of mill process water with the ability to discharge treated process water on a nonroutine basis if necessary.

The mine and mill site surface facilities are shown in Figure 1.

The water management system for the Crandon Project includes the following important elements:

Mine & Process Water Systems

- Mine Drainage
- Concentrator
- Tailings Thickener
- Tailings Pond
- Reclaim Ponds
- Water Treatment Plant
- Water Discharge Lagoons
- Water Discharge Pipeline

Other

- Surface Runoff Systems
- Potable Water System
- Sanitary Water Treatment System

The water management system for the project is depicted in the form of an overall mill water balance in Figure 2. This water balance represents the average flow rates, including the average groundwater inflow into the mine. In addition to the mill, this balance includes other major items such as the mine, tailings thickener, tailings pond, reclaim ponds, and the water treatment plant. The projected flow rates shown are based on metallurgical testing and engineering completed to date. The flows shown are for the concentrator average ore treatment capacity of 7,400 tons per day. For the purpose of developing this balance, a situation was selected considering two tailings ponds; one pond in actual operation, while reclamation work is being conducted on the other.

The important items in the water management system are discussed in the following paragraphs.

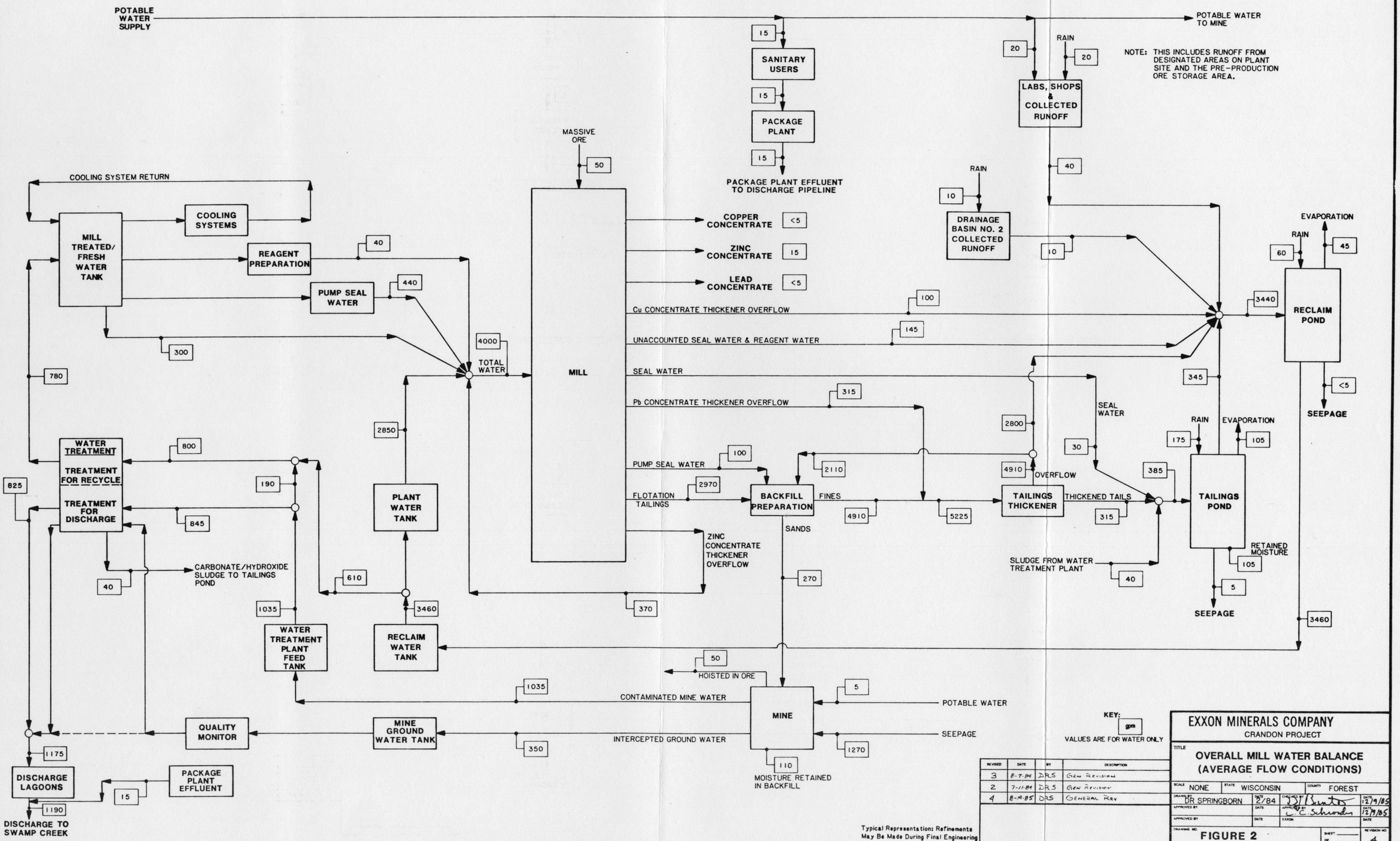
REVISED	DATE	BY	DESCRIPTION

Typical Representation; Refinements May Be Made During Final Design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MINE/MILL SURFACE FACILITIES

SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 8/86	CHECKED BY C C Schroeder		DATE 9/16/86	
APPROVED BY	DATE	APPROVED BY J A DeMonte		DATE 9/16/86	
APPROVED BY	DATE	EXEC		DATE	
DRAWING NO **FIGURE 1**			SHEET ___ OF ___	REVISION NO	



Typical Representation: Refinements May Be Made During Final Engineering

REVISED	DATE	BY	DESCRIPTION
3	8-7-84	DRS	Gen Revision
2	7-11-84	DRS	Gen Revision
4	8-19-85	DRS	General Rev

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
OVERALL MILL WATER BALANCE
(AVERAGE FLOW CONDITIONS)

SCALE NONE	STATE WISCONSIN	COUNTY FOREST

DRAWN BY DR SPRINGBORN	DATE 2/84	CHECKED BY DJ Benton	DATE 12/9/85
APPROVED BY	DATE	APPROVED BY C. C. Schroeder	DATE 12/9/85
APPROVED BY	DATE	EXXON	DATE

DRAWING NO. FIGURE 2
SHEET ___ OF ___
REVISION NO 4

DESIGN PRODUCTS CO.

3.1 MINE DRAINAGE

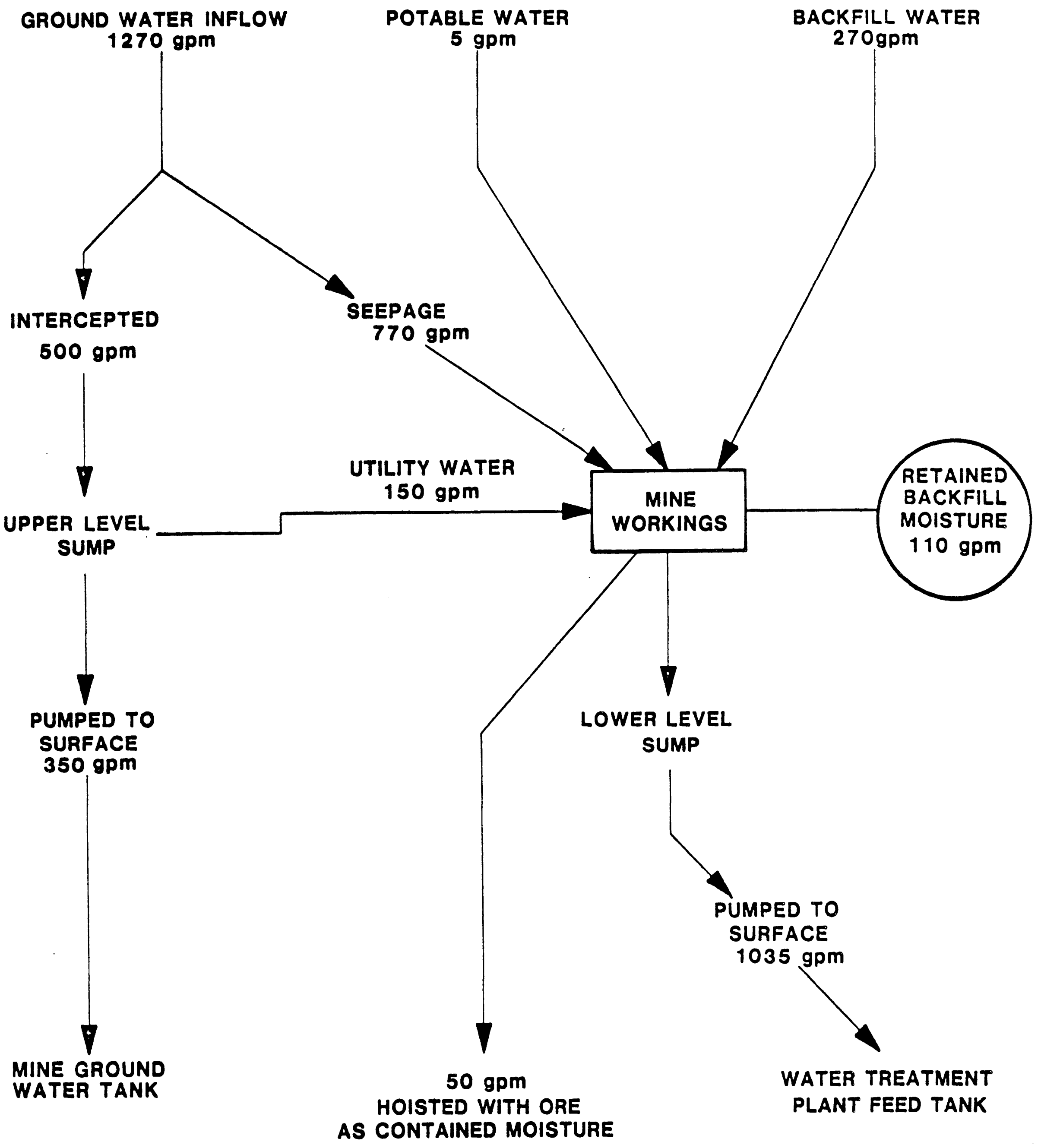
The predicted steady state rate of uncontrolled groundwater inflow to the proposed Crandon mine is 1,270 gallons per minute based on an infiltration rate of 8.5 inches per year as documented in "Predictive Groundwater Inflow Modeling and Sensitivity Analysis for the Proposed Crandon Mine," Prickett & Associates, December 1984. However, for the purpose of designing the mine water handling systems, the maximum projected inflow rate of 2,000 gallons per minute was used. The maximum mine inflow rate was developed by using a high infiltration rate of 11 inches per year and omitting the resistive layer above the mine used in other model simulations of mine inflow. This resulted in a mine inflow of approximately 2,000 gallons per minute.

The average flow conditions for the Crandon mine water inflow are depicted in Figure 3.

Groundwater inflow to the proposed Crandon mine will be collected in two separate systems. First, a groundwater interceptor system will be installed on the uppermost mine levels. Groundwater collected from exploration drilling or other drill holes placed specifically for inflow interception will be piped directly to a clean water sump and pump station near the main shaft on an upper mine level. With the exception of water inflow diverted for mine utility water use, water from the segregated groundwater system will be pumped to the surface through a separate pipe column in the main shaft. This water will be collected in the mine groundwater tank.

Mine inflow intercepted, contained, and pumped to the surface by this system is expected to remain near ambient groundwater quality, except for possible transient effects during orebody storage depletion and initial flushing of pore volumes. In the steady state, partially saturated flow conditions will exist in the weathered bedrock courses. Some oxygen may then be introduced to this previously anaerobic environment, but its effects are expected to be minor. The oxidation and leaching potential of the water courses are already limited by the extensive preglaciation weathering, and the residence time for further groundwater flow will be of a duration which can be measured in hours or days.

Groundwater seepage that is not contained by the interceptor system will infiltrate the mine workings and ultimately be recovered in the normal mine sumps located on each level. This is the second water handling system. The water will either be pumped or drained to the main mine water sumps and pump stations located near the main shaft on the main production haulage level. These sumps will also receive backfill seepage and used mine utility water. This system is shown in Figure 4.

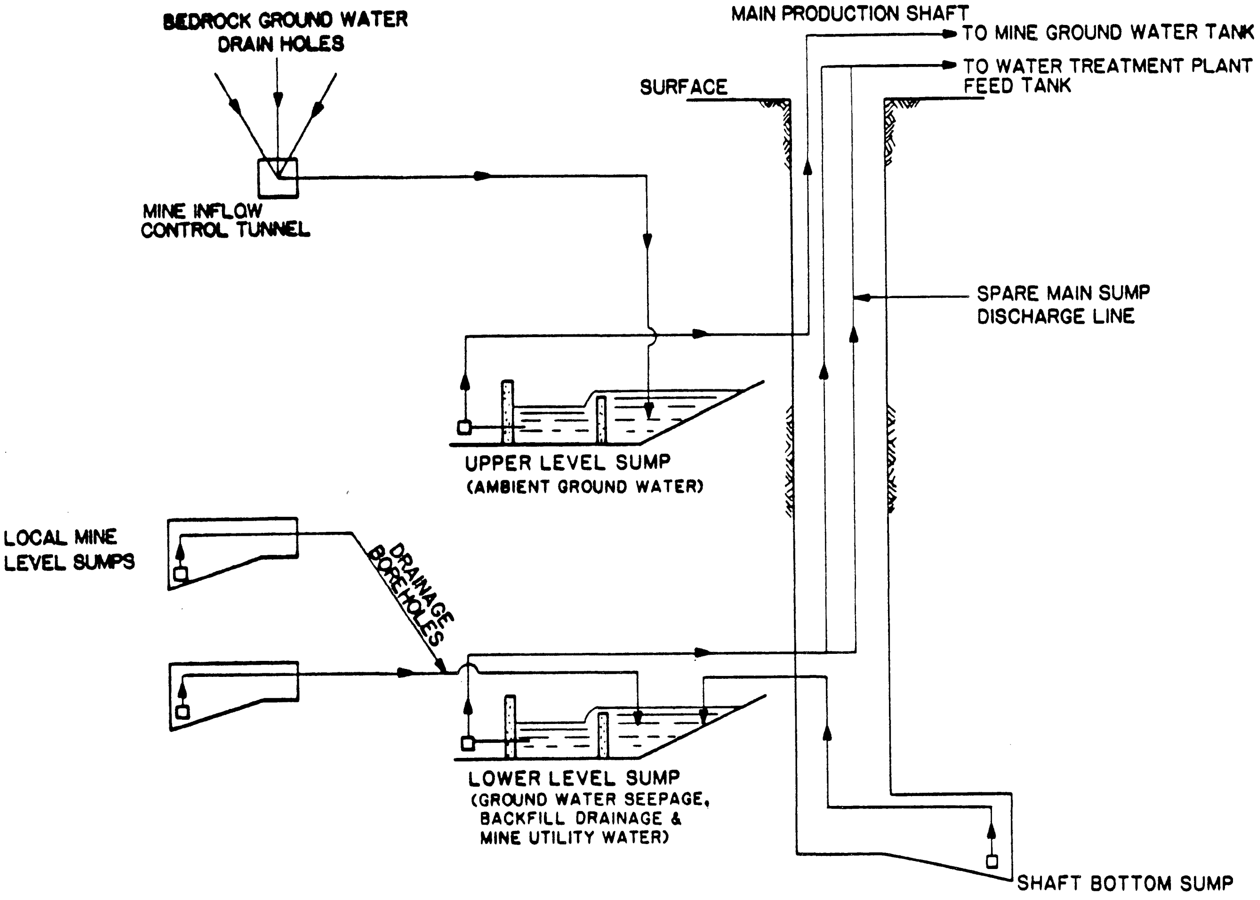


Typical Representation : Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MINE DRAINAGE SCHEMATIC & WATER BALANCE

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 9/83	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Sch[illegible]	DATE 11/86
APPROVED BY	DATE	EXXON D.E. M[illegible]	DATE [illegible]
DRAWING NO FIGURE 3		SHEET ____ OF ____	REVISION NO 2



Typical Representations Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE MINE WATER DRAINAGE SCHEMATIC SUMP SYSTEM					
SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 10/83	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11/13/85	
APPROVED BY	DATE	EXXON		DATE [illegible]	
DRAWING NO FIGURE 4			SHEET ____ OF ____	REVISION NO 1	

The mine pumping systems including pumps and shaft columns will be designed for the conservative maximum inflow of 2,000 gallons per minute and will also feature 100 percent spare pump capacity. Surface surge storage capacity will exist in the reclaim and tailings ponds for temporary handling of excess inflow. The total surge capacity while still providing the minimum 3-foot freeboard in the reclaim ponds, for example, is 210 acre-feet, or enough capacity for an excess flow of 1,000 gallons per minute mine pumpage and discharge for over 47 days.

An alternative to handling mine water 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 groundwater 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 groundwater. At steady state inflow rates less than about half the 2,000 gpm design maximum, it may be prudent to allow all groundwater seepage to flow to the normal mine drainage sumps.

To summarize, there will generally be two segregated streams of water pumped from the mine; the intercepted groundwater at a design flow of 850 gallons per minute and the contaminated mine water at a design flow of about 1,265 gallons per minute. Average flows for these two streams will be 350 and 1,035 gallons per minute, respectively. These two streams, however, may be combined and treated as a single stream when it is prudent to do so. In addition, the moisture contained in the ore will amount to about 50 gallons per minute.

3.2 CONCENTRATOR AND TAILINGS THICKENER

The concentrator will be the largest single user of water at the Project. The water balance for the concentrator was included in Figure 2. The average quantity of water required for the mill process will be about 4,050 gallons per minute which includes all process requirements, reagent preparation, and pump seal water in the mill, backfill preparation, and pumps used to transport water and tailings. This quantity of water includes 50 gallons per minute contained with the ore hoisted from the mine. Approximately 370 gallons per minute will overflow the zinc concentrate thickener and be recycled directly back to the zinc flotation circuit without leaving the mill facility. As Figure 2 indicates, no continuous need for freshwater as process makeup is required because of the intention to rely on treated and untreated water from the reclaim ponds. Approximately 2,850 gallons per minute will be recycled to the mill from the reclaim ponds without any treatment and 780 gallons per minute will be recycled from the water treatment plant. A small amount of water will enter the mill with the ore, approximately 50 gallons per minute.

Water overflowing the copper concentrate thickener, 100 gallons per minute, will be sent to the reclaim ponds. Overflow from the lead concentrate thickener is a low-volume flow and will be pumped to the fine tailing thickener so that any heavy metals in this stream can be precipitated (precipitates then become part of the solid tailing product).

The zinc flotation tailings stream will have 2,970 gallons per minute and 6,100 tons per day of solids. This stream will be pumped to the backfill preparation circuits where the coarse tailings particles will be separated from the fine tailing particles. An additional 2,110 gallons per minute will be required in the backfill circuits; this water will be recycled from the fine tailings thickener overflow water. The coarse tailings (referred to as sands), along with 270 gallons per minute will go to the mine as backfill. The fine tailings from the backfill preparation circuits will be a very dilute suspension of fine solids in water and cannot be used as fill in the mine. The fine material will be pumped to the tailings thickener where it will be thickened to about 55 percent solids by weight. The thickened tailings stream along with the carbonate/hydroxide sludges from the water treatment plant will be pumped to the tailings pond. This total flow is estimated to be 385 gallons per minute. The thickener overflow stream will be 4,910 gallons per minute of which 2,110 gallons per minute will be recycled to the backfill preparation area as required dilution water in the cyclone classification circuits. The remainder of the tailings thickener overflow water, 2,800 gallons per minute, will be pumped to the reclaim water ponds. It is possible that once operating experience is gained in the mill, some water can be recycled directly from the tailings thickener overflow stream thus reducing the volume pumped to the reclaim ponds.

During startup of the mill, water that will have accumulated in the reclaim ponds during construction will be used as a source of water. If another source of water is needed during startup, or intermittently during normal operation, it can be obtained from the mine water or from one of the high-capacity wells.

The basis for the mill water balance discussed above is the cumulative result of metallurgical process studies, engineering work, and water management studies conducted by Exxon. The flow quantities shown in Figure 2 are the quantities used in developing the current designs for the project. During final engineering, maximum and minimum flow quantities for all streams will be further developed so that pumps, sumps, and pipelines can be definitively sized.

3.3 TAILINGS PONDS

The tailings ponds will allow for settling and ultimate disposal of the fine tailings. These ponds will also allow for water recovery from the thickened tailings by the use of the decant system and underdrains. Lime will be added to the tailings slurry as it leaves the mill site (lime added at tailings thickener underflow sump). This will provide short-term neutralizing capacity in the operating pond and keep the water recovered from the tailings (decant and underdrain) at least slightly alkaline or near-neutral in pH.

A typical water balance for the tailings pond is shown in Figure 5. This balance was calculated under the conditions where tailings pond T2 is in use and tailings pond T1 has just been filled and has not been reclaimed. The gain from precipitation was calculated over the total area of the two ponds while the evaporation loss was calculated over 80 percent of the area of the two ponds. In this water balance the following data was used:

o Average Yearly Precipitation (inches/yr):	30.77
o Average Yearly Lake Evaporation (inches/yr):	23.36

3.4 RECLAIM PONDS

An important feature of the Project will be recycle of water for ore processing. The use of reclaim water ponds will ensure the ability to successfully recycle water to the mill. There will normally be no direct discharge of water to the environment from the reclaim ponds. The water balance around the reclaim pond for average flow conditions was presented as part of Figure 2. The functions of the reclaim ponds are as follows:

- Provide water surge capacity for all process-related surface facilities.

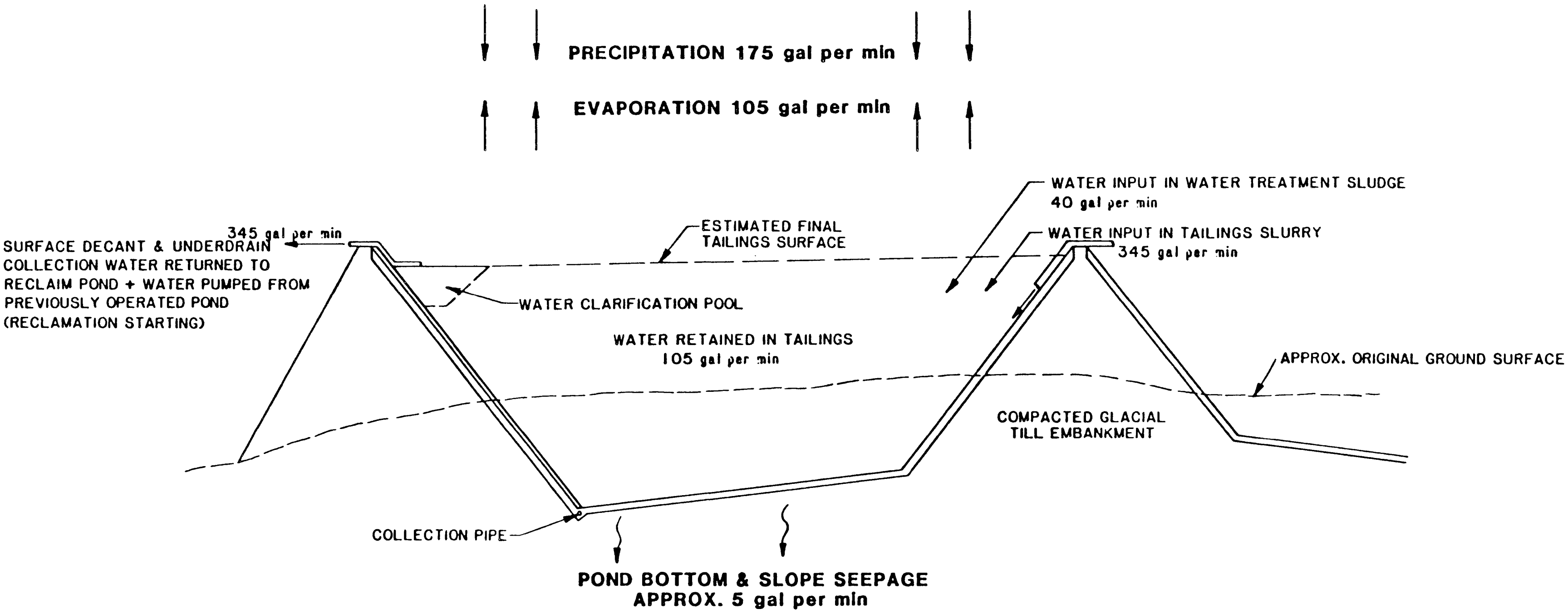
- Allow sufficient residence time for settling of fine particulate matter.

- Allow sufficient residence time for evaporation, oxidation, and biological processes to occur and thereby control the concentrations of certain chemical constituents in the water to be recycled to the mill.

The volume of the reclaim ponds (as well as the tailing ponds) will provide surge capacity for the water management system. They will ensure that temporary interruptions of service of any of the components in the system will not cause a

TYPICAL TAILINGS POND WATER BALANCE DURING OPERATION

(COMPUTATIONS BASED ON TOTAL PONDS T1 &T2 AREA WITH AVERAGE PRECIPITATION)



NOTE:

PRECIPITATION - 30.77 in/YEAR

EVAPORATION - 23.36 in/YEAR
OVER 80% OF POND AREA

Typical Representations: Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL FACILITY
TYPICAL TAILINGS POND
WATER BALANCE

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 10/85
CHECKED BY
DATE
APPROVED BY
DATE
APPROVED BY C.C. Schroeder
DATE 11/13/85
APPROVED BY
DATE
LIAISON
DATE 7/1/85
DRAWING NO FIGURE 5
SHEET ____
OF ____
REVISION NO

complete shutdown of the mine and mill. The total operating volume of the reclaim ponds is 158 million gallons. The total net flow to the ponds including annual average precipitation is estimated to be 3,455 gallons per minute for a calculated residence time of 32 days.

The two ponds in the reclaim pond system are designated cell A and cell B. Each pond will have a depth of 33 feet. The maximum operating level in cell A will be 20 feet and the maximum operating level in cell B will be 23 feet. The normal volume in the ponds will fluctuate depending on water requirements in the mill, volume of water being recovered from the tailings pond, and precipitation. The freeboard capacity in the ponds will allow for storage of water from the following events:

- One-hundred-year, 24-hour storm and wave runup. (Note: 100-year, 24-hour storm = 5.1 inches precipitation, per Golder Associates, 1982)
- Probable maximum precipitation (PMP) for 6 hours. (Note: 6 hour PMP = 23 inches precipitation, per Golder Associates, 1982)
- Mine water, assuming that 1,385 gallons per minute (average projected flows) of water are pumped from the mine, it could all be pumped to the reclaim pond for about 30 days and use up only 50 percent of the total freeboard.

If a PMP event were to occur simultaneously with discharge of minewater to the ponds, the freeboard would still be sufficient to hold about 20 days of minewater.

The reclaim ponds are designed as separate ponds in a two-cell system. Shutdown of one of the ponds is not planned nor anticipated. However, if that became necessary, a change in operating procedures would be required. If concentrator throughput were to be maintained, the retention time would be reduced, which should not cause any problems for the length of time that the one pond is out of service.

The two largest streams that flow to the reclaim ponds will contain small amounts of particulate matter. These are estimated as follows:

	Suspended Solids
Tailings Thickener Overflow	100 to 1,000 mg/L
Decant Water from Tailings Pond	Trace to 100 mg/L

The amount of solids estimated to accumulate in the reclaim ponds over the life of the project has been conservatively estimated to be 140,000 cubic yards. This estimate is based on the volume of water expected to flow through the ponds with an average suspended solids concentration of 415 ppm, and a settled solids density of 50 percent solids by weight. This volume of sludge can be held in the reclaim ponds without affecting the operation of the ponds. The settled sludge overall will occupy 18 percent of the total normal operating volume and will occupy a depth of 4.8 feet if divided evenly between the two ponds.

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

It is not planned, but if it would ever be necessary to remove settled solids from either reclaim pond, there are suitable methods that would not damage the pond liner while still allowing continued pond operation. A small floating suction dredge with depth control on the suction head could be used. In practice, a small depth of settled solids (1.0 foot) would not be removed to maintain an additional layer over the liner. If the estimated 140,000 cubic yards of settled solids were distributed evenly over the final tailings surface of pond T4, the depth of sludge would be approximately 0.8 foot. There will be ample time for proper management of the sludge through drying or blending with tailings or cover soil. The sludge could also be incorporated into the thick till grading layer planned as the first step in reclamation of the tailings pond.

Retention of water in the reclaim ponds will promote the oxidation of thiosulfate and other polythionate compounds to sulfate. During warm weather, this process will take place rapidly and will slow down in the winter months. The concentrations of these compounds will generally be reduced by about 90 percent in summer and 10 percent in winter. Lime will be added to the water where it flows from cell B to cell A to neutralize the acid formed as a result of thiosulfate oxidation.

Most of the cyanide added in the mill process will exist in the form of an insoluble complex of ferric ferrocyanide precipitate on pyrite in the tailings pond and in backfilled stopes. The total cyanide concentration of water entering the reclaim ponds is estimated to be about 0.10 mg/L and final reclaim ponds effluent is expected to contain about 0.02 mg/L. Most of this cyanide will exist as complex ions rather than the toxic, free cyanide ion form. Factors causing natural degradation of cyanide include photodecomposition by sunlight, acidification, oxidation by oxygen in the air, and biological action. Cyanide will be converted to hydrocyanic acid which will evaporate. When more complete oxidation occurs, carbon dioxide and ammonia (NH_3) will be formed. These processes will continue in the winter especially where there are open areas of the ponds.

Organic compounds will be present in the water from the collectors and frothers used in the flotation process. The concentrations of organic compounds are expected to range from less than 1 mg/L to between 10 and 20 mg/L. Natural processes of evaporation and oxidation will reduce the concentrations of these compounds by 90 percent or more; these processes will continue throughout the year.

Treatment efficiency of the reclaim ponds will be reduced during winter conditions. This will primarily be reflected in a decrease in the ponds' ability to allow oxidation of thiosulfate and other polythionates to sulfate. However, this also is accounted for in the design of the mill water treatment system and will not reduce the plant's capability to sufficiently treat the process water.

Water will be pumped from the reclaim ponds via a pipeline system. The water will be transported to the reclaim water tank for distribution to the plant water tank and the water treatment plant. There will be no discharge of water to the environment from the reclaim ponds under normal operating conditions. Under some nonroutine conditions, such as an unexpected buildup of water in the reclaim ponds, it may be necessary to treat and discharge some water from the reclaim ponds through the Recycle Water Treatment System.

3.5 WATER TREATMENT

The water treatment plant for the Crandon Project will consist of three separate treatment systems. One system will treat approximately 82 percent of the contaminated water pumped from the mine for discharge. This same system, however, will be designed with sufficient capacity to treat all the contaminated mine water for discharge when necessary. The second system will be designed to treat intercepted groundwater for discharge. The third system will be designed to treat the remaining 18 percent of the contaminated mine water and a sufficient volume of water from the reclaim ponds for use as process water. Facilities will also be provided to monitor the quality of the various treated waters to ensure that the treatment systems are functioning properly and providing effluent meeting discharge quality standards.

Lime precipitation, in conjunction with sulfide precipitation and filtration, will be used as the process to treat contaminated mine water and intercepted groundwater. Water treated in these process systems will be pumped to the excess water discharge lagoon system. These treated waters will be routinely monitored for pH, conductivity, and turbidity and a composite sampler will be installed to collect samples for any required chemical analysis.

To operate the mill with a high level of water recycle dictates that water low in total dissolved solids, particularly calcium and sulfate, be provided to control scaling in the process equipment and piping. This requires a treatment process capable of removing both cations and anions. Approximately 18 percent of the average contaminated groundwater flow and 18 percent of the water from the reclaim ponds will be combined and treated to remove dissolved solids. This process can also be used to treat only water from the reclaim ponds when necessary. This treated water will be used to provide all necessary process makeup water. The treatment system for recycle water will use lime/soda ash softening, clarification, filtration, reverse osmosis, and evaporation as unit operations.

The treatment plant will be designed with sufficient operating flexibility to permit operators to respond to certain situations that may arise. Accordingly, all unit process equipment for treating contaminated mine water and intercepted groundwater water will be sized to handle 20 percent more volume than the maximum anticipated. The unit process equipment for treating recycled process water will also be designed to handle about 20 percent more volume than anticipated. The system for treating water for recycle to the mill will be designed with sufficient flexibility to allow operation at much lower rates then the design capacity. This will be achieved by building the reverse osmosis treatment equipment in a number of modules.

Design and engineering considerations for these treatment processes are discussed in Sections 4.0 and 5.0 of this report.

3.6 SURFACE RUNOFF SYSTEMS

MILL SITE RUNOFF

Runoff from the bulk reagent storage area and the area from the services building extending NNW to the mill area has potential for contamination; this area is shown in Figure 6. Runoff from this area will flow to a swale immediately north of the conveyor gallery leading to the SAG mill. The outlet from the swale has an oil/water separator and discharge will be controlled with a manually operated sluice gate. Water collected from this area will be sent to the tailings thickener overflow sump. This water will go to the reclaim ponds and become part of the process water system.

The oil/water separator sized for this location is based on 200 percent of the flow from a 25-year, 24-hour storm so as to accommodate runoff from the truck shop as well as rainfall. The design flow is 400 gpm.

EXXON MINERALS COMPANY
CRANDON PROJECT

MINE/MILL SURFACE FACILITIES
RUNOFF COLLECTION AREA

SHOWN	WISCONSIN	FOREST
DR SPRINGBORN	9/86	C C Schroeder 9/16/86
		J A DeMarte 9/16/86

FIGURE 6

Typical Representation: Refinements May Be Madê During Final Design.

SURFACE WATER DRAINAGE

Figures 7 and 8 show the current mine/mill site layout, including the locations of the surface water drainage basins used for collection, retention, and release of all uncontaminated surface waters in the mine/mill area. Drainage basin No. 1 will be an unlined earthen basin with turf established in accordance with the Reclamation Plan. Drainage basin No. 2 will be equipped with a synthetic liner installed in accordance with NR213. Details of the drainage basins and the other surface water drainage facilities, the drainage area for each basin, and the basin sizing criteria are all included in Figures 7 and 8.

Except for possible contaminants from parking lots and roadways and slightly higher suspended solids content, the surface runoff water quality should be comparable to current surface drainage water quality in the site area.

Water from drainage basin No. 1 will be discharged to the south of the mine/mill site into wetland F11 between Skunk and Little Sand Lakes. Ultimately, this water would enter Little Sand Lake.

Prior to mill startup, basin No. 2 will discharge surface water into wetland P2 north of the mine/mill site. Ultimately, this water would enter Swamp Creek. After mill startup, the discharge from basin No. 2 will be sent to the reclaim ponds because of the potential contamination of this runoff from an inadvertent mill spillage.

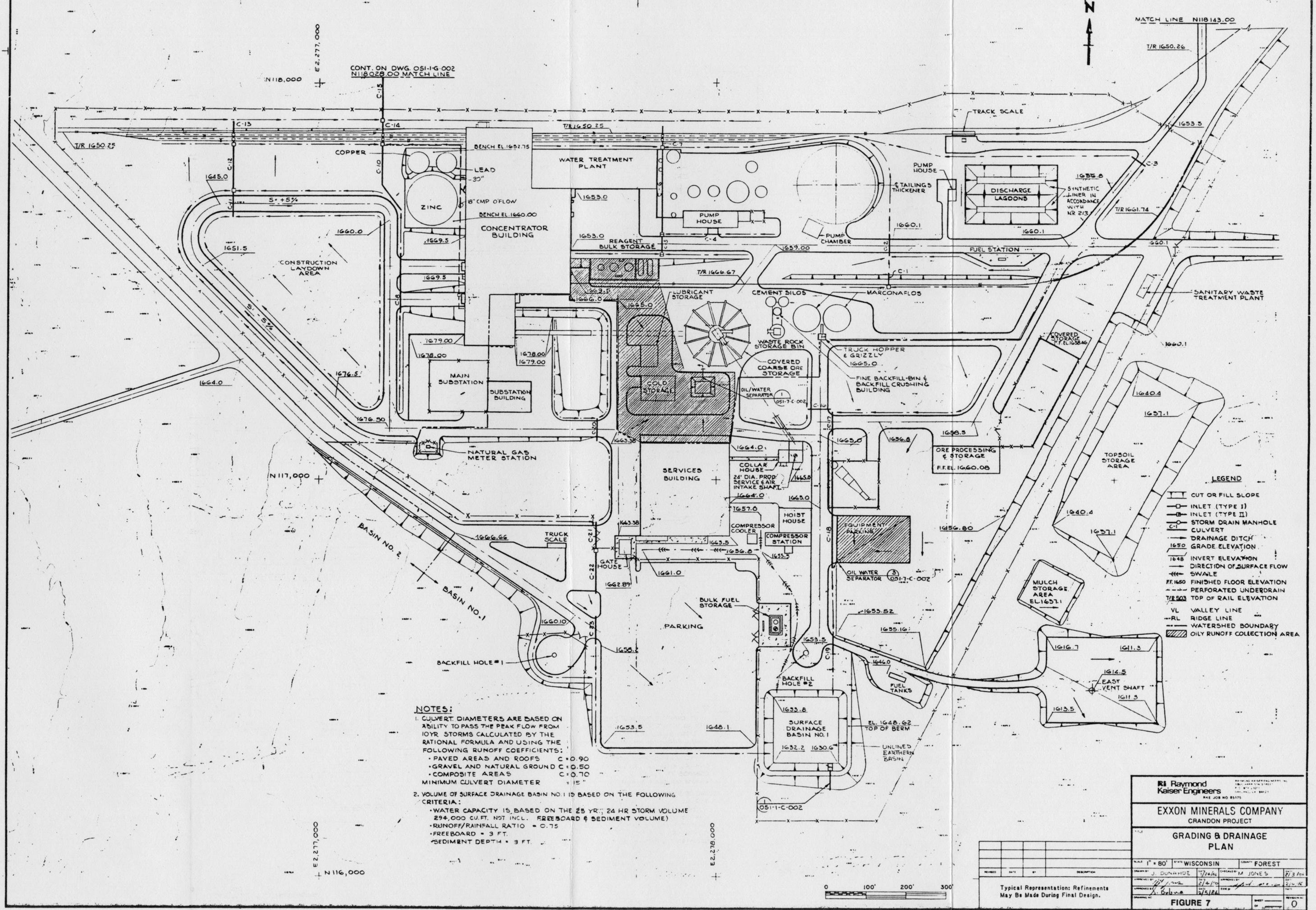
As stated in Figures 7 and 8, the design basis for sedimentation basins 1, 2, and 3 is a 25-year, 24-hour storm. The volumes of the basins are:

Drainage Basin	Working Capacity[a]
1	10,900 yd^3
2[b]	14,250 yd^3
3	4,530 yd^3

---

[a] Not including 3.3 feet of freeboard and 3.5 feet of sediment depth.

[b] Collection basin withdischarge to reclaim ponds.



LEGEND

⊤⊤	CUT OR FILL SLOPE
—□—	INLET (TYPE I)
—▯—	INLET (TYPE II)
—○—	STORM DRAIN MANHOLE
C-1	CULVERT
·——▸	DRAINAGE DITCH
1650	GRADE ELEVATION
1648	INVERT ELEVATION
——▸	DIRECTION OF SURFACE FLOW
⟵⟵	SWALE
F.F. 1650	FINISHED FLOOR ELEVATION
– – – –	PERFORATED UNDERDRAIN
T/R 503	TOP OF RAIL ELEVATION
VL	VALLEY LINE
RL	RIDGE LINE
–·–—	WATERSHED BOUNDARY
▨	OILY RUNOFF COLLECTION AREA

NOTES:

1. CULVERT DIAMETERS ARE BASED ON ABILITY TO PASS THE PEAK FLOW FROM 10YR STORMS CALCULATED BY THE RATIONAL FORMULA AND USING THE FOLLOWING RUNOFF COEFFICIENTS:
   - PAVED AREAS AND ROOFS C = 0.90
   - GRAVEL AND NATURAL GROUND C = 0.50
   - COMPOSITE AREAS C = 0.70

   MINIMUM CULVERT DIAMETER = 15"
2. VOLUME OF SURFACE DRAINAGE BASIN NO. 1 IS BASED ON THE FOLLOWING CRITERIA:
   - WATER CAPACITY IS BASED ON THE 25 YR., 24 HR STORM VOLUME 294,000 CU.FT. NOT INCL. FREEBOARD & SEDIMENT VOLUME)
   - RUNOFF/RAINFALL RATIO = 0.75
   - FREEBOARD = 3 FT.
   - SEDIMENT DEPTH = 3 FT.

Typical Representation: Refinements May Be Made During Final Design.

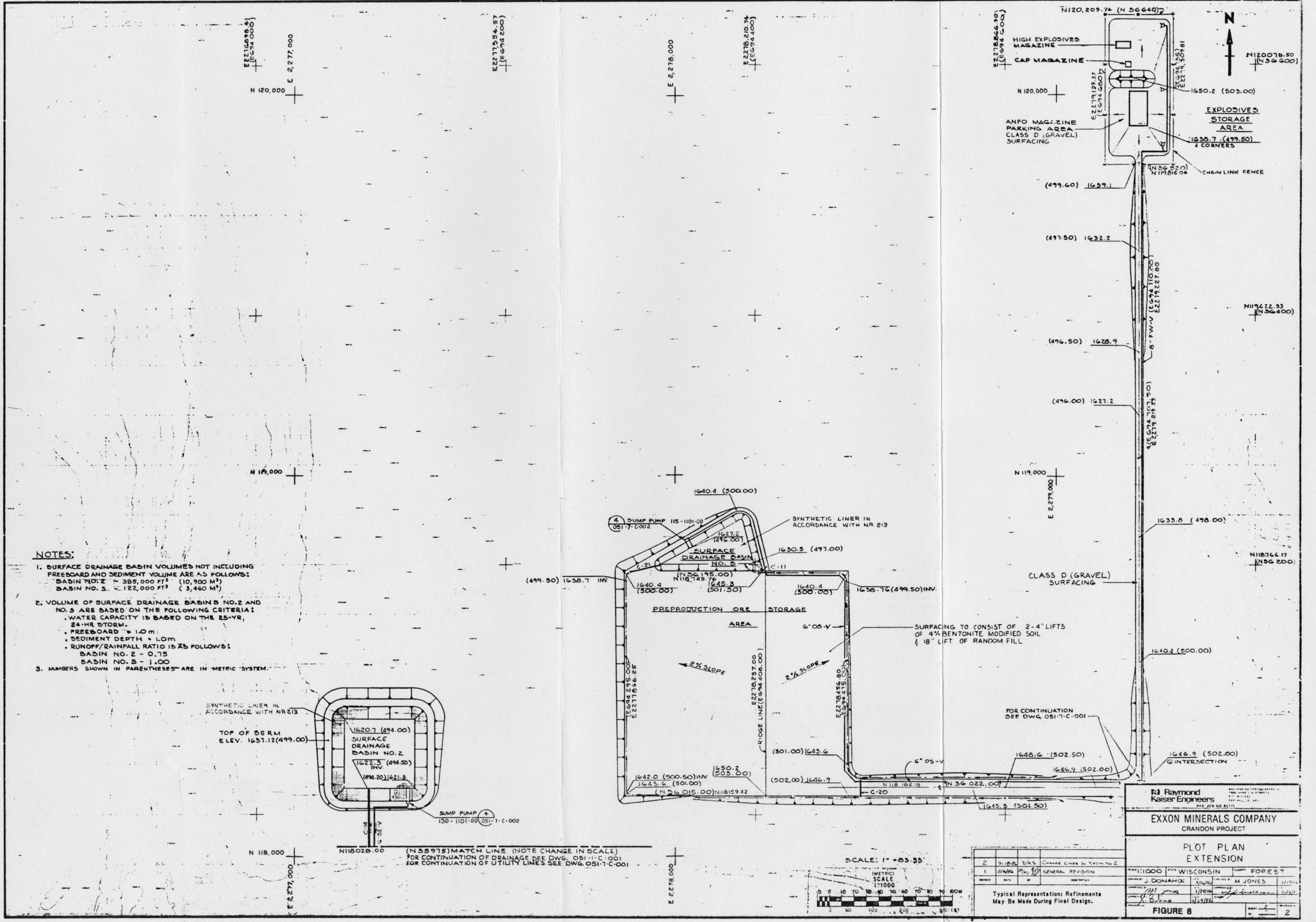
REVISED	DATE	BY	DESCRIPTION

Raymond Kaiser Engineers
RKE JOB NO 85175

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
GRADING & DRAINAGE
PLAN

SCALE 1" = 80'	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J. DONAHOE	DATE 1/24/86	CHECKED BY M JONES	DATE 2/3/86
APPROVED BY	DATE 2/4/86	APPROVED BY	DATE 2/4/86
APPROVED BY S. Bobna	DATE 2/5/86		DATE
DRAWING NO. FIGURE 7		SHEET OF	REVISION NO. 0



NOTES:

1. SURFACE DRAINAGE BASIN VOLUMES NOT INCLUDING FREEBOARD AND SEDIMENT VOLUME ARE AS FOLLOWS:
   - BASIN NO. 2 - 385,000 FT³ (10,900 M³)
   - BASIN NO. 3 - 122,000 FT³ (3,460 M³)
2. VOLUME OF SURFACE DRAINAGE BASINS NO. 2 AND NO. 3 ARE BASED ON THE FOLLOWING CRITERIA:
   - WATER CAPACITY IS BASED ON THE 25-YR, 24-HR STORM.
   - FREEBOARD = 1.0m
   - SEDIMENT DEPTH = 1.0m
   - RUNOFF/RAINFALL RATIO IS AS FOLLOWS:
     - BASIN NO. 2 - 0.75
     - BASIN NO. 3 - 1.00
3. NUMBERS SHOWN IN PARENTHESES ARE IN METRIC SYSTEM.

REVISED	DATE	BY	DESCRIPTION
2	9-18-86	DRS	Change Liner in Basin No 2
1	2/4/86	JD/MJ	GENERAL REVISION

Typical Representation: Refinements May Be Made During Final Design.

Raymond Kaiser Engineers
RKE JOB NO 85175

EXXON MINERALS COMPANY
CRANDON PROJECT

PLOT PLAN
EXTENSION

SCALE 1:1000	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J. DONAHOE	DATE 1/16/86	CHECKED BY M JONES	1/17/86
APPROVED BY M Jones	1/24/86	APPROVED BY	1/24/86
APPROVED S. Bolino	DATE 1/24/86		
DRAWING NO. FIGURE 8		SHEET 2 OF 2	REVISION 2

EQUIPMENT LAYDOWN AREA

Another area located just south of the mine air heater will be used as an equipment laydown area; runoff from this area will have potential for oil contamination. Runoff will be directed to the southwest corner to an oil/water separator. Water that has been through the separator will normally be pumped to the tailings thickener overflow sump and then to the reclaim ponds. Provision has been made to allow more water than can be handled by the sump pump (such as more than the 25-year, 24-hour storm) to overflow the sump and pass into the ditch flowing to surface drainage basin No. 1.

The oil/water separator sized for this area is based on 100 percent flow or runoff from a 25-year, 24-hour storm (50 gpm). Both oil/water separators are of standard API design. The design details of the oil/water separators will be provided in the final construction plans.

Waste oil from oil/water separators will be collected and shipped with other waste lubricants to an offsite reprocessing facility. The estimate of the volume of waste oil is not available and, therefore, frequency of shipment to reprocessing facilities is unknown, but will likely be at least monthly. We anticipate that waste oil will be collected in oil/water separators and waste oil will be stored in drums until transported offsite by a contractor to a reprocessing facility.

This equipment laydown area and the area in the mill site cover a combined 3 acres. Assuming average precipitation and no allowance for evaporation, runoff from these areas will add 6 gallons per minute to the reclaim ponds.

PREPRODUCTION ORE STORAGE

A storage area will be located at the north edge of the mine/mill site to store ore-grade rock and waste rock hoisted to the surface during mine development and prior to the start of mill operations. The preproduction storage area has been designed to accommodate about 815,000 short tons and will occupy an area of 8.0 acres. Details of the storage area are shown in Figure 8. A central ridge divides the area on a north-south axis. Each side of the pad slopes away from this ridge at a 2 percent grade. The east, south, and west sides of the area are bounded by berms with runoff collection ditches which route water to surface drainage basin No. 3 located on the north side of the area. Also, a high point exists on the road to the storage area; runoff collected on the road west of the high point is also collected and will flow to surface drainage basin No. 3.

The pump chosen at this time to return water from basin No. 3 to the reclaim ponds via the tailings thickener overflow is a 3.5-inch vertical pump with 50 horsepower. Details such as this will be reexamined in final engineering.

Drainage basin No. 3 will be equipped with a synthetic liner installed in accordance with NR213. A protective cover of approximately 46 cm (18 inches) of compacted random soil till will be placed over the liner. The ore storage area will be lined with two 10-cm (4-inch) layers of compacted bentonite modified soil mixture.

MINE WASTE DISPOSAL FACILITIES

Figure 9 depicts the surface water drainage controls planned for the Phase 1 development (years 1-4) of the Mine Waste Disposal Facility (MWDF). Information on the additional phases is shown in Figure 10. Further information related to the details of all the development phases for the MWDF is presented in the NR182.08 MWDF Feasibility Report (November, 1985).

The five drainage sediment basins which are used during Phase 1 are sediment ponds SP-A, SP-B, SP-C, HBF-M, and SP-P as shown in Figure 9. These sediment basins are designed to contain estimated quantities of soil eroded during the life of the facility. The outflow structures are designed to pass the peak flow from a 100-year 24-hour storm. The details of the design of these basins will be provided in the MWDF Plan of Operations.

The wetlands south of the proposed MWDF through which water drains into Deep Hole Lake have received special attention. The large wetland in the lower portion of this wetland system will be preserved since surface water drainage from the MWDF area will be maintained to it. Sedimentation and water flowrates will be controlled to maintain, as much as possible through the construction/operation phases, the water quantity and quality currently entering this lower portion of the wetland system. Post-operation conditions are discussed in the report on "Water Balance Analyses for Wetlands in the Mine Waste Disposal Facility Area", prepared by Ayres and Associates, October 1985.

ACCESS ROAD AND RAILROAD

The mine/mill access road is described in the August 1982 Preliminary Engineering Report by Foth and Van Dyke. The general location of each discharge point is identified in Figure 11. The three mile access road is constructed in Years 1 and 2 of the Project with drainage control in place by the end of Year 1. The storm water drain control is described

LEGEND

HBF-A	Hay Bale Filter A With Stone Spillway
— — — —	Dike
⟶	Drainage Ditch & Flow Direction
—·—	Drainage Basin Limits
5	Drainage Basin #5
➡ El. 520	Discharge Point & Spillway Elevation
Q_{100}= 1.2 cms	100 Year Discharge (Cubic Meters/Second)
(T4)	Tailings Pond T-4
SP-A	Sedimentation Pond A
▩	Area Of Construction
▦	Area Of Confinement
▨	Area Of Reclamation

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AEROMETRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS

REVISED	DATE	BY	DESCRIPTION

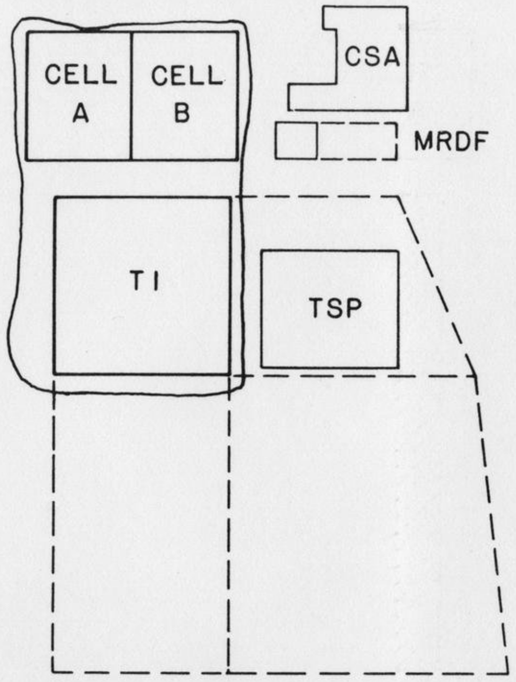
Typical Representation: Refinements May Be Made During Final Design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL SYSTEM
SITE 41-114C
EROSION CONTROL - PHASE 1

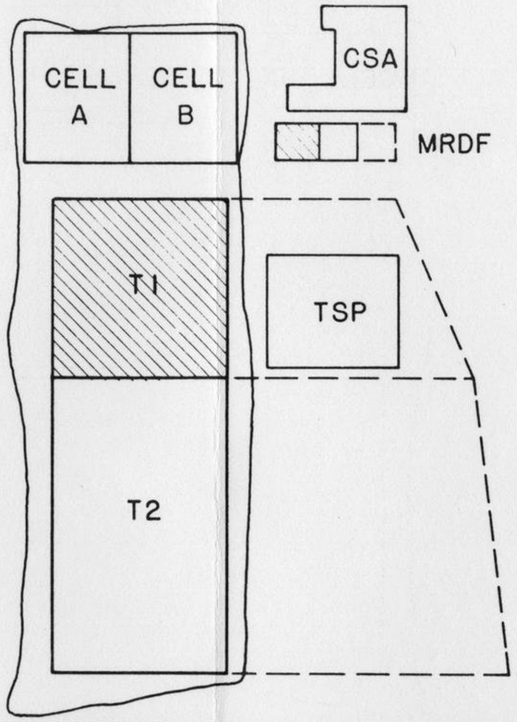
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY CJD	DATE 11-85	CHECKED BY		DATE	
APPROVED BY WJW	DATE 11-85	APPROVED BY		DATE	
APPROVED BY TKD	DATE 11-85	EXXON		DATE	
DRAWING NO FIGURE 9		SHEET 2 OF 7		REVISION NO	

PHASE 1 - YEARS 1-4



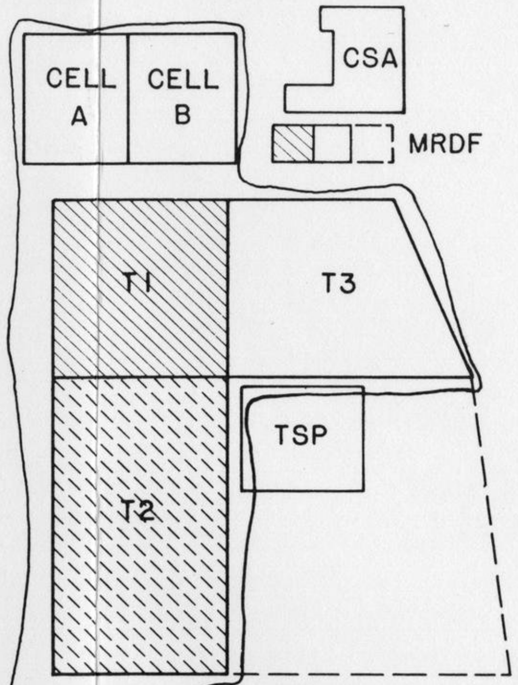
CONSTRUCTION OF TAILING POND T1,
WATER RECLAIM POND, MRDF CELL 1 & CSA

PHASE 2 - YEARS 5-11



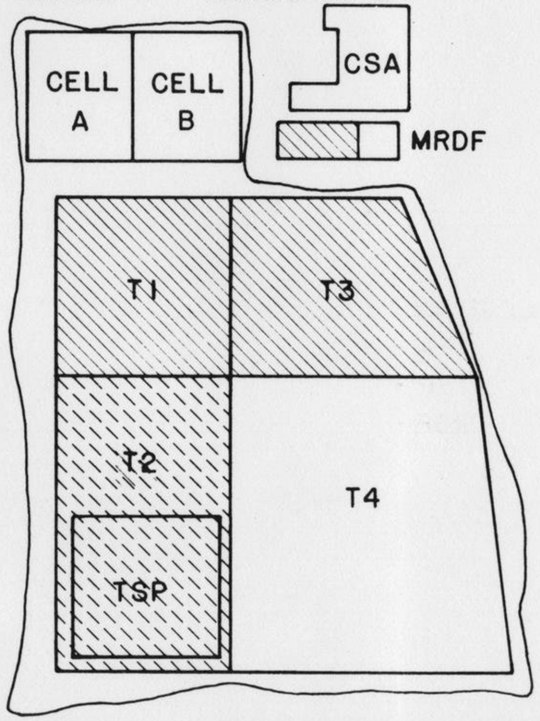
CONSTRUCTION OF TAILING POND T2
& MRDF CELL 2
RECLAMATION OF TAILING POND T1 &
MRDF CELL 1

PHASE 3 - YEARS 12-16



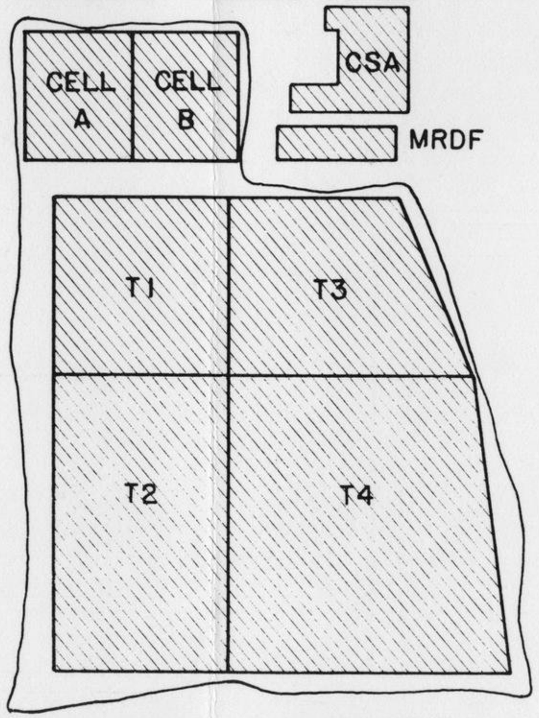
CONSTRUCTION OF TAILING POND T3
PARTIAL RECLAMATION OF TAILING POND T2

PHASE 4 - YEARS 19-23



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

PHASE 5 - YEARS 33-36



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

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

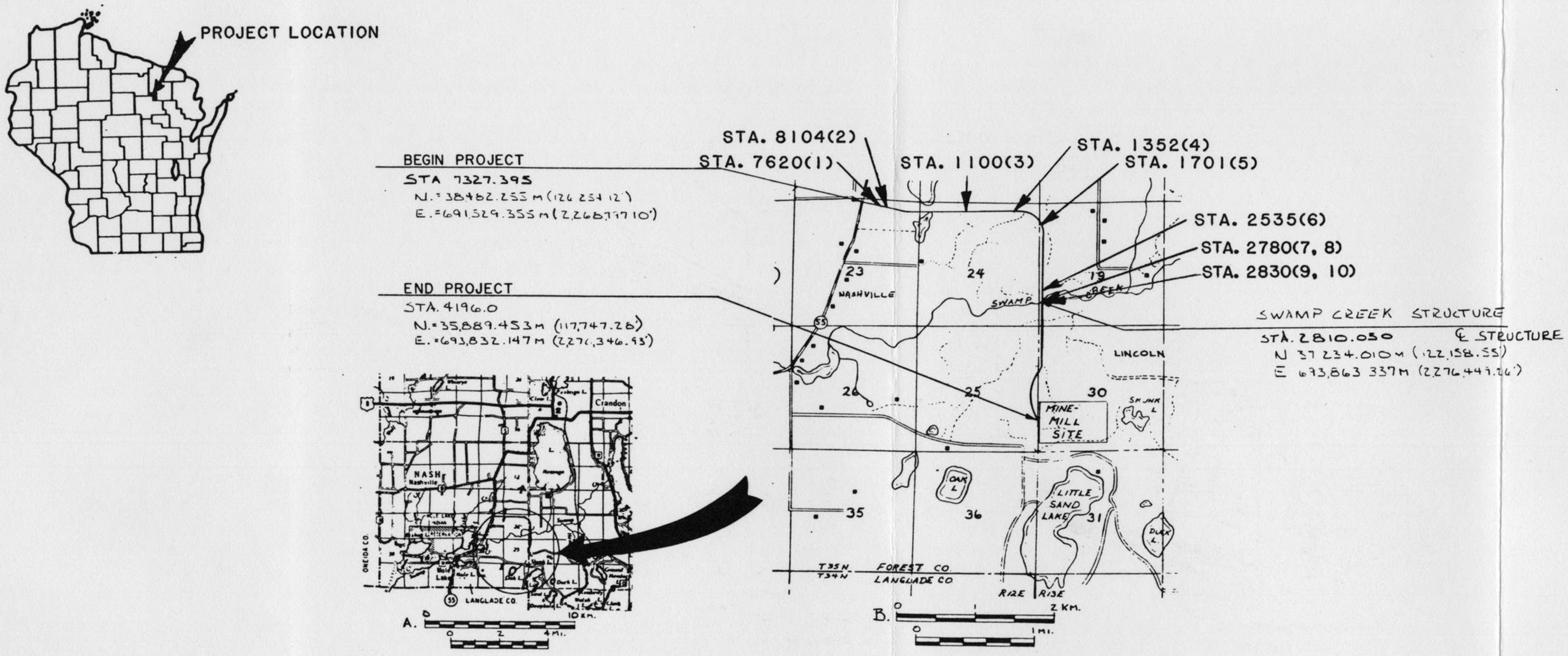
Typical Representation: Refinements
May Be Made During Final Design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WASTE DISPOSAL AREA FACILITIES
CONSTRUCTION &
RECLAMATION PHASES

SCALE NONE	STATE WISCONSIN	COUNTY FOREST

DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/13/85
APPROVED BY	DATE	EXXON D.E. Moe	DATE 11/13/85
DRAWING NO **FIGURE 10**		SHEET ____ OF ____	REVISION NO



Typical Representations: Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MINE/MILL ACCESS ROAD/SURFACE RUNOFF DISCHARGE LOCATIONS

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY J J II	DATE 6-15	CHECKED BY JGL	DATE 8-6-82
APPROVED BY PRW	DATE 8-6-82	APPROVED BY	DATE
APPROVED BY TJJ	DATE 8-6-82	EXXON	DATE
DRAWING NO FIGURE 11		SHEET OF	REVISION NO

in Appendix 4 of the Foth and Van Dyke Report. The first six road culverts from State Highway 55 toward the mine/mill site are summarized as follows:

Discharge Point	Station	Culvert Size (inches)	Drainage Area (Acres)	Design Flow-10-year Storm (CFS)[a]
1	7620	24	345	16
2	8104	24	86	18
3	1100	24	124	15
4	1352	24	124	14
5	1701	24	157	20
6	2535	24	140	13

---

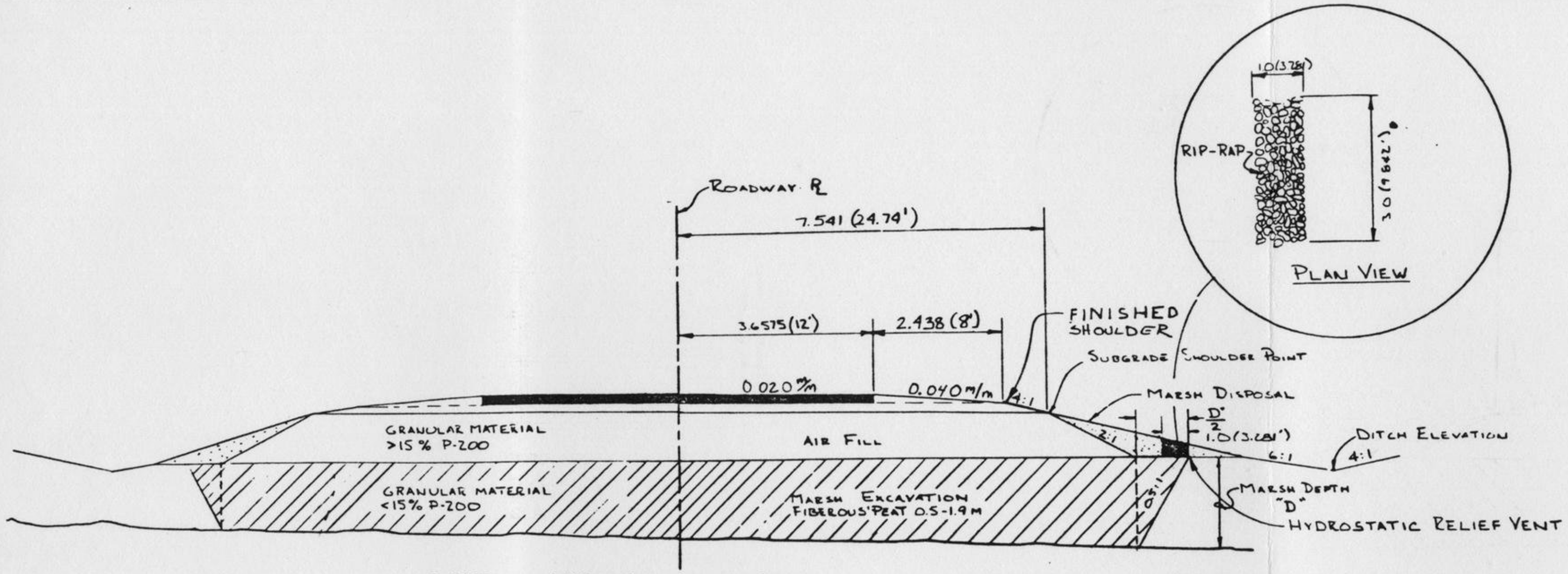
[a] CFS = Cubic feet per second.

There is a culvert at station 7920 which is essentially an equalizer pipe and has a negligible flow associated with it. It has therefore not been identified as a discharge point.

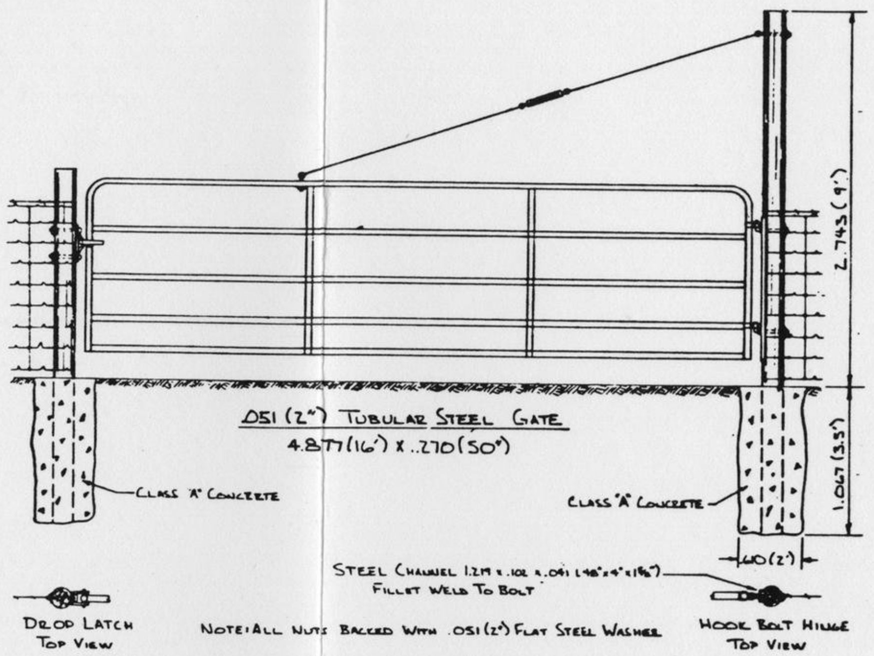
The Swamp Creek bridge is at station 2780 and is designed to handle a 100-year flood flow of 1,010 CFS. The ditches along road drain into Swamp Creek from the north and south banks at the Swamp Creek bridge. The discharge on the north bank is surface water runoff from approximately 820 feet of right-of-way between station 2535 and 2780. These two ditches do not have settling basins. On the south side of the stream, settling basins for both roadside ditches are located uphill from the bridge. The discharge from these two settling basins to Swamp Creek is at station 2830. The design of these settling basins is shown in Figure 12 which also shows special details of the ditch bottom. The total discharge to Swamp Creek from these four points is:

Discharge Point	Station	Drainage Area (acres)	Design Flow-10-year Storm (CFS)
7	2780	1	1
8	2780	1	1
9	2830	1	1
10	2830	5	3

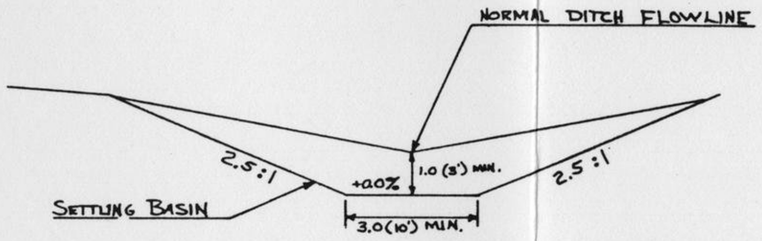
In summary, six culverts, two settling basins, and two short ditch discharges are associated with the mine/mill access road. This represents ten storm water runoff discharge points (numbers 1 thru 10).



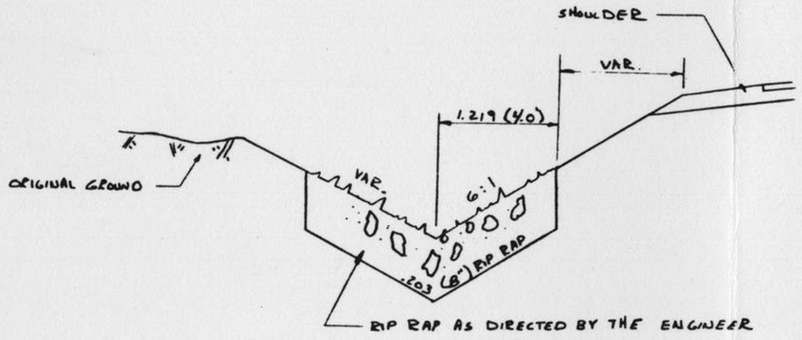
TYPICAL MARSH EXCAVATION SECTION



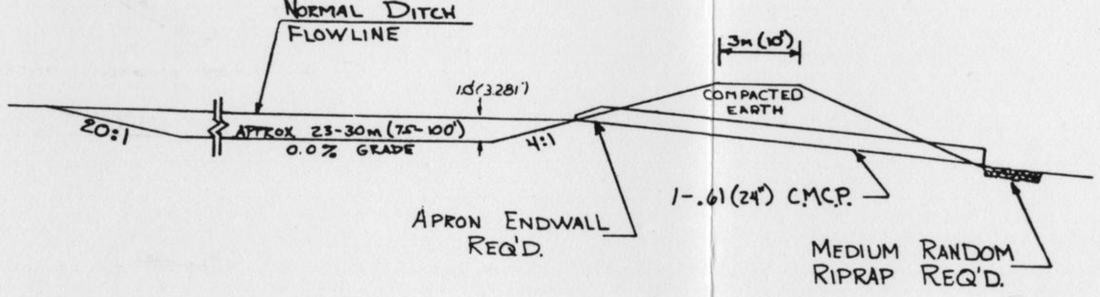
STEEL GATE



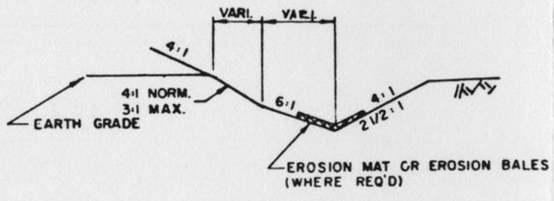
TYPICAL SECTION SETTLING BASIN



DITCH BOTTOM DETAIL



SETTLING BASIN DETAIL



SPECIAL DITCH *

Typical Representation: Refinements
May Be Made During Final Design.

REVISED	DATE	BY	DESCRIPTION
1	8-18-81	P.R.W.	DITCH DETAILS
2	8-6-82	JGL	MINOR REVISIONS

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **MINE/MILL ACCESS ROAD**
TYPICAL SECTIONS
SPECIAL DETAILS

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY M. J. O.	DATE 3-27	CHECKED BY J.G.L	DATE 8-6-82
APPROVED BY P.R.W.	DATE 8-6-82	APPROVED BY	DATE
APPROVED BY TJJ	DATE 8-6-82	EXXON	DATE
DRAWING NO. **FIGURE 12**		SHEET ___ OF ___	REVISION NO.

DESIGN PRODUCTS CO.

The mine/mill railroad spur is described in the Preliminary Engineering Report by Foth and Van Dyke (1981). This 2.7 mile railroad spur is scheduled for construction in Project Year 1 and 2 with drainage control completed in Year 1. The railroad is shown in Figure 13 with arrows indicating the general location of 13 storm water discharge points (numbers 11 through 23).

The seven railroad culverts associated with the storm water discharge points are described below:

Discharge Point	Station	Culvert Size (inches)	Drainage Area (Acres)	Design Flow-10-year Storm (CFS)[a]
11	501 + 80	24	13	2
12	501 + 00	24	12	1
13	502 + 20	24	17	4
14	509 + 70	30	166	19
15	511 + 80	96	282	38[a]
20	522 + 90	24	90	29
21	533 + 60	24	12	2

---

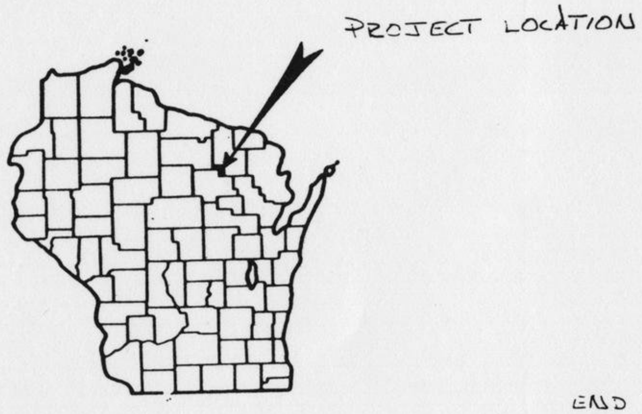
[a] Discharge point 15 design was based on a 100-year 24-hour storm.

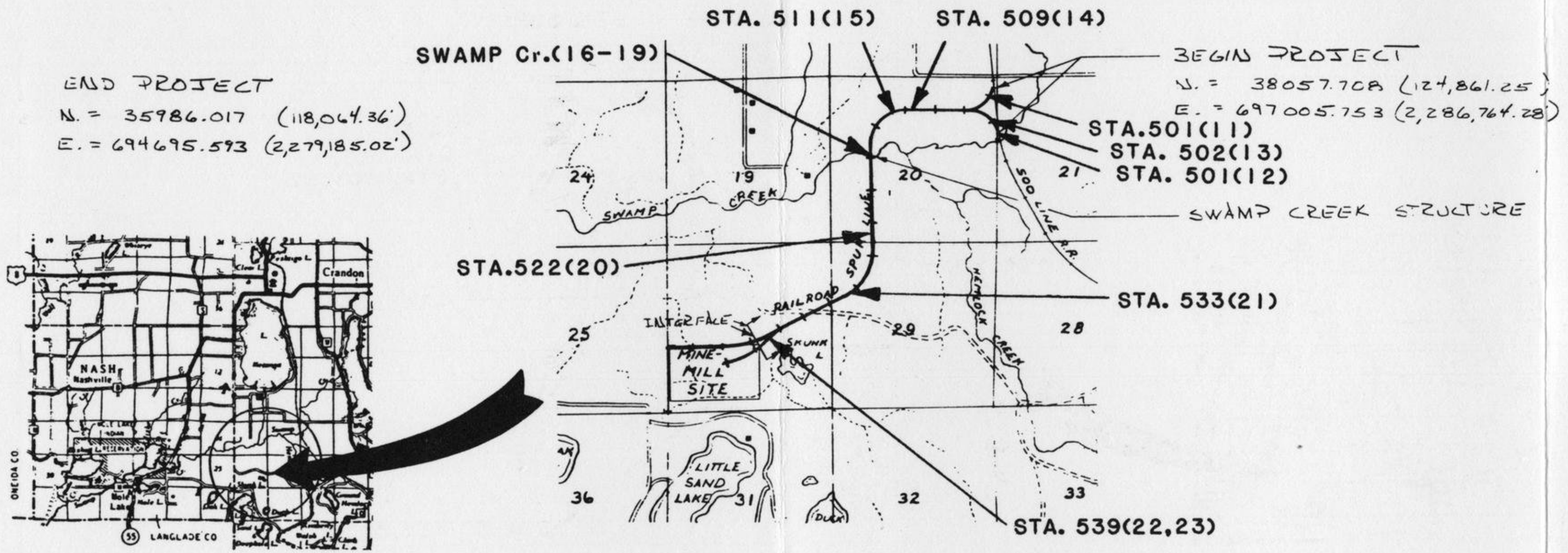
Discharge points 16-19 represent surface water drainage to Swamp Creek from either side of the track at the Swamp Creek bridge. The surface water drainage on the south side of Swamp Creek has two settling basins just uphill from the bridge. The design of these basins is presented in Figure 14. Surface water drainage into the north bank of Swamp Creek is from a small watershed and as in the case of the access road does not need settling basins. The affected areas are:

Discharge Point	Station	Drainage Area (acres)	Design Flow-10-year Storm (CFS)
16	517 + 00	1	1
17	517 + 00	1	1
18	517 + 60	12	6
19	517 + 60	1	1

Surface water runoff discharge points 22 and 23 represent drainage away from each side of the track at a point just before the railroad spur enters the mine/mill site. In this situation the track runs along the spine of a ridge and drainage is from a very short section of track. The affected acreage on either side is approximately 1 acre and the 10-year flow would be less than 1 CFS.

The Swamp Creek bridge is designed to handle a 100-year flood flow of 1,010 CFS.





A. SCALE 1.0cm. = 1.610 KM (1.0 MI.)

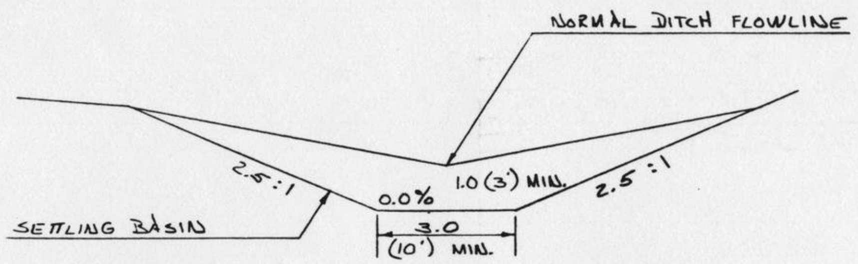
B. SCALE 1.0cm. = 0.322 KM. (0.2 MI.)

Typical Representations: Refinements
May Be Made During Final Engineering

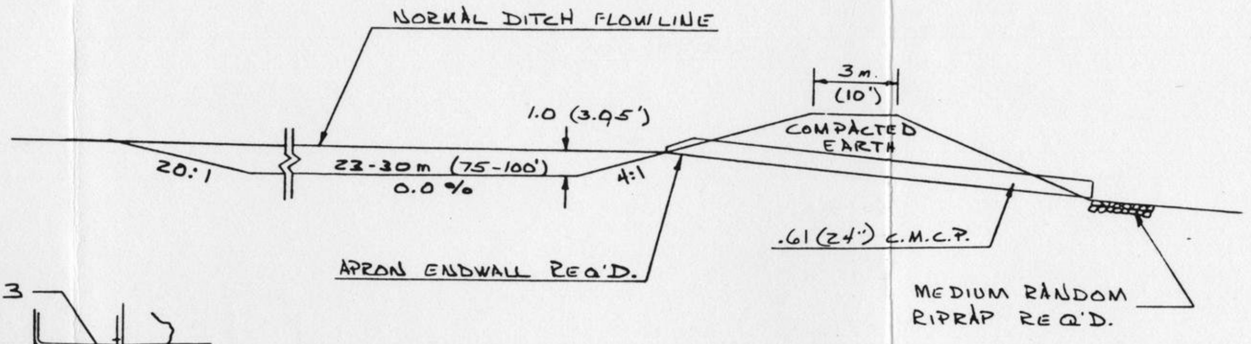
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MINE/MILL RAILROAD
SPUR/SURFACE RUNOFF
DISCHARGE LOCATIONS

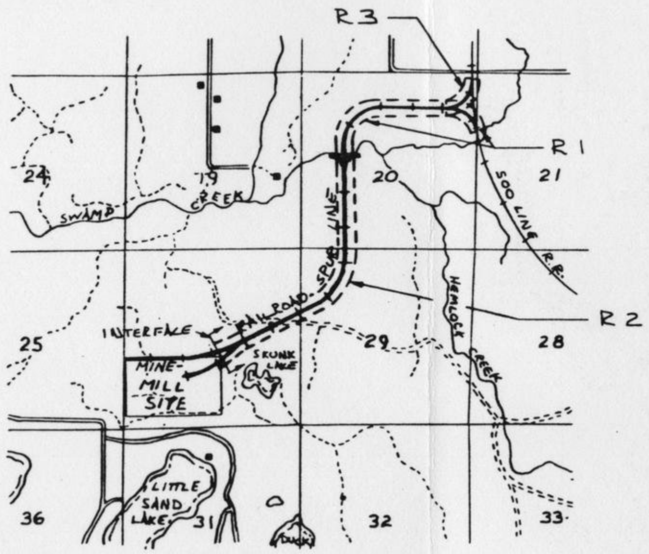
SCALE AS SHOWN
STATE [illegible]
COUNTY [illegible]
DRAWN BY [illegible]
DATE [illegible]
CHECKED BY [illegible]
DATE [illegible]
APPROVED BY [illegible]
DATE 2-8
APPROVED BY [illegible]
DATE [illegible]
APPROVED BY
DATE
EXXON
DATE
DRAWING NO. FIGURE 13
SHEET
OF
REVISION NO



TYPICAL SECTION SETTLING BASIN



SETTLING BASIN DETAIL



COMPUTER RUN LOCATIONS

■ TOPSOIL

▨ PEAT OR MUCK

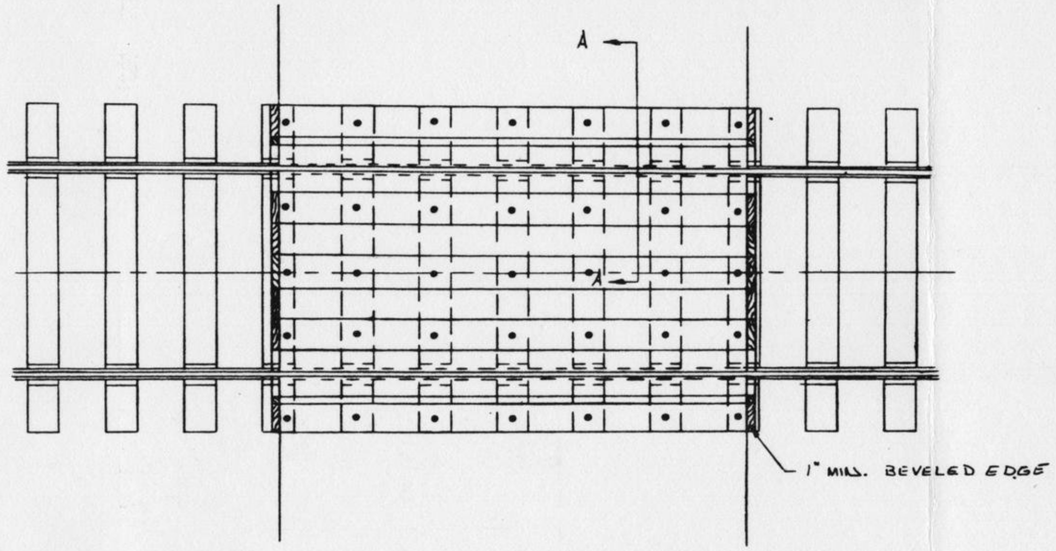
▨ SAND

▨ SAND & GRAVEL

▥ SILT

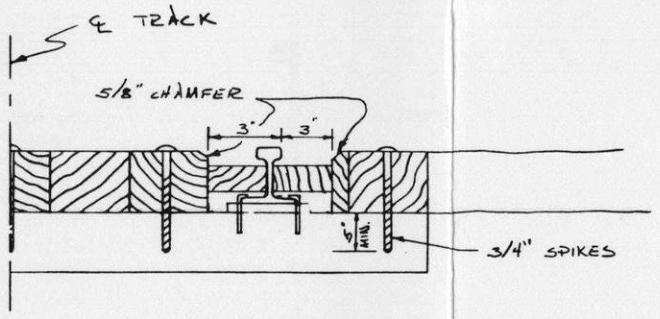
▥ SILTY SAND & CLAYEY SILT

SOILS LEGEND



TYPICAL AT GRADE WOOD PLANK CROSSING

PLAN



PROFILE

SECTION A-A

NOTE: ACTUAL WIDTH OF WOOD PLANK CROSSING SHALL BE DETERMINED BY THE ENGINEER IN THE FIELD.

Typical Representation: Refinements
May Be Made During Final Design.

REVISED	DATE	BY	DESCRIPTION

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MINE/MILL RAILROAD SPUR
SPECIAL DETAILS

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY M.J.O.
DATE 11/4
CHECKED BY JMM, DRW.
DATE 12-81
APPROVED BY D.R.W.
DATE 12-81
APPROVED BY T.J.J.
DATE 12-81
APPROVED BY
DATE
EXXON
DATE
DRAWING NO FIGURE 14
SHEET
OF
REVISION NO

G88 5/1981

3.7 POTABLE WATER FACILITIES

Potable water will be pumped from a new well to be located in the southwest area of the mine/mill site. From the supply well and pumphouse, underground piping will carry the water to the fresh water tank. A separate system of pumps and pipelines will distribute the potable water to points of use within the mine/mill facilities. It is not anticipated that treatment of this water will be required; however, a chlorinator treatment system will be provided and available for use if necessary.

A 10-inch diameter well is planned with a 600 gallon per minute vertical turbine pumping system located in a small pumphouse. The capacity of the fresh water tank is 50,000 gallons.

The potable water well and distribution piping will be designed in compliance with NR112 and H62, respectively. The potable water distribution system and wells will be periodically inspected for bacteriological quality.

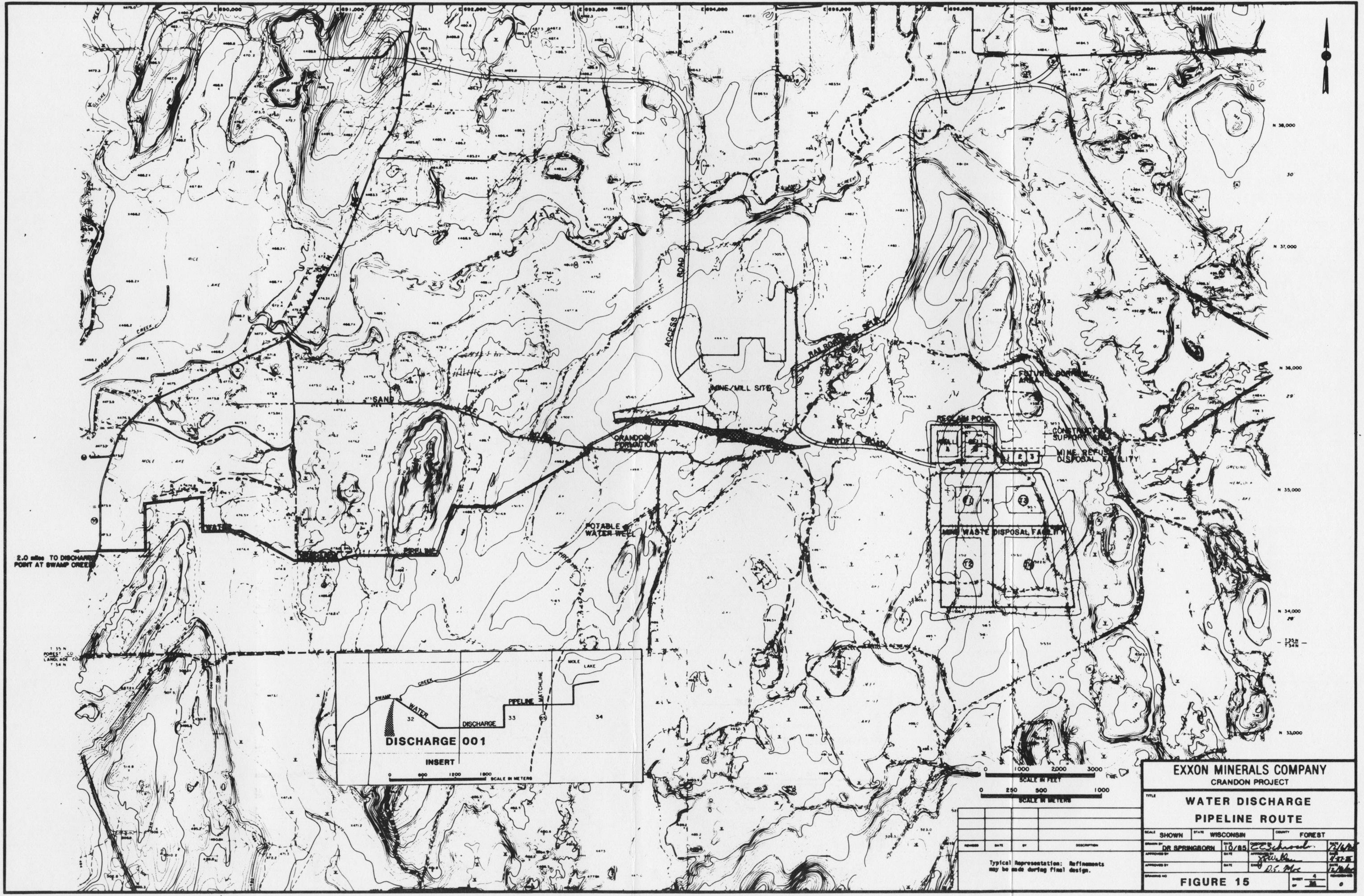
The potable water system will supply a nominal demand of approximately 40 gallons per minute. This is based on 650 people each with a 35 gallon per day water requirement for a total of 15 gallons per minute for sanitary usage plus 25 gallons per minute total use in the laboratory, shop, and mine. The system is sized to also provide required reagent preparation water and pump gland water if it would ever be necessary. The operation of the well pump will be controlled by level switches in the fresh water tank.

3.8 DISCHARGE PIPELINE DESIGN

Excess water (treated mine water and intercepted groundwater) will be discharged into Swamp Creek downstream from the bridge on County Trunk Highway M about 5 miles west of the Project site. There will be approximately 6.1 miles of buried 14-inch diameter pipe and a discharge structure at Swamp Creek. The routing of the pipeline is shown in Figure 15.

There will be three pumps available to pump discharge water: two 110-hp pumps and one 170-hp pump. During normal operation (discharge less than 2,000 gallons per minute), one 110-hp will be used with the others available as spares. When the discharge rate approaches 3,000 gallons per minute, all three pumps will be used.

The water discharge pipeline will be constructed of 14-inch diameter, high-density polyethylene (HDPE) pipe that will be buried 6 feet below ground and beneath the frost level.



REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE

WATER DISCHARGE PIPELINE ROUTE

SCALE SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 10/85	CHECKED BY CCSchroede		DATE 12/6/85	
APPROVED BY	DATE	APPROVED BY JSWelle		DATE 1-27-86	
APPROVED BY	DATE	D.S. Moe		DATE 12/16/85	
DRAWING NO FIGURE 15			SHEET 4 OF 36		0

SECTION 4
Treatment Process Description

Section 4
TREATMENT PROCESS DESCRIPTION

The Crandon Project water treatment system will be designed to handle water from three sources. The treatment plant will contain three completely independent treatment processes.

One process train will be devoted to treating a portion of the contaminated water pumped from the mine to provide an effluent suitable for discharge to Swamp Creek.

The second process train will be devoted to treating intercepted groundwater collected in the interceptor system to provide an effluent suitable for discharge to Swamp Creek.

The third process train will treat a combination of contaminated mine water and water from the reclaim pond system. This train will be designed to provide a sufficient volume of treated water with low concentrations of calcium and sulfate to completely meet the mill's requirement for makeup water.

Figure 16 shows several modes of operation that are possible with the proposed water treatment plant design. The normal mode of operation is shown as the Base Case.

Alternative A depicts a mode of operation whereby process water treated by lime/soda softening, reverse osmosis and vapor compression evaporation is discharged with treated contaminated mine water. This mode allows the discharge of accumulated natural gain in precipitation on the tailings and reclaim ponds.

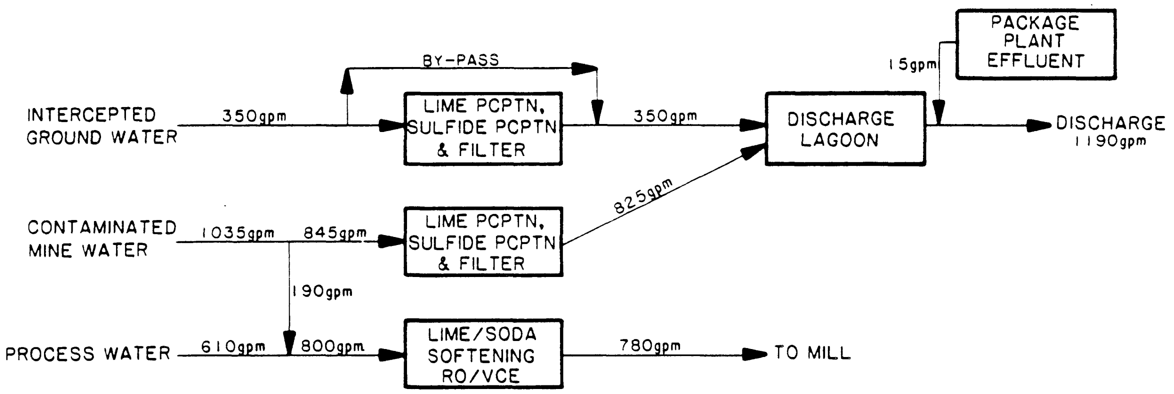
Alternative B shows a mode of operation whereby the mill makeup water is a mixture of intercepted groundwater and treated reclaim water. This mode of operation demonstrates the flexibility that will be designed into the system.

It is also possible that the intercepted groundwater and contaminated mine water will be mixed prior to treatment.

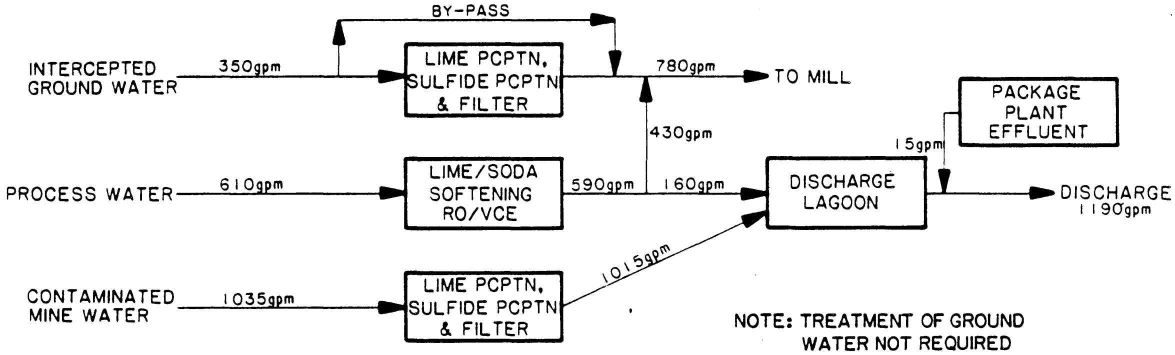
Figure 17 is a simplified block flow diagram for the base case showing the treatment unit operations proposed for the Crandon water treatment system. A detailed description of individual items of equipment and piping and instrumentation diagrams are presented in Section 5.

4.1 TREATMENT OF CONTAMINATED MINE WATER FOR DISCHARGE

The management of mine water and sources of water contributing to the contaminated mine water were discussed in Section 3. Contaminated mine water will be pumped to the surface to the water treatment plant feed tank. The water will

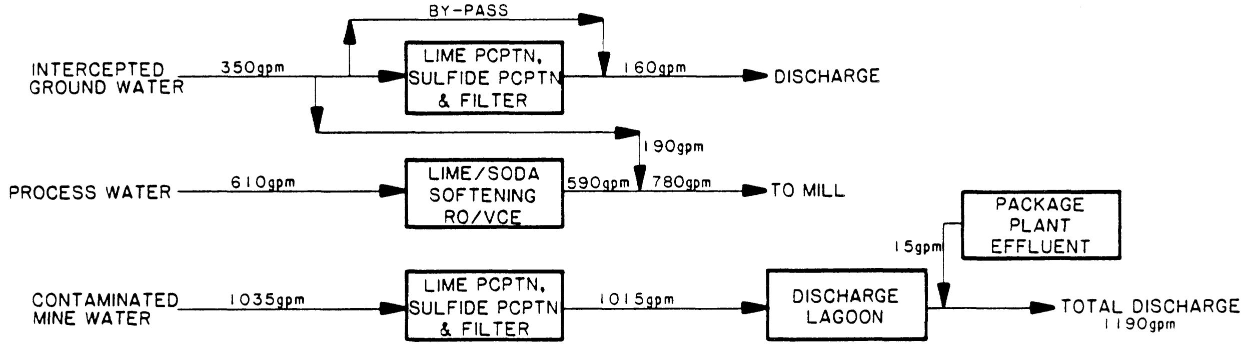


BASE CASE



NOTE: TREATMENT OF GROUND WATER NOT REQUIRED WHEN USED IN MILL.

OPERATING ALTERNATIVE A



OPERATING ALTERNATIVE B

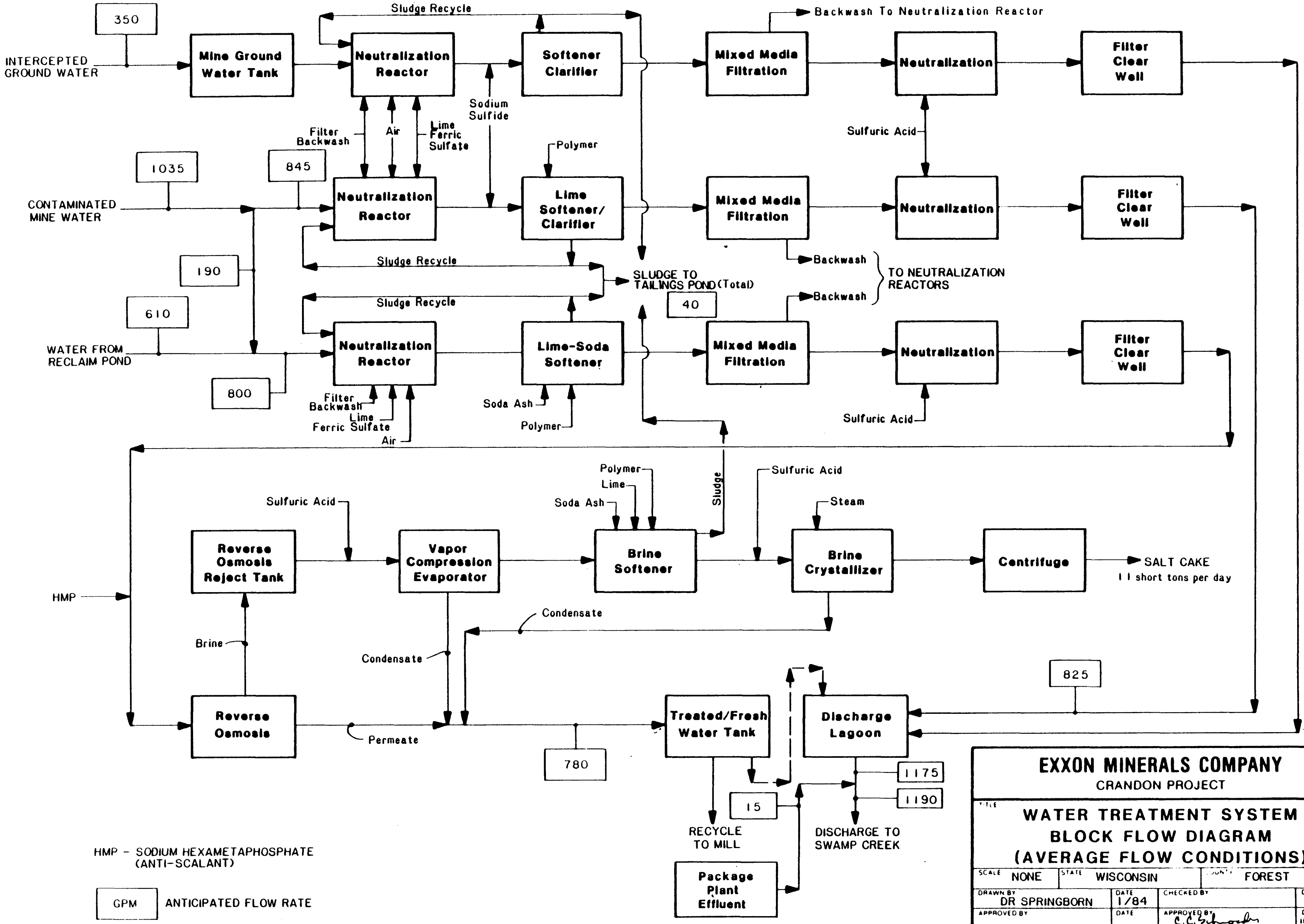
Typical Representations: Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

WATER MANAGEMENT & TREATMENT
OPERATING ALTERNATIVES
(AVERAGE FLOW CONDITIONS)

NONE	WISCONSIN		FOREST
DR SPRINGBORN	8/85		
		C.C. Schwarden	11/5/85

FIGURE 16



Typical Representation: Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
WATER TREATMENT SYSTEM
BLOCK FLOW DIAGRAM
(AVERAGE FLOW CONDITIONS)

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY DR SPRINGBORN	DATE 1/84	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY C.C. Schroeder	DATE 11/15/85
APPROVED BY	DATE	EXXON	DATE
DRAWING NO **FIGURE 17**		SHEET ____ OF ____	REVISION NO 2

be pumped from the feed tank to the treatment plant where the flow will split between the Mine Water Treatment System and the Recycle Water Treatment System. Approximately 82 percent of the contaminated mine water will be treated for discharge and the remainder will be treated for mill recycle use along with water from the reclaim ponds.

The volume of water routed to the Recycle Water Treatment System will be that volume of water required to supply all mill makeup water, effectively eliminating fresh water use other than for potable water use. The only water which will be treated in the Contaminated Mine Water Treatment System will be that excess volume of water which must be discharged from the Crandon Project to maintain a water balance within the overall mine/mill water system.

The process for treating contaminated mine water for discharge will consist of lime and sodium sulfide precipitation, filtration and pH adjustment. The unit processes that will be used to make up this process are described in the following paragraphs.

MIXING, NEUTRALIZATION, AERATION

The first step in the treatment process will be to mix recycle sludge with lime in a flash mix reactor. The residence time in the flash mix reactor will be 2 minutes. The contact between recycle sludge and lime will allow for sludge particle growth, will enhance the sludge settling rate in the subsequent reactor/clarifier, and will cause the final settled sludge to be more dense.

The contents of the flash mix reactor will overflow to the neutralization reactor where influent contaminated mine water will be introduced. The pH of the influent stream will rise to about 10.5 as a result of being mixed with the lime/sludge slurry. This will begin the process of precipitating soluble metals as metal hydroxides. Ferric sulfate will be added to the reactor if needed as a coagulant. Additionally, activated carbon will be added to the flash mix reactor if needed for organics removal. Compressed air will be introduced through a diffuser at the bottom of the reactor to ensure that any ferrous iron will be oxidized to ferric iron. The tank contents will be mixed with a top-mounted propeller mixer.

LIME/SULFIDE PRECIPITATION AND CLARIFICATION

The purpose of this process will be to settle out solids contained in the water pumped from the mine and remove soluble metals through precipitation as metal hydroxides and metal sulfides. A solids recycle system will be used, based on gypsum scale aversion, enhanced sludge thickening properties, and reported improvements in metals removal by operating facilities.

In the lime precipitation process, slaked lime [$Ca(OH)_2$] added to the water in the neutralization reactor will precipitate metals as metal hydroxides. For a typical metal (M^{2+}) the following reaction will occur:

$$Ca(OH)_2 + M^{2+} \rightarrow Ca^{2+} + M(OH)_2\downarrow$$

Effluent from the neutralization reactor (at pH = 10.5) will flow by gravity to the centerwell of a solids contact type reactor clarifier with a design overflow rate of 1 gpm/ft². Polymer solution will be added to the flocculating centerwell of the clarifier by ratio flow control to promote the growth of settleable floc in the clarifier. Polymer dosage will normally be in the range of less than 1 mg/L to 2 mg/L.

A solution of sodium sulfide will also be added to the flocculating centerwell of the clarifier. Metal sulfides are typically less soluble than metal hydroxides. The addition of sodium sulfide to the clarifier centerwell will precipitate additional metals which will still be in a soluble state after equilibration with lime in the neutralization reactor. For a typical metal (M^2+) the following reaction will occur:

$$Na_2S + M^{2+} \rightarrow 2Na^+ + MS\downarrow$$

Metal hydroxide and metal sulfide sludge generated in the treatment process will settle to the bottom of the clarifier where the clarifier mechanism will sweep it into a sludge hopper at the center of the clarifier. Settled sludge will be pumped from the clarifier and will be split into two streams. Approximately 85 percent of the settled sludge will be returned to the flash mix reactor upstream from the neutralization reactor. The remaining 15 percent of the sludge will be pumped to the tailing thickener sump, from which it will be pumped to the tailings pond for disposal.

MIXED MEDIA FILTRATION

Effluent from the lime precipitation reactor clarifier will overflow by gravity to a pH adjustment tank and, from there, will flow to four parallel mixed media gravity filters with a design surface loading rate of 3.5 gpm/ft². The pH of the water will, if necessary, be reduced in the pH adjustment tank upstream from the filters. The mixed media filters will remove residual solids (primarily metal hydroxides) which overflow the clarifier in the lime/sulfide precipitation system.

The capability of adding acid to lower pH prior to filtration is in the design as a means of minimizing scaling of the filter media. However, this capability will be used only if absolutely necessary and then only as long as it does not interfere with producing a satisfactory effluent.

The filters will consist of a dual media bed of 18 inches of anthracite and 21 inches of silica sand to filter out any particulate matter in the water. The filters will be backwashed with effluent from the filters. Backwash will be initiated by high water level in the filters, filter throughput, or by timed cycle. Solids backwashed from the filters will be routed back through the neutralization reactor for recycle through the lime precipitation process.

NEUTRALIZATION

The pH of effluent from the filters will be adjusted with H_2SO_4 to reduce the pH to within WPDES permit limits. Effluent from the filters will flow by gravity into a sump arrangement which will include neutralization tanks with mixing compartments and filter clearwells with filter backwash compartments (to provide a source for filter backwash water). This process will provide final effluent neutralization prior to discharge to the Excess Water Discharge Lagoon System. Effluent from the neutralization tank will be continuously monitored for pH, specific conductance, and turbidity. Alarms for off-specification conditions will alert operators of any process upsets.

Effluent from the Excess Water Discharge Lagoon System will be pumped to Swamp Creek via the excess discharge water pipeline. The final effluent will be continuously monitored for pH, specific conductance, and turbidity. Alarms for off-specification conditions will alert operators of any process upsets.

The proposed treatment system will be similar to the "model" (BATEA) system used by EPA to develop NSPS limitations for copper, lead, and zinc mines. The system will differ from the "model" in three significant respects.

1. The NSPS "model" system does not use ferric sulfate for promotion of the floc formation or sodium sulfide for removal of trace concentrations of metals. The proposed Crandon Project treatment process, through use of these two additional chemicals, will achieve better removal of metals than the NSPS "model" system.

2. The NSPS "model" system does not contain a filtration process after lime precipitation and clarification. The filters proposed for the Crandon Project treatment system will remove virtually all metal hydroxide/sulfide precipitates in the overflow from the lime precipitation

clarifier, thereby achieving better effluent quality than required by NSPS.

3. NSPS allows treatment and discharge of all water pumped from the mine. The proposed Crandon Project water management plan allows for the use of roughly one-fifth of the water pumped from the mine as mill makeup water. The proposed Crandon Project system, therefore, will result in a lower discharge volume than allowed by NSPS.

OIL REMOVAL

It is anticipated by Exxon that no more than 20 ppm of oil will be present in the contaminated mine water. The equipment manufactures have indicated that the treatment plant will effectively remove this quantity of oil through mechanisms of precipitation, adsorption and filtration. There is the option of retrofitting an oil skimmer or oil/water separator in the mine if necessary. This option was mentioned in the Phase III Water Management Study (CH2M HILL, 1982). There is also the capability of adding activated carbon in the flash mix reactor which would aid in oil removal.

4.2 TREATMENT OF INTERCEPTED GROUNDWATER FOR DISCHARGE

Groundwater collected in the interceptor system is designated as "Intercepted Groundwater," and will be similar in quality to the groundwater in the aquifer above the orebody. Water pumped from the groundwater interceptor system will be routed to a surge tank, monitored, and normally discharged. If treatment is necessary it will be pumped through the Intercepted Groundwater Treatment System. This system will be identical to the contaminated mine water treatment system, but will be sized smaller because of the lower projections of flow rates for this stream.

4.3 TREATMENT OF PROCESS WATER AND MINE WATER FOR RECYCLE

The management of process water in the mine/mill water circuit and of mine water were discussed in Section 3.

As shown in Figure 2, all process water from the mill eventually passes through the reclaim pond prior to being recycled to the mill. Most of the reclaim ponds' overflow is recycled directly, without treatment. A portion is blended with contaminated mine water, as discussed earlier, and then routed through the Recycle Water Treatment System. Effluent from the system is recycled to the mill as fresh water makeup.

Water will be pumped from the reclaim ponds to the Reclaim Water Tank at the mill. Approximately 82 percent of the effluent from the reclaim ponds will be recycled directly to the mill processes. Approximately 18 percent of the effluent from the reclaim ponds will be routed through the Recycle Water Treatment System where it will be blended with approximately 18 percent of the contaminated mine water stream. The combined blend of waters will be treated for removal of dissolved salts, primarily gypsum ($CaSO_4$). As mentioned earlier, the volume of water routed to this treatment system will be sufficient to control scaling in the mill process water circuit.

The unit processes to be used in the Recycle Water Treatment System are described in the following paragraphs.

MIXING, NEUTRALIZATION, AERATION

This process will provide for mixing of recycled sludge with Milk-of-lime, pH adjustment, oxidation of ferrous iron, and adjustment of the pH of influent water to approximately 10.5. The design and operation of this process will be identical to that described earlier for the same operation in the Contaminated Mine Water Treatment System.

LIME/SODA SOFTENING

The purpose of this process will be to remove solids from the water routed to this system from the mine, remove soluble metals as metal hydroxides, and remove calcium through precipitation as $CaCO_3$. (Calcium removal will be important to downstream processes because it will mitigate $CaSO_4$ scaling potential in the reverse osmosis system). A solids recycle system will be used, similar to that described for the Contaminated Minewater Treatment System.

In the lime/soda softening process, sufficient lime will be added at the neutralization reactor to raise the reaction pH to 10.5. Metal hydroxides will precipitate in the same reactions described earlier. In addition, soda ash will be added to the system to precipitate calcium:

$$Na_2CO_3 + Ca^{2+} \rightarrow CaCO_3\downarrow + 2Na^+$$

Effluent from the neutralization reactor will flow by gravity to the centerwell of a solids contact type reactor clarifier with a design overflow rate of 1 gpm/ft². Polymer solution and soda-ash solution will be added to the flocculating centerwell of the clarifier by ratio flow control. One to 2 mg/L polymer will normally be added. The amount of soda-ash solution to be added will be operator controlled to optimize the removal of calcium from the influent water.

Metal hydroxide and calcium carbonate sludge generated in the process will settle to the bottom of the clarifier where the clarifier mechanism will sweep it to a sludge well at the center of the clarifier. Settled sludge will be pumped from the clarifier and will be split into two streams. Approximately 85 percent of the settled sludge will be recycled and 15 percent will be pumped to the tailings thickener underflow sump for disposal in the tailings pond.

MIXED MEDIA FILTRATION

Effluent from the lime/soda precipitation reactor clarifier will flow by gravity to a splitter structure and will flow by gravity to three parallel mixed media gravity filters with a design surface loading rate of 3.5 gpm/ft^2. The pH of the water will be adjusted in the splitter structure with H_2SO_4 to avoid calcium carbonate deposition on the filter media. This process will remove residual solids (primarily metal hydroxides and calcium carbonate) which overflow the clarifier in the lime/soda softening system. (Solids removal will also be an important pretreatment step to mitigate fouling problems in the downstream reverse osmosis system.)

The design and operation of this process will be identical to that described earlier for the same operation in the Contaminated Mine Water Treatment System.

NEUTRALIZATION

Effluent from the filters will flow by gravity into a sump arrangement which will include neutralization tanks with mixing compartments and filter clearwells with filter backwash compartments (to provide a source for filter backwash water).

The design and operation of this neutralization process will be identical to that described earlier for the same operation in the Contaminated Mine Water Treatment System, except that effluent from the neutralization system will be pumped to the reverse osmosis (RO) system rather than to discharge.

The contents of the neutralization tank will be continuously monitored for pH, specific conductance, and turbidity. Alarms will be provided to alert operators of off-specification conditions which could affect the operation of downstream unit operations.

REVERSE OSMOSIS (RO)

The purpose of this process will be to recover water with low concentrations of dissolved solids for recycle to the mill. The dissolved solids present in the influent to the process (primarily sodium sulfate) will be concentrated in the brine stream which will be routed to the vapor compression evaporator. A list of operating RO water treatment plants is presented in Appendix G.

In the reverse osmosis (RO) system, the feed water will be pumped at high pressure through a series of semi-permeable membranes. The pressure will force water through the membranes. Most soluble substances will be "rejected" by (i.e., will not pass through) the membranes and will be concentrated in a brine stream from the RO system. The water that passes through the RO membranes will account for about 80 percent of the total treated water recycled to the mill.

Water from the post-filter neutralization tank will be pumped by low-pressure feed pumps and booster pumps (in series) through cartridge filters upstream from the RO modules. Sodium hexametaphosphate (SHMP) will be injected into the RO feed lines, paced (adjusted in proportion to) by the RO influent flow rate. SHMP will be added to mitigate scaling in the RO membranes. The pH of the RO influent water will be controlled via H_2SO_4 injection, with acid addition rate paced by an in-line pH element and controller.

To protect the RO system, the specific conductance, temperature, and turbidity of the feedwater, will be monitored. High conductivity will be alarmed. High turbidity in the feedwater will shut off flow to the system.

The rate of product water (i.e., permeate) recovery will be controlled by the ratio of the reject (brine) and feedwater flow rates. Conductivity of the reject stream will be continuously monitored and high conductivity will be alarmed.

RO membranes could be fouled if the concentration of scale forming compounds in the brine stream exceed their solubility. Care will be exercised to ensure that the concentrations of $CaSO_4$, $CaCO_3$, $BaSO_4$, and similar scale forming compounds do not exceed their solubility. (This points to the importance of the lime/soda softening process as a pretreatment step ahead of the RO.) The conductivity alarms provided in the RO reject stream will alert operators of impending problems.

RO membranes will be protected from fouling with suspended solids by the upstream mixed media filters. The membranes will be protected from iron fouling because iron will be oxidized in the neutralization reactor and will be removed as iron hydroxide in the lime/soda softeners.

Even with optimum operation and control of the RO process, some long-term fouling of the membranes can normally be expected, requiring occasional cleaning of the membranes. For the anticipated water quality at Crandon, three cleaning solutions are likely to be used:

Solution 1

Ingredients	Quantity per 100 Gallons of Cleaning Solution
Citric Acid	17.0 pounds
Liquid non-ionic Detergent Concentrate (Triton X-100, Tergitol 8, etc.)	0.45 quarts
RO Product water	100 gallons

Adjust to pH 4.0 with ammonium hydroxide (NH_4OH)

Solution 2

Ingredients	Quantity per 100 Gallons of Cleaning Solution
Sodium Tripolyphosphate	17.0 pounds
Sodium EDTA (Verseme or equal)	7.0 pounds
Liquid non-ionic Detergent Concentrate (Triton X-100, Tergitol 8, etc.)	0.43 quarts
RO Product water	100 gallons

Adjust to pH 7.5 with sulfuric acid (H_2SO_4)

Solution 3

Ingredients	Quantity per 100 Gallons of Cleaning Solution
Liquid non-ionic Detergent Concentrate (Triton X-100, Tergitol 8, etc.)	0.43 quarts
Sodium Perborate	4.15 pounds

Adjust to pH 8.0 with sulfuric acid (H_2SO_4)

For the Crandon Project, it is anticipated that these three solutions will be used on a rotating basis and that the RO membranes will be routinely cleaned about once per month. Approximately 1,000 gallons of cleaning solution (total) will be required each month. The solutions are made of primarily biodegradable ingredients. Spent cleaning solution will be contained and then pumped into the tailings disposal system. Shock chlorination for membrane sterilization may also be necessary from time to time. Spent chlorine solution would also be pumped to the tailings disposal system.

VAPOR COMPRESSION EVAPORATOR (VCE)

The brine stream from the RO system will be collected in the RO reject tank. This tank will provide surge capacity and will decouple the RO system from the evaporator system. Brine will be pumped from the RO reject tank into the vapor compression evaporator through heat exchangers designed to recover heat from the evaporator product water.

The VCE will concentrate dissolved solids in the reverse osmosis brine to near the limit imposed by readily soluble salts (primarily Na_2SO_4) while crystallizing out readily insoluble calcium salt ($CaSO_4$). The clean water condensate stream (approximately 95 percent of the feed brine volume) will be recycled to the mill. The concentrated brine stream will be routed on to the brine softening system.

In the vapor compression evaporator, clean condensate will be produced in a vertical tube falling-film-type evaporator. Fuel economy will be achieved by using compressed evaporator product steam to vaporize evaporator contents. Other types of evaporators are available on the market, but a VCE was selected as most appropriate for the Crandon Project.

The VCE system will be purchased as a turnkey process from one of several vendors who market this type of equipment. Depending on the vendor selected, the configuration of the equipment and system controls may be slightly different. All controls within the VCE unit operation will be the responsibility of the VCE supplier. A list of operating VCE water treatment plants is presented in Appendix G.

LIME/SODA SOFTENING OF VCE BRINE

Concentrated brine (at approximately 20 percent solids) from the VCE will be pumped to a solids-contact-type reactor clarifier. In the centerwell of the clarifier, lime will be added via pH control and soda-ash solution and polymer will be added via flow pacing.

This process will be included in the treatment process to precipitate gypsum, metal hydroxides, and calcium carbonate from the VCE brine to produce a relatively pure solution of sodium sulfate.

The design and operation of this softening process is similar to that described earlier for the lime/soda softener used to treat the main influent flow stream.

Sludge produced in the softener will be pumped to the tailings thickener underflow sump for disposal in the tailings pond.

CRYSTALLIZING EVAPORATOR

This final process will concentrate residual brine to a high purity solidified form of sodium sulfate, which may potentially be a saleable byproduct (salt cake), and to produce clean water condensate for recycle to the mill.

The overflow from the brine lime/soda softener will be pumped to a crystallizing evaporator. The crystallizing evaporator will be a forced-circulation vertical tube evaporator. VCE brine will be further evaporated to produce a 55-percent solids slurry consisting primarily of anhydrous sodium sulfate (Na_2SO_4) and sodium thiosulfate ($Na_2S_20_3$). A boiler will be used as the heat source for evaporation.

Clean condensate from the crystallizer will be recycled to the mill.

The brine slurry from the crystallizer will be dewatered in a screen bowl centrifuge to a concentration of about 80 to 95 percent solids. A small washwater stream will be injected in the centrifuge to solubilize chlorides present in the final brine product. This chloride-bearing wastewater stream will be pumped to the tailings thickener underflow sump along with other sludges produced at the treatment plant. Upon cooling, any water remaining in the cake will combine with anhydrous sodium sulfate to form sodium sulfate decahydrate. The resulting product will have no free water.

Solidified brine will be disposed of in an isolated area of tailings pond T1 while marketability of the material is being determined.

As with the VCE, the crystallizer will be purchased as a turnkey system. Crystallizer controls will be provided by the supplier.

EFFLUENT

Effluent from the Recycle Water Treatment System will be routed to the treated/fresh water tank, and from there will be pumped to the mill for use in locations which require high purity water. This stream will normally represent the only freshwater makeup to the mill.

4.4 TREATMENT OF SANITARY WASTEWATER FOR DISCHARGE

The sanitary wastewater collected from the mine/mill complex will be treated by an extended aeration activated sludge system. Extended aeration is a well established technology which is widely used for treatment of sanitary wastewater. The process uses biological matter (bacteria) suspended in water to degrade the organic wastes. The extended aeration system for this application will include a bar screen, grit chamber, flow equalization tank, aeration tank, final clarifier, chlorine contact tank, and sludge storage tank. The flow diagram for this system is presented in Figure 18.

The sanitary wastewater will pass through a small grit chamber and bar screen into a flow equalization chamber. Wastewater will then flow by means of an air lift system to the aeration chamber to be aerated/digested for a period of 30 to 40 hours. Effluent from the aeration chamber will overflow to the clarifier to settle out the biomass. Settled sludge in the clarifier will be pumped back to the aeration chamber or wasted to a sludge holding tank. Effluent from the clarifier will flow by gravity to a chlorine contact chamber for disinfection prior to discharge. Sludge will be disposed offsite by contract hauler.

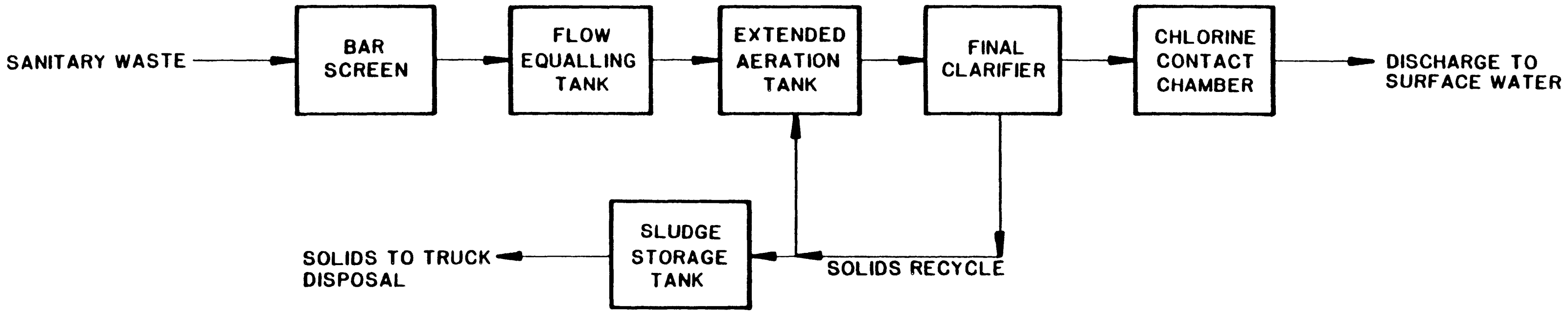
A detailed description of the sanitary treatment facilities is presented in "Facilities Plan for the Exxon Minerals Company Mine/Mill Complex Sanitary Wastewater, Crandon, Wisconsin" (CH2M HILL, 1985).

4.5 EFFLUENT MONITORING

Automatic composite samplers will collect flow proportional samples of intercepted groundwater, contaminated mine water, and reclaim pond water. Samples collected at these locations will be used to monitor the quality of influent to each of the three water treatment systems.

Effluent from the contaminated mine water and intercepted groundwater treatment systems will be pumped to the Excess Discharge Lagoon System, consisting of two lagoons operated in series. In the event of treatment system upset in one or both treatment trains, the lagoon system will be designed with the flexibility to:

- Isolate off-specification effluent in the first-stage lagoon for reprocessing through the treatment process via the treatment plant feed tank or the reclaim pond.



Typical Representations: Refinements May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
FLOW DIAGRAM FOR SANITARY WASTEWATER TREATMENT

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 12/85
CHECKED BY
DATE
APPROVED BY
DATE
APPROVED BY
DATE
APPROVED BY
DATE
DATE
DRAWING NO **FIGURE 18**
SHEET ______
OF ______
REVISION NO

- Bypass the clean effluent from either or both treatment systems to the second-stage lagoon for discharge, while recycling off-specification effluent from the first-stage lagoon.

Flow proportional composite samplers will also be installed to collect effluent samples from each of the three treatment systems on a daily basis. A final sampler will be installed at the outlet from the Excess Water Discharge Lagoons to measure effluent quality immediately before it is discharged to Swamp Creek. Effluent samples will be collected daily and analyzed for all parameters required by the WPDES permit. Additionally, 8-hour composite samples will be taken and analyzed for critical elements as specified in the WPDES permit.

Effluent from each of the three systems and the lagoon will also be analyzed continuously for pH, specific conductance, and turbidity to alert operators of any short-term fluctuations in effluent quality.

A composite sampler will also be installed at the discharge point of the sanitary wastewater package treatment plant. Samples will be collected daily and analyzed for residual chlorine and other parameters specified in the WPDES permit.

Uncontaminated runoff collected in the runoff sedimentation basins will be manually sampled and water will be chemically analyzed for alkalinity, hardness, oil and grease, sulfate, total dissolved solids, and total suspended solids. Field measurements will also be taken for pH, specific conductance, stream discharge and velocity, temperature, and water level.

At the outfall to Swamp Creek, combined effluent from the water treatment systems and the sanitary wastewater treatment system will be continuously monitored for dissolved oxygen, flow rate, pH, turbidity, and specific conductance.

Water samples from Swamp Creek will be collected regularly and tested to determine the in-stream concentration of a wide range of compounds as required by the mine permit. Chemical analysis will be conducted for aluminum, arsenic, barium, biological oxygen demand (BOD), cadmium, chromium (+3 and +6), copper, cyanide, fluoride, hardness, iron, lead, manganese, mercury, selenium, silver, sodium, sulfate, total alkalinity, total dissolved solids, total organic carbon, total sulfur, total suspended solids, and zinc. Field measurement will be conducted for dissolved oxygen, pH, specific conductance, stream discharge and velocity, temperature, and water levels. These samples will be collected quarterly at a point upstream from the outfall and monthly at both a point within the mixing zone in the creek and a point well downstream.

In addition to the stream water sampling program, duplicate sediment samples will be collected annually upstream from, downstream from, and within the mixing zone and will be chemically analyzed for aluminum, arsenic, cadmium, chromium (total), copper, iron, lead, manganese, mercury, selenium, silver, sulfate, sulfur (total), and zinc.

The sample points, frequency of sampling and the analyses to be performed on the samples are described in detail in the Monitoring and Quality Assurance Plan (MQAP) which was submitted as part of Mining Permit application. In the event that the monitoring requirements as described in the MQAP and/or the WPDES permit differ from those described above, the former (MQAP and/or WPDES permit) will govern.

GLT182/4

SECTION 5
Design of Treatment System

Section 5
DESIGN OF TREATMENT SYSTEM

5.1 DESIGN BASIS

As described in earlier sections of this report, the selection and preliminary design of the water treatment system for the Crandon Project is based on several years of study by Exxon and CH2M HILL and is further supported by work completed by a number of other consultants working under Exxon's direction.

Based on mine water inflow studies, overall water balances prepared for the Crandon Project and computer modelling runs completed to assess water chemistry in the water circuits, estimated flowrates of waters to be routed to the Crandon water treatment system were developed.

Estimated flows of water to be pumped from the mine are as follows:

Mine Water Source	Average Flowrate (gpm)	Maximum Predicted Flowrate (gpm)
Contaminated Mine Water	1,035	1,265
Intercepted Groundwater	350	850

Computer model predictions were used to estimate the volume of reclaim pond effluent which must be treated to mitigate scaling potential in the mill water circuit. These predictions were also compared to the minimum volume of high quality recycle water required to fulfill mill operating requirements. These dual operating requirements led to selection of the following average estimated flowrates of reclaim pond effluent to the Recycle Water Treatment System:

Season	Reclaim Water to Treatment gpm
Winter	610
Summer	810[a]

---

[a] This approximate summertime blowdown rate could be reduced if scale inhibitor addition can effectively mitigate scaling in the mill water circuit.

To maintain an overall, long-term, water balance in the mill water circuit, 190 gallons per minute of contaminated mine water must be added to the Recycle Water Treatment System. Predicted average total feed rates to the system in winter and summer, therefore, are 800 gallons per minute and 1,000 gallons per minute, respectively.

CH2M HILL and Exxon jointly agreed that each of the three water treatment systems should be sized and designed with capacities higher than the predicted flowrates. Twenty percent excess capacity over the predicted flowrate was selected for each of the three systems. This excess capacity, built into the design basis of the plant, is provided to allow for:

- Downtime for equipment maintenance and repairs.
- Potential periods of excess precipitation.
- Allowance for estimating flowrates.

The design capacity and sizing safety factors for each of the three treatment systems are summarized in Table 5-1.

5.2 PIPING AND INSTRUMENT DIAGRAMS

Preliminary piping and instrument diagrams (P&ID's) are shown in Figures 19 through 27 (Drawings 051-7-004 through -012). These drawings illustrate all unit processes, major process equipment, process piping and control valves, basic instrumentation and controls, certain block valves important to process understanding, sampling locations and both water and material balances (average wintertime operating conditions are shown on the water and material balances). Potential future equipment is shown in dotted line (see Section 5.11). See Section 4.0 for process descriptions.

5.3 EQUIPMENT SIZING CALCULATIONS

This section describes the rationale used to size the major items of equipment in the proposed Crandon Project water treatment system.

As shown in Figure 17 (Section 4), the anticipated flow rate of contaminated mine water which will be treated for discharge is 845 gallons per minute. The anticipated flow rate of water to be treated for recycle (a blend of contaminated mine water and reclaim pond water) is 800 gallons per minute, based on winter operating conditions. The anticipated flow rate of intercepted groundwater to be treated for discharge is 350 gallons per minute. These three streams are the influent streams shown in Figures 19 and 27 (Drawings 051-7-P-005 and 012).

The water and material balances shown on the P&ID's correspond with the flow rates described above and the influent water qualities summarized in Section 6.

Table 5-1
DESIGN CAPACITIES FOR TREATMENT SYSTEMS

Treatment System	Projected Influent Flow Rate (gpm)[a]				Maximum Predicted Flow (gpm)	Design Capacity (gpm)	Design Contingency (percent)[c]
	Mine Development Period[b]	Base Case	Operating Alternatives				
			A	B			
1. Contaminated Mine Water Treatment System	150	845	1,035	1,035	1,265[d]	1,550[h]	22
2. Intercepted Groundwater Treatment System	0	350	[e]	160	850[d]	1,000	20
3. Recycle Water Treatment System							
- Softening and Filtration	0	800	610	610	1,000[f]	1,200	20
- Reverse Osmosis	0	785	590	590	785/990[g]	940/1,190[g]	20
- VCE/Crystallizer	0	160	120	120	200[f]	240	20

---

[a] Base case and operating alternatives are based on an average mine inflow of 1,270 gpm.
See Figure 9 for description of alternatives.

[b] Month 30 of construction (maximum flow during development).

[c] Percent contingency over largest anticipated flow.

[d] Flow at maximum mine inflow of 2,000 gpm.

[e] Intercepted groundwater used in mill; does not require treatment.

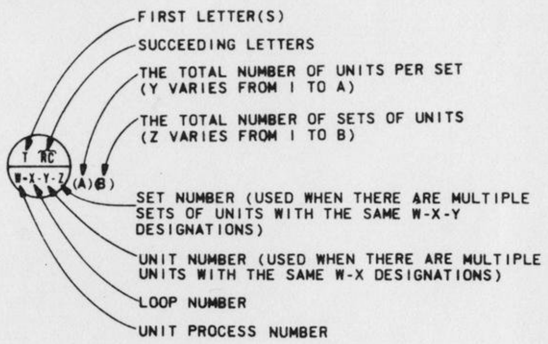
[f] Flows based on summertime flowrates.

[g] Winter/summer RO capacities.

[h] Design capacity is based on treating all contaminated mine water in this system.

INSTRUMENTATION & CONTROL LEGEND

INSTRUMENT IDENTIFICATION TAG NUMBERS



INSTRUMENT SOCIETY OF AMERICA TABLE

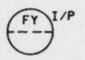
	FIRST LETTER(S)		SUCCEEDING LETTERS		
LETTER	PROCESS OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS(†)		ALARM		
B	BURNER FLAME		USERS CHOICE(†)	USERS CHOICE(†)	USERS CHOICE(†)
C	CONDUCTIVITY			CONTROL	
D	DENSITY (S.G.)	DIFFERENTIAL			
E	VOLTAGE		PRIMARY ELEMENT		
F	FLOW RATE	RATIO			
G	GAUGE		GLASS	GATE.	
H	HAND (MANUAL)				HIGH
I	CURRENT		INDICATE		
J	POWER	SCAN			
K	TIME OR SCHEDULE			CONTROL STATION	
L	LEVEL		LIGHT (PILOT)		LOW
M	MOTION				MIDDLE
N	USERS CHOICE(†)		USERS CHOICE(†)	USERS CHOICE(†)	USERS CHOICE(†)
O	USERS CHOICE(†)		ORIFICE		
P	PRESSURE (OR VACUUM)		POINT (TEST CONNECTION)		
Q	QUANTITY OR EVENT(†)	INTEGRATE	INTEGRATE		
R			RECORD OR PRINT		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE(†)		MULTIFUNCTION(†)		
V	VISCOSITY			VALVE	
W	WEIGHT OR FORCE		WELL		
X	UNCLASSIFIED(†)		UNCLASSIFIED(†)	UNCLASSIFIED(†)	UNCLASSIFIED(†)
Y	USERS CHOICE(†)			RELAY OR COMPUTE(†)	
Z	POSITION			DRIVE, ACTUATE OR UNCLASSIFIED FINAL CONTROL ELEMENT	

(†) WHEN USED, EXPLANATION IS SHOWN ADJACENT TO INSTRUMENT SYMBOL. SEE ABBREVIATIONS AND LETTER SYMBOLS.

TRANSDUCERS

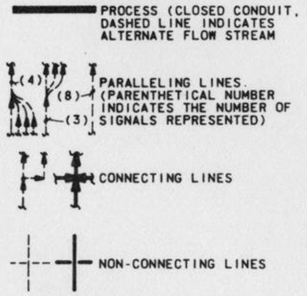
A	ANALOG
D	DIGITAL
E	VOLTAGE
F	FREQUENCY
I	CURRENT
P	PNEUMATIC
PF	PULSE FREQUENCY
PD	PULSE DURATION

EXAMPLE:

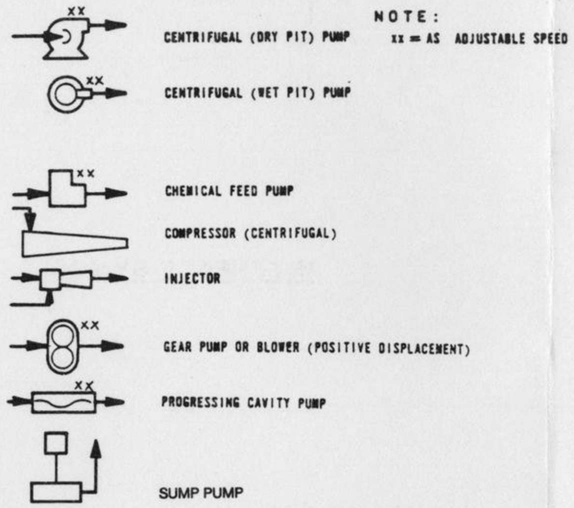


CURRENT TO PNEUMATIC TRANSDUCER (BACK OF PANEL, IN A FLOW LOOP)

LINE LEGEND

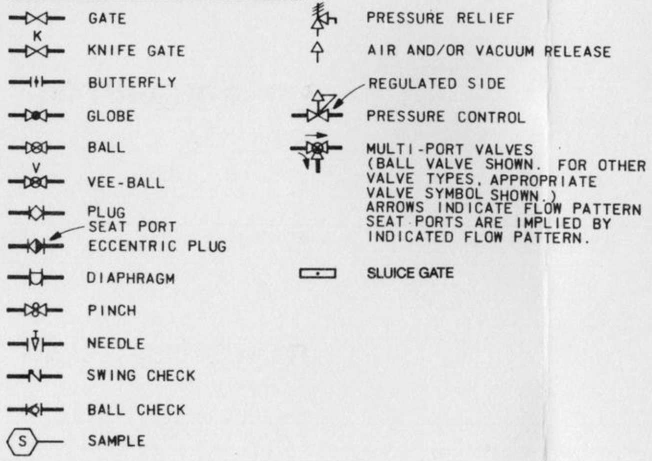


PUMP & COMPRESSOR SYMBOLS



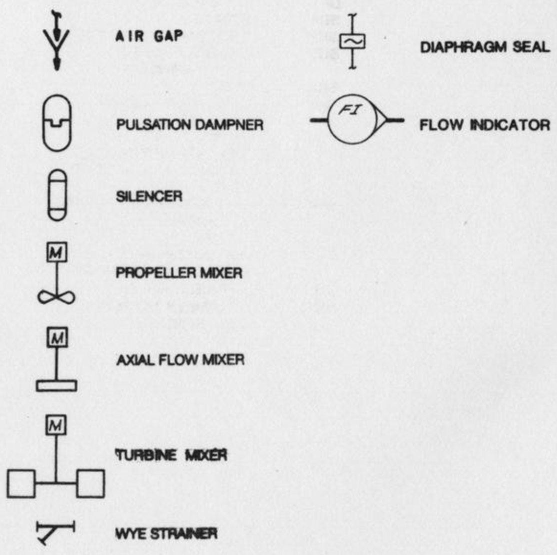
NOTE:
xx = AS ADJUSTABLE SPEED

VALVE SYMBOLS

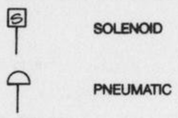


MULTI-PORT VALVES (BALL VALVE SHOWN. FOR OTHER VALVE TYPES, APPROPRIATE VALVE SYMBOL SHOWN.) ARROWS INDICATE FLOW PATTERN SEAT PORTS ARE IMPLIED BY INDICATED FLOW PATTERN.

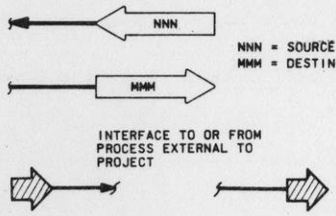
MISCELLANEOUS SYMBOLS



ACTUATOR SYMBOLS

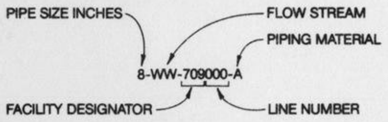


INTERFACE SYMBOLS



NNN = SOURCE SHEET NO.
MMM = DESTINATION SHEET NO.

PIPING DESIGNATION



FLOW STREAM IDENTIFICATION

AC	ACTIVATED CARBON
ACD	SULFURIC ACID
BA	BLOWER AIR
BSD	BUILDING SUMP DISCHARGE
BWW	BACKWASH WATER
CLS	CLEANING SOLUTION
DR	DRAIN
FS	FERRIC SULFATE
GAS	NATURAL GAS
IA	INSTRUMENT AIR
MOL	MILK OF LIME
OF	OVERFLOW
PA	PLANT AIR
LP	LIQUID POLYMER
SDA	SODA ASH
SHM	SODIUM HEXAMETAPHOSPHATE
SLD	SLUDGE-SOFTENER -BRINE SOFTENER
STM	STEAM
TW	SOFTENER EFFLUENT FILTER EFFLUENT RO PERMEATE EVAPORATOR DISTILLATE CRYSTALIZER CONDENSATE
V	VENT
WW	CONTAMINATED MINE WATER RECLAIM WATER RO REJECT EVAPORATOR BRINE INTERCEPTD GROUNDWATER
VS	VARIABLE SPEED
NNF	NORMALLY NO FLOW
NAS	SODIUM SULFIDE

MATERIAL ABBREVIATIONS

A	CARBON STEEL
B	CARBON STEEL GALVANIZED
F	316L
H	ALLOY 20
G	POLYETHYLENE
I	POLYPROPYLENE

NOTES:

1. SYMBOL, LEGENDS, AND USE IDENTIFICATIONS WHICH ARE SHOWN ON THIS DRAWING ARE FOLLOWED THROUGHOUT THE PLANS WHENEVER APPLICABLE. ALL OF THE VARIOUS SYMBOLS, LEGENDS AND USE IDENTIFICATIONS ARE NOT NECESSARILY UTILIZED IN THE PROJECT.

REVISED	DATE	BY	DESCRIPTION
1	7-15-84	MRH	GENERAL REVISIONS

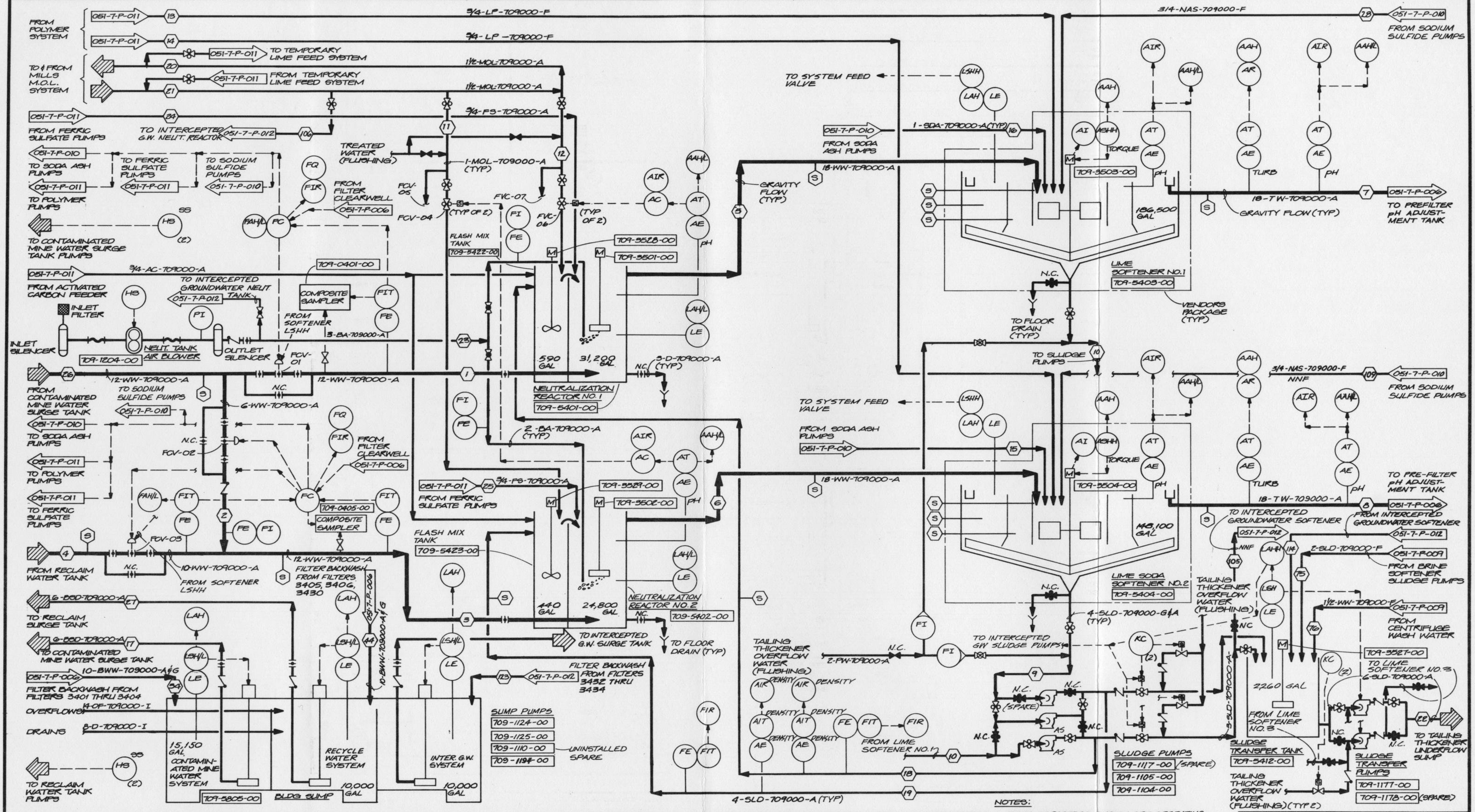
CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
LEGEND

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SWB	DATE 11-18-83	CHECKED BY MTI	DATE 11-18-83
APPROVED BY MND	DATE 11-18-83	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO 051-7-P-004	FIGURE 19	SHEET OF	REVISION NO 1



STREAM NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13†	14†	15	16	17	18	19	20	21	22	23	24	25	26	27	28
FLOW, GPM		845	190	800	610	994	940	833	796	159	166	0.46	0.84	4.63	4.4	9.6	0	(80 AVG)	148	140	22.6	25.0	300 (43.2 AVG)	351 SCFM	.18	.2	1035	(60 AVG)	.02
DRY SOLIDS, LBS/HR										4733	4982								4442	4202									
PRESSURE, PSI		40	40	40	50																								
TEMP °C (°F)	SUMMER WINTER	9 (48) 9 (48)	9 (48) 9 (48)	17.4 (63) 4.4 (40)	20 (68) 3 (37)	9 (48) 9 (48)	17.4 (63) 4.4 (40)	9 (48) 9 (48)	17.4 (63) 4.4 (40)																		9 (48) 9 (48)		
INTERMITTENT FLOWS	OCCURANCES/DAY DURATION (MIN)																												
pH		5.8	5.8	7.4	7.5	9.5-10.5	9.5-10.5	9.5-10.5	9.5-10.5																				

† POLYMER FLOW RATE BASED ON 5PPM AT .1 PERCENT SOLUTION

∗ INCLUDES 3 GPM AVG FLUSHING WATER

NOTES:

1. TANK CAPACITIES SHOWN ARE OPERATING CAPACITIES UNDER DESIGN FLOW CONDITIONS
2. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.
3. FLOW RATES SHOWN DO NOT INCLUDE MARGIN FOR FILTER BACKWASH COMPENSATION OF ~60GPM AND ~80 GPM AVG

REVISED	DATE	BY	DESCRIPTION
2	10/17/85	RRO	GENERAL REVISONS
1	7/15/84	MRH	GENERAL REVISIONS

CH2M HILL

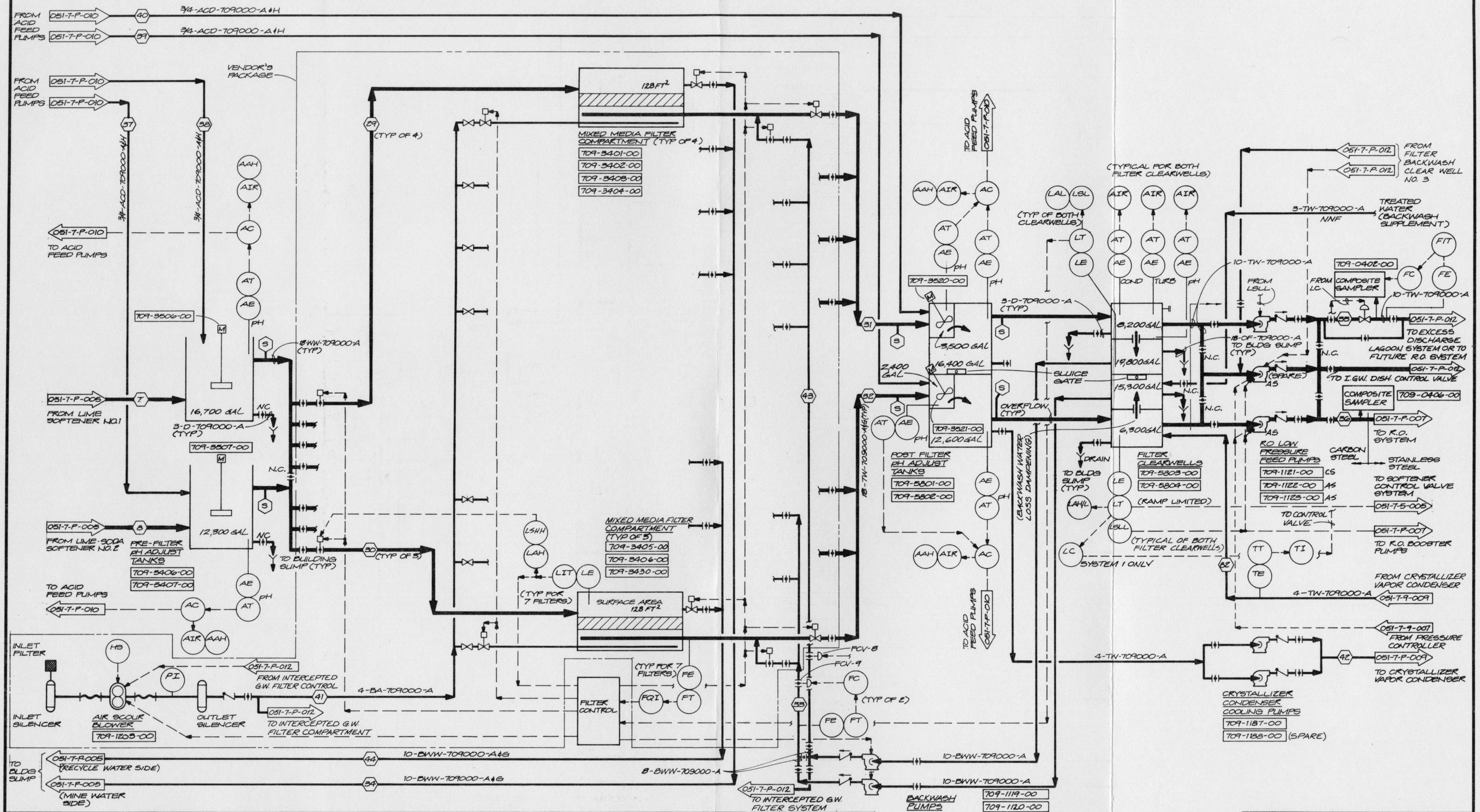
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
LIME & LIME/SODA SOFTENERS

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY SWB		DATE 11-18-83	CHECKED BY MTI		DATE 11-18-83
APPROVED BY MND		DATE 11-18-83	APPROVED BY		DATE
APPROVED BY		DATE	EXXON		DATE
DRAWING NO. 051-7-P-005		FIGURE 20	SHEET ___ OF ___		REVISION NO. 2

DESIGN PRODUCTS CO.



STREAM NUMBER	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
FLOW, GPM	208	265	833	796	960 (60 AVG)	960 (80 AVG)	833	796	(0.93 GPH)	(0.63 GPH)	0	(0.14 GPH)	(245 SCFM)	255.5	960 (80 AVG)	960 (60 AVG)	NOT USED		
DRY SOLIDS, LBS/DAY						472										272			
PRESSURE, PSI							50	50											
TEMP °C (°F) SUMMER / WINTER	9 (48) / 9 (48)	17.4 (63) / 4.4 (40)	9 (48) / 9 (48)	17.4 (63) / 4.4 (40)			9 (48) / 9 (48)	20 (68) / 8 (46)						17.4 (63) / 4.4 (40)					
INTERMITTENT FLOWS OCCURANCES/DAY / DURATION (MIN)					18 / 5	24 / 5							60 / 5		24 / 5	18 / 5			
pH	8.3	8.3	8.3	8.3			7.0	8.3						8.3					

NOTES:
1. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.
2. TANK CAPACITIES SHOWN ARE OPERATING CAPACITIES.
3. FLOW RATES SHOWN DO NOT INCLUDE MARGIN FOR FILTER BACKWASH COMPENSATION OF 80gpm.

CH2M HILL

REVISED	DATE	BY	DESCRIPTION
2	10/18/85	RRO	GENERAL REVISONS
1	7-15-84	MRH	GENERAL REVISIONS

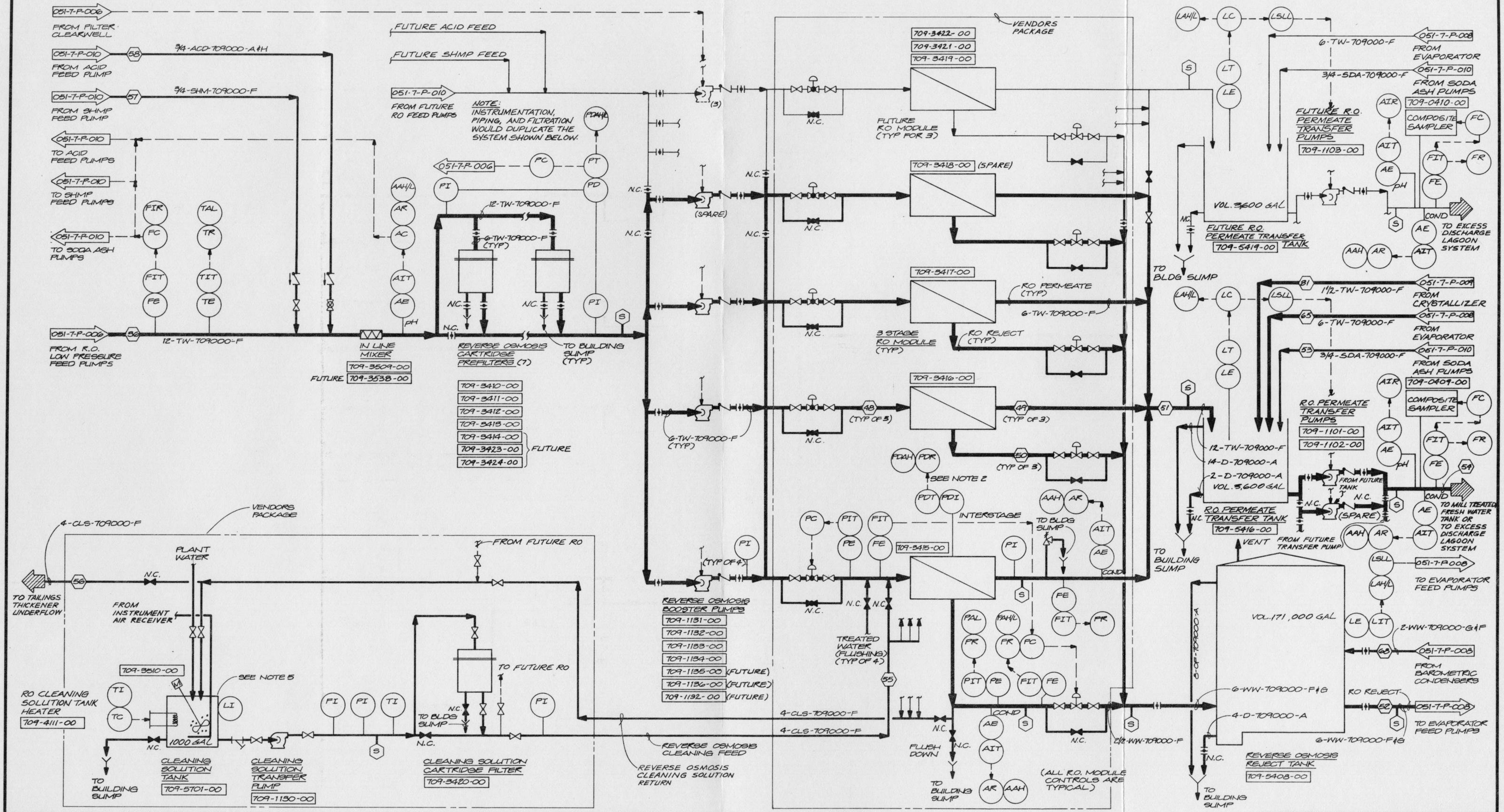
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
GRAVITY FILTER SYSTEM

SCALE NONE | STATE WISCONSIN | COUNTY FOREST
DRAWN BY SWB | DATE 11/18/83 | CHECKED BY MTI | DATE 11/18/83
APPROVED BY MND | DATE 11/18/83 | APPROVED BY | DATE
APPROVED BY | DATE | EXXON | DATE
DRAWING NO. 051-7-P-006 **FIGURE 21** SHEET OF | REVISION NO. 2

DESIGN PRODUCTS CO.



STREAM NUMBER		48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
FLOW GPM		265.3	212.3	53	636.8	160	0.08	793.2	265.3	265.3	0.08	0.77GPH				
SOLIDS LBS/HR																
PRESSURE PSI		340-600 NOM.	20	310-570 NOM.	20	2-15		50	100							
TEMP °C (°F)	SUMMER WINTER	22 (72) 9 (49)	22 (72) 9 (49)	22 (72) 9 (49)	22 (71.5) 9 (49)	22 (71.5) 9 (49)										
INTERMITTENT FLOWS	OCCURANCES/DAY DURATION (MIN)								1 PER MO. 1-4 HR	1 PER MO. 3.8 MIN						
pH		5.5-6.5	5.5-6.5	5.5-6.5	5.5-6.5	5.5-6.5		6.5-7.5								

NOT USED

NOTES:

1. TANK CAPACITIES SHOWN ARE MAXIMUM OPERATING CAPACITIES.
2. PRESSURE DIFFERENTIAL RECORDING ACROSS 1ST, 2ND, & 3RD STAGES OF REVERSE OSMOSIS.
3. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.
4. FLOW RATES SHOWN DO NOT INCLUDE FUTURE EQUIPMENT FLOW REQUIREMENTS.
5. CLEANING SYSTEM SHALL ALSO BE USED FOR SHOCK CHLORINATION OF THE R.O. SYSTEM.

CH2M HILL

REVISED	DATE	BY	DESCRIPTION
2	10/19/85	MRH	GENERAL REVISIONS
1	7/15/84	MRH	GENERAL REVISIONS

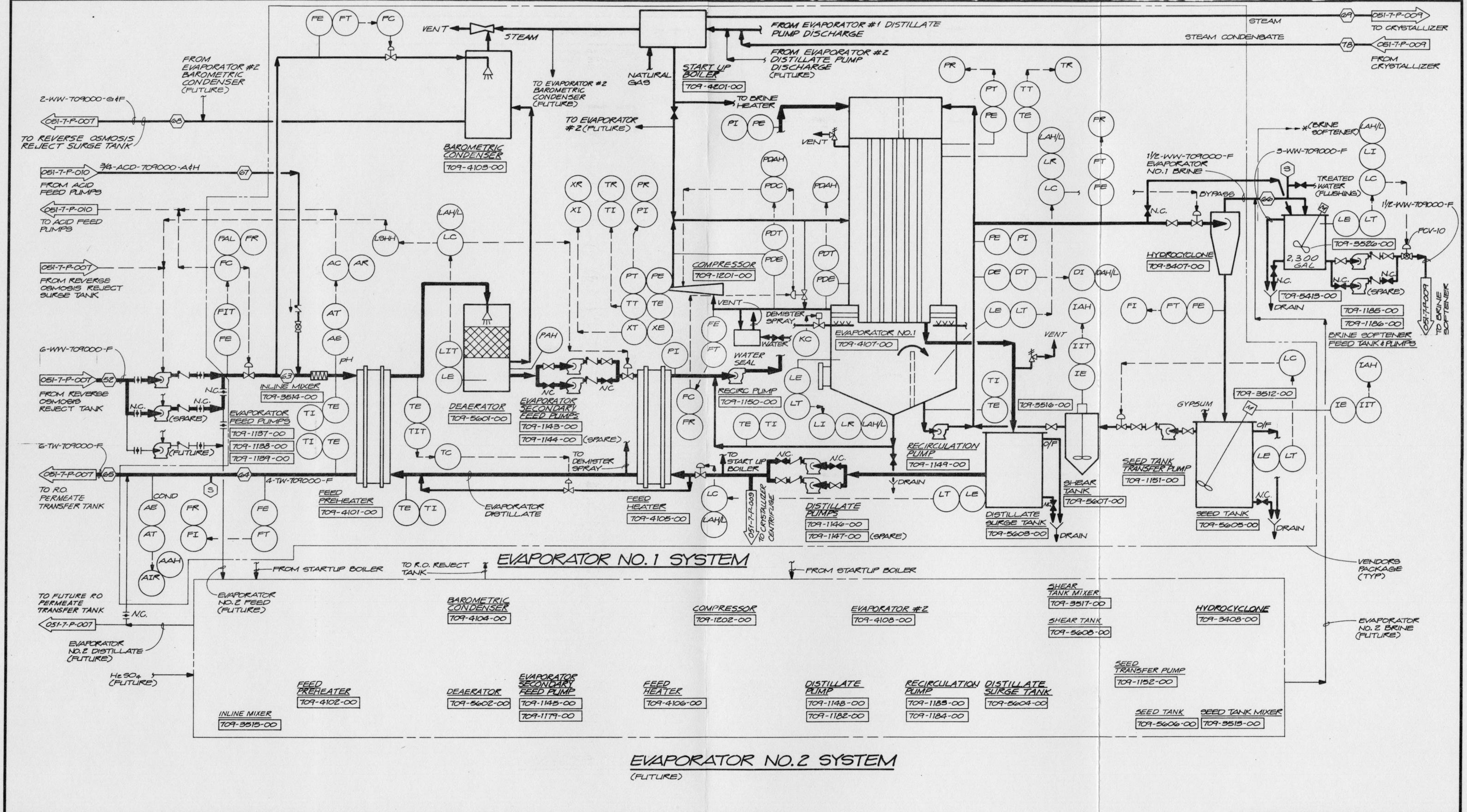
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
REVERSE OSMOSIS SYSTEM

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY SWB DATE 11-18-83
CHECKED BY MTI DATE 11-18-83
APPROVED BY MND DATE 11-18-83
APPROVED BY
DATE
APPROVED BY
DATE
EXXON
DATE
DRAWING NO. 051-7-P-007
FIGURE 22
SHEET OF
REVISION NO. 2

DESIGN PRODUCTS CO.



STREAM NUMBER		63	64	65	66	67	68	69	70	71	72	73							
FLOW GPM		159.6	150.7	150.7	7.7	0.2 GPH	0.8 APPROX	3.780 (lb/hr)											
SOLIDS LBS/HR					35.9														
PRESSURE PSI		50	50	50	14.7			40											
TEMP °C (°F)	SUMMER WINTER	22 (72) 9 (49)	26 (80) 14 (57)	26 (80) 14 (57)	100 (212)					NOT USED									
INTERMITTENT FLOWS	OCCURANCES/DAY DURATION (MIN)																		
pH		5.5-6.5	7.0	7.0	5.5-6.5														

NOTES:

1. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.
2. BOILER IS NATURAL GAS FIRED.
3. FLOWS SHOWN DO NOT INCLUDE FUTURE EQUIPMENT FLOW REQUIREMENTS.

REVISED	DATE	BY	DESCRIPTION
2	10/18/85	MRH	GENERAL REVISIONS
1	7/15/84	MRH	GENERAL REVISIONS

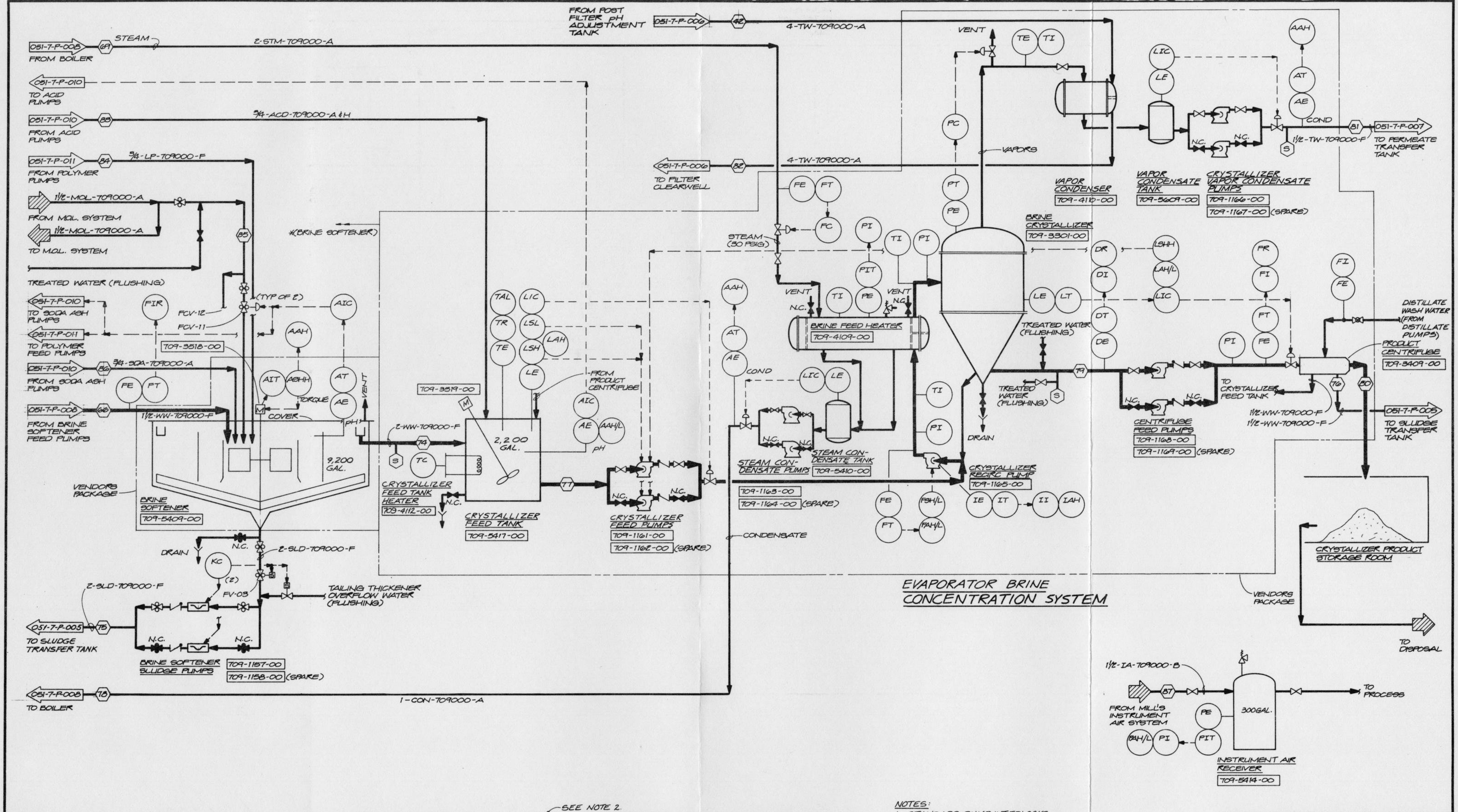
CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
EVAPORATOR SYSTEM

SCALE NONE | STATE WISCONSIN | COUNTY FOREST
DRAWN BY SWB | DATE 11-18-83 | CHECKED BY MTI | DATE 11-18-83
APPROVED BY MND | DATE 11-18-83 | APPROVED BY | DATE
APPROVED BY | DATE | EXXON | DATE
DRAWING NO. 051-7-P-008 **FIGURE 23** SHEET ___ OF ___ REVISION NO. 2



SEE NOTE 2.

STREAM NUMBER		74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
FLOW GPM		6.3	1.78	1	6.3	7.6	1		5.7	255.5	0.22GPH	0.02	0.12	0.41	100 SCFM					
SOLIDS LBS/HR			56.3				784.5	784.5												
PRESSURE PSI			30		3.7		10		20											
TEMP °C (°F)	SUMMER WINTER	(212) 100	(212) 100		(212) 100		(220) 104	37 99 24 75	32 90 14 57											
INTERMITTENT FLOWS	OCCURANCES/DAY DURATION (MIN)																			
pH		10-11	10-11		6-7		6-7		7	8.5										

NOT USED

NOTES:

1. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.
2. POLYMER ADDITION AT 5ppm.

REVISED	DATE	BY	DESCRIPTION
3	10-20-85	MRH	GENERAL REVISIONS
2	7-15-84	MRH	GENERAL REVISIONS
1	12-20-83	MND	CHANGED SOLIDS NOTES IN STREAM 75

CH2M HILL

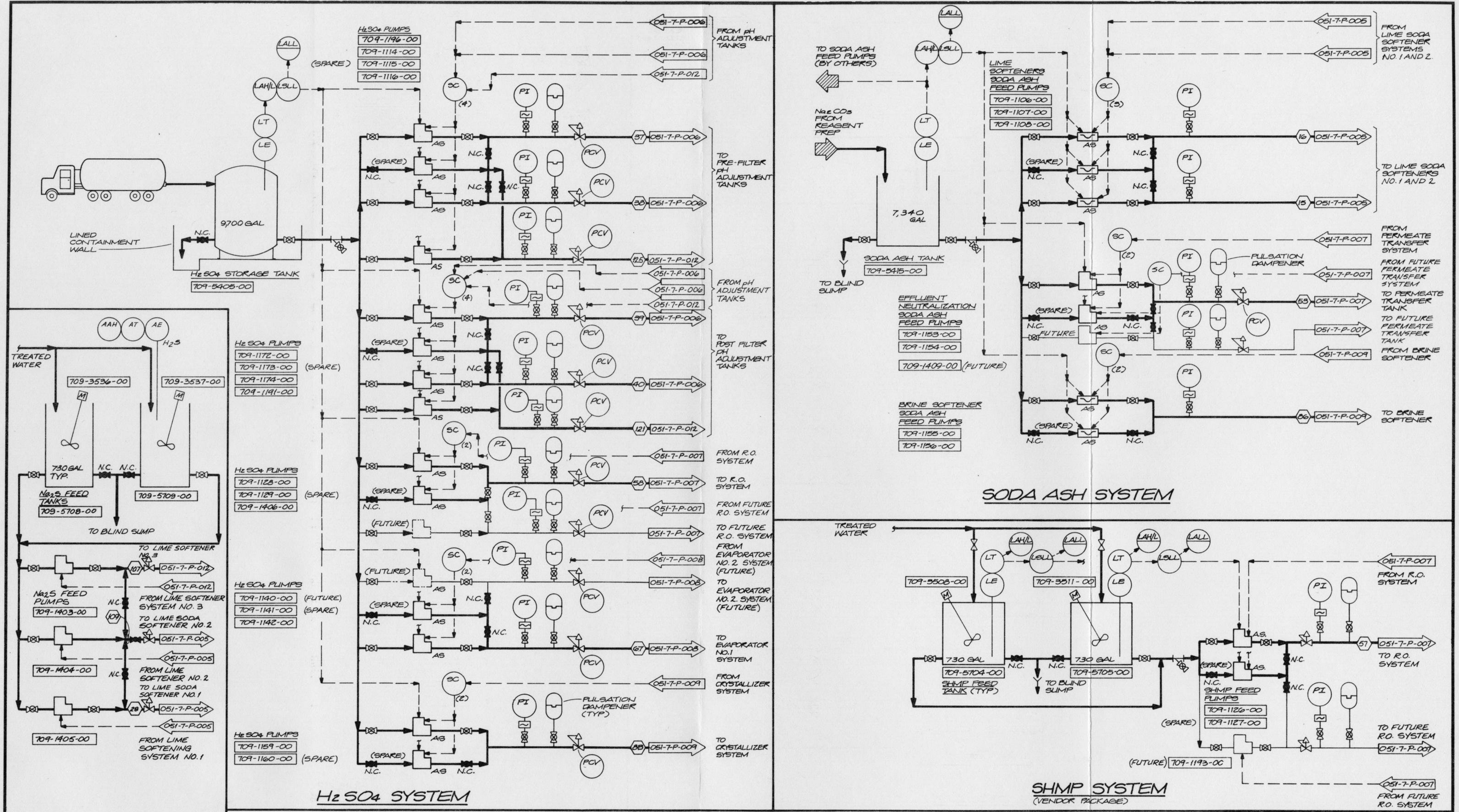
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
BRINE CONCENTRATION SYSTEM

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY SWB
DATE 11-18-83
CHECKED BY MTI
DATE 11-18-83
APPROVED BY MND
DATE 11-18-83
APPROVED BY
DATE
APPROVED BY
DATE
EXXON
DATE
DRAWING NO. 051-7-P-009
FIGURE 24
SHEET
OF
REVISION NO. 3

GSS 5/1981



NOTE:
INSTRUMENTATION AND CONTROL (NOT SHOWN) ARE SIMILAR TO SHMP SYSTEM

SODIUM SULFIDE SYSTEM

NOTES:
1. TANK CAPACITIES SHOWN ARE OPERATING CAPACITIES.
2. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.

REVISED	DATE	BY	DESCRIPTION
2	10/19/85	RRO	GENERAL REVISIONS
1	7/15/84	MRH	GENERAL REVISIONS

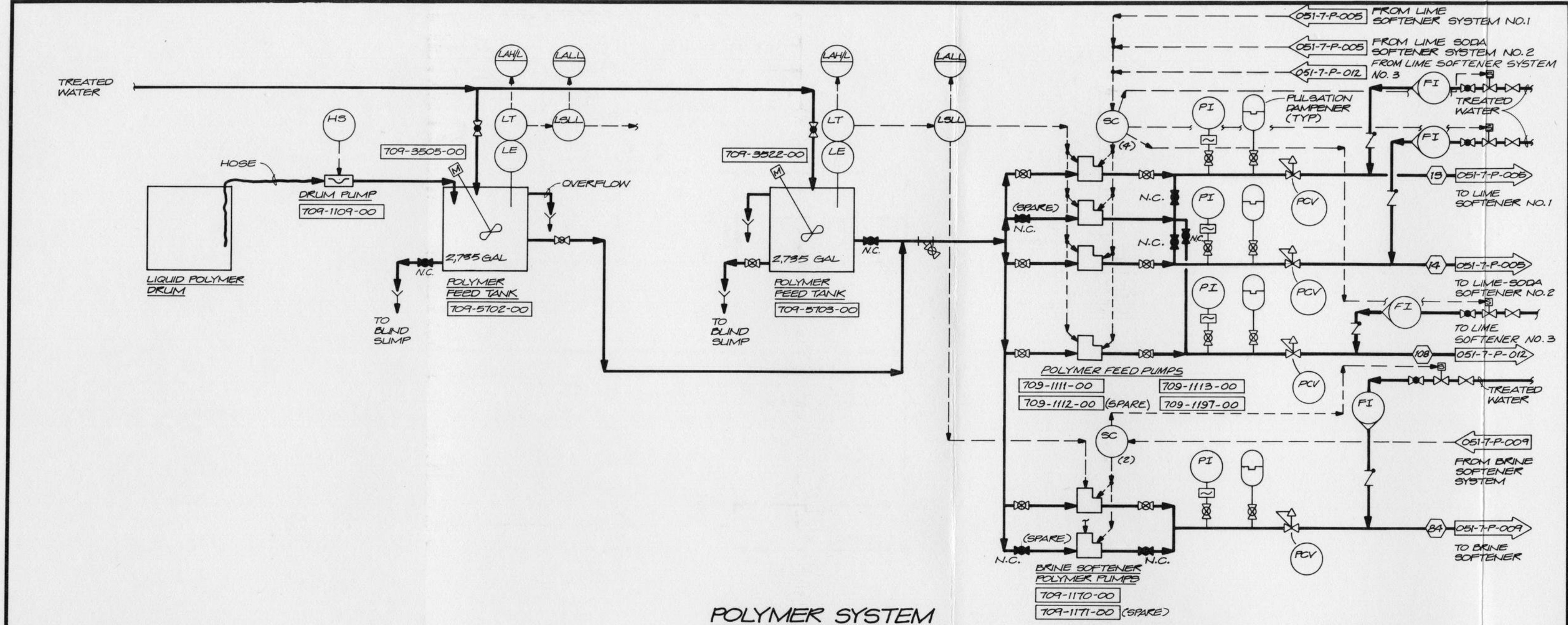
CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

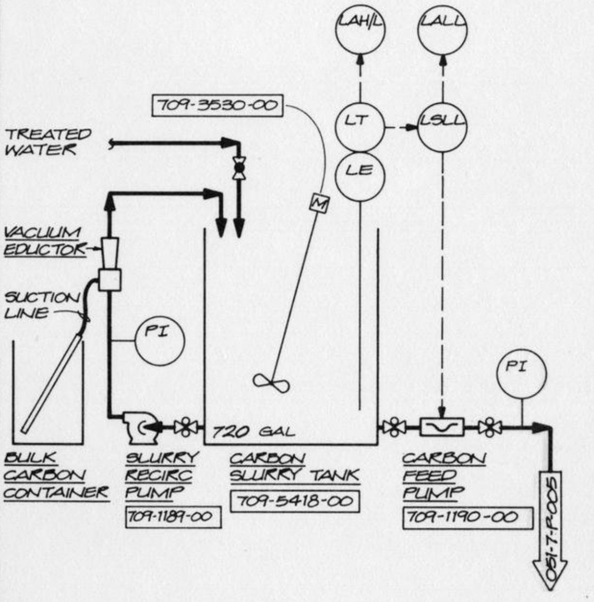
TITLE PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
CHEMICAL FEED SYSTEMS

SCALE NONE | STATE WISCONSIN | COUNTY FOREST
DRAWN BY SWB | DATE 11-18-85 | CHECKED BY MTI | DATE 11-18-85
APPROVED BY MND | DATE 11-18-85 | APPROVED BY | DATE
APPROVED BY | DATE | EXXON | DATE
DRAWING NO. 051-7-P-010 **FIGURE 25** SHEET OF | REVISION NO. 2

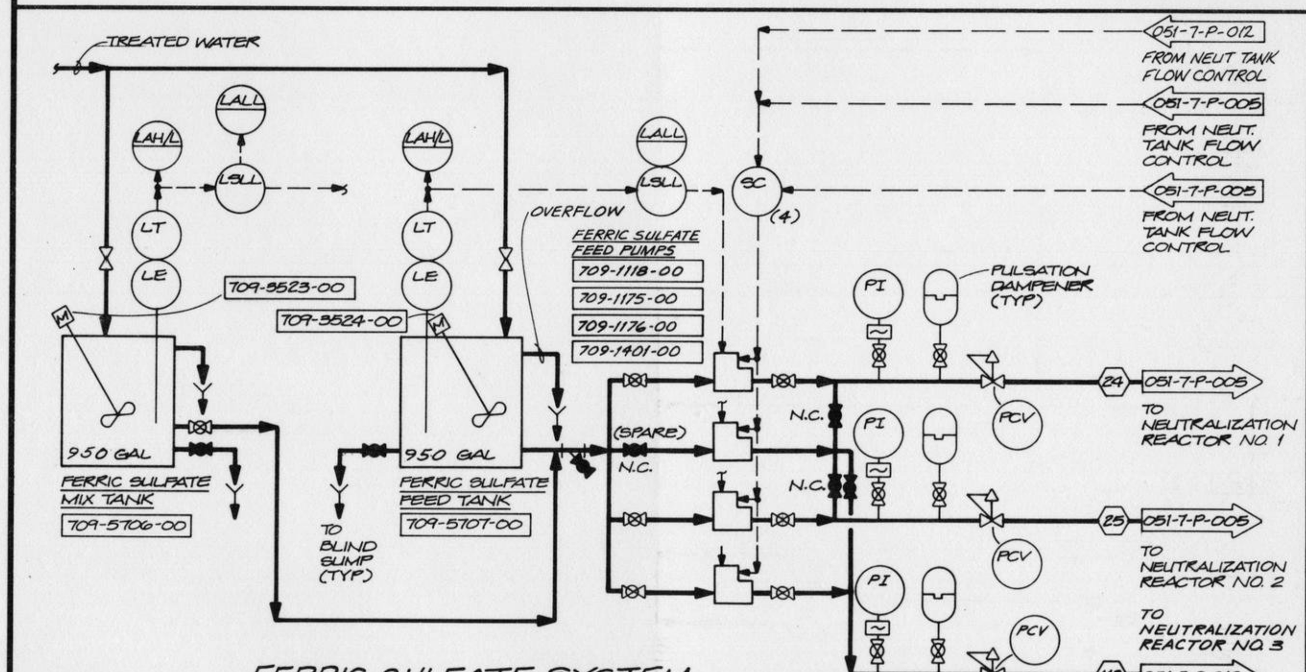


POLYMER SYSTEM

(VENDOR PACKAGE)

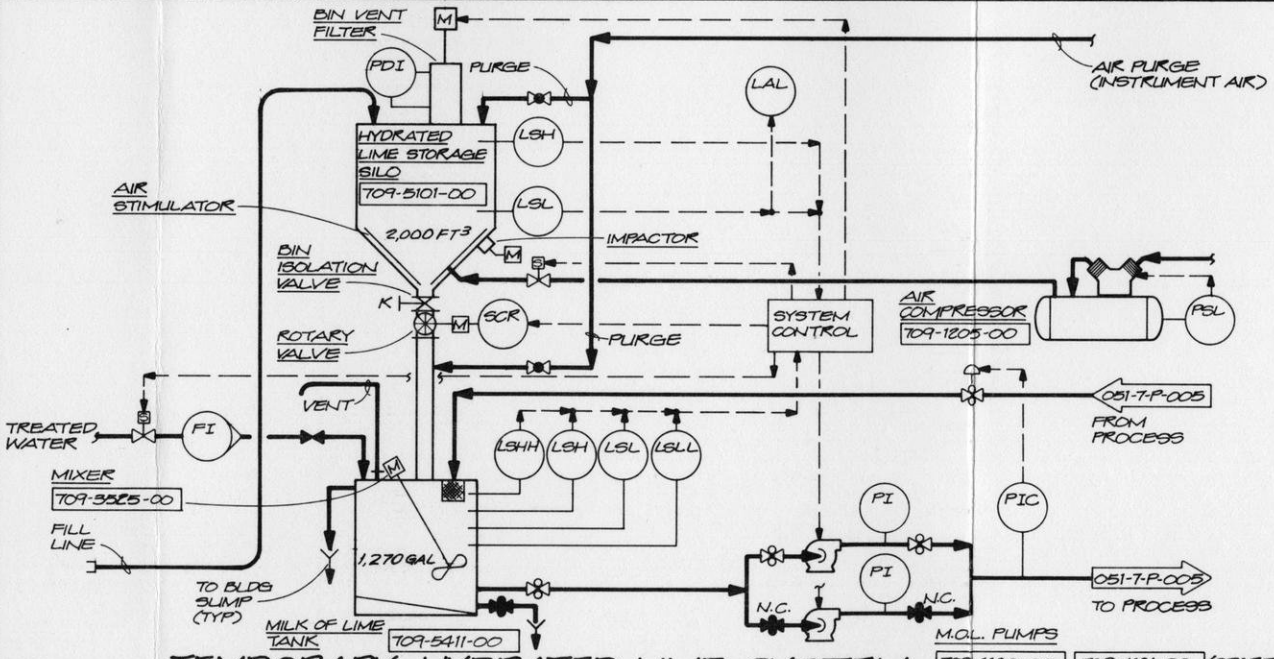


ACTIVATED CARBON SYSTEM



FERRIC SULFATE SYSTEM

(VENDOR PACKAGE)



TEMPORARY HYDRATED LIME SYSTEM

(VENDOR PACKAGE)

NOTES:

1. TANK CAPACITIES SHOWN ARE OPERATING CAPACITIES.
2. STANDARD PUMP INTERLOCKS AND PROTECTION NOT SHOWN.

REVISED	DATE	BY	DESCRIPTION
2	10/19/85	RRO	GENERAL REVISIONS
1	7/15/84	MRH	GENERAL REVISIONS

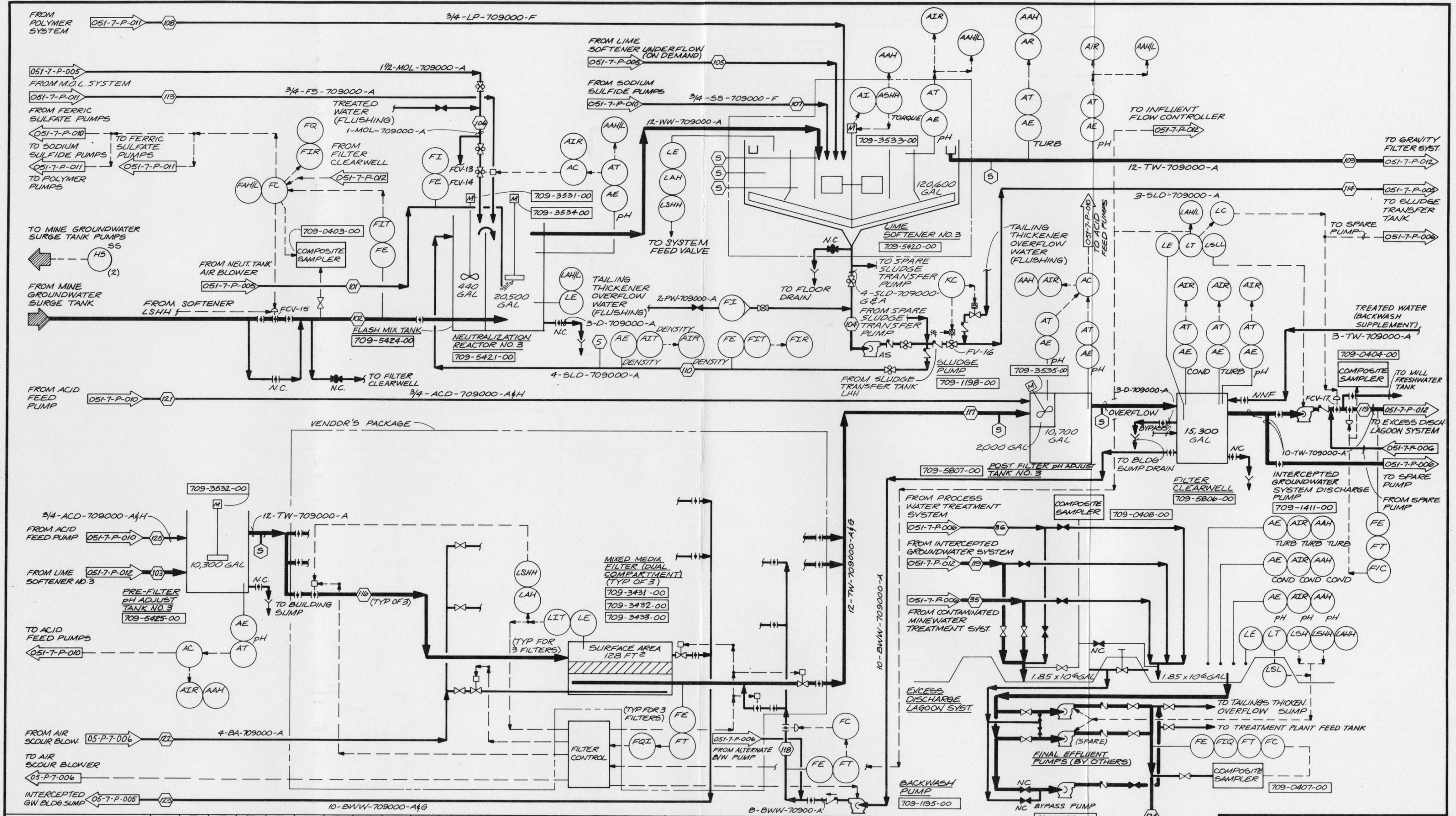
CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
PRELIMINARY
PIPING AND INSTRUMENTATION DIAGRAM
CHEMICAL FEED SYSTEMS

SCALE NONE	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY SWB	DATE 11-18-83	CHECKED BY MTI	DATE 11-18-83
APPROVED BY MND	DATE 11-18-83	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO. 051-7-P-011	**FIGURE 26**	SHEET ___ OF ___	REVISION NO. 2



STREAM NUMBER		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
FLOW, GPM		23 SCFM	350	351	71	0	0.58	0.57 GPH	2.1	0	70	NOT USED	NOT USED	0.08	0.58	NOT USED	117	351	960 AVG. 60	351	NOT USED	0.50 GPH	243 SCFM	960 AVG. 60	1,184	1.16 GPH
SOLIDS, LBS/HR											2091				18									10.9		
PRESSURE, PSI																										
TEMP °C (°F)	SUMMER WINTER		9 (48) 9 (48)																							
INTERMITTENT FLOWS	OCCURANCES/DAY DURATION (MIN)																		18 5				18 5	18 5		
pH																	8.3	8.3		7.0						

NOTES:
1. FLOW RATES SHOWN DO NOT INCLUDE ~60 gpm (AVG) COMPENSATION FOR FILTER BACKWASH
2. POLYMER FLOW RATE IS BASED ON 5PPM AT .1 PERCENT SOLUTION.

REVISED	DATE	BY	DESCRIPTION
1	10/18/85	FAE	GENERAL REVISIONS

CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY PIPING AND INSTRUMENTATION DIAGRAM
INTERCEPTED GROUNDWATER TREATMENT SYSTEM

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY MJL	DATE	CHECKED BY RRO		DATE 7-12-84	
APPROVED BY	DATE	APPROVED BY MRH		DATE 7-17-84	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO 051-7-P-012	FIGURE 27	SHEET ___ OF ___		REVISION NO 1	

The water treatment plant will be designed to provide maximum flexibility for alternative operational arrangements.

Based on the best available projections of effluent quality (see Section 6) the RO, VCE, brine softening, and brine crystallizer systems will not be required to meet discharge standards in effluent from the Contaminated Mine Water Treatment System. The systems will be installed and operational; however, if they are necessary to meet effluent discharge limitations during the mine development period.

FEED WATER TANKS

There are three feed water tanks for the water treatment facility, one for each treatment system: contaminated mine water, intercepted groundwater, and recycle water. These tanks were sized to provide 11, 8, and 7 hours, respectively, of feed water to the treatment plant at the design flowrate.

Contaminated Mine Water

Design Flow = 1,550 gpm
1,550 gpm x 660 minute = 1,023,000 gal operating volume
Tank size = 60 feet diameter by 55 feet high
(Allows 1-foot depth below discharge and 2 feet above overflow)
Total tank volume = 1,096,000 gal

Intercepted Groundwater

Design Flow = 1,000 gpm
1,000 gpm x 480 minute = 480,000 gal operating volume
Tank size = 43 feet diameter by 50 feet high
(Allows 1-foot depth below discharge and 2 feet above overflow)
Total tank volume = 500,000 gal

Recycle Water

Design flow = 1,200 gpm
1,200 gpm x 420 minute = 504,000 gal operating volume
Tank size = 43 feet diameter by 55 feet high
(Allows 1-foot depth below discharge and 2 feet above overflow)
Total tank volume = 540,000 gal

FLASH MIX AND NEUTRALIZATION REACTORS

Flash mixing and neutralization will be accomplished in separate reactors. In the Contaminated Mine Water and Intercepted Groundwater Treatment Systems these reactors will be sized based on the maximum expected flow rate of mine water entering the treatment systems. In the Recycle Water Treatment System, sizing will be based on the average expected flow rates under summer operation.

The flash mix reactors will be located immediately upstream from the neutralization compartment and will be designed to provide a 2-minute residence time for complete mixing of recycle sludge and Milk-of-Lime.

The neutralization reactors will be designed as completely mixed reactors and will be sized based on a hydraulic retention time of 20 minutes. This will provide an adequate residence time for flow equalization, pH adjustment, and oxidation of ferrous iron. Provisions will be made to add powdered activated carbon for organics control if necessary.

An air diffuser system will provide oxygen to the neutralization tanks for oxidation reactions.

For the Recycle Water Treatment System, crossover piping, valves, and controls will be provided upstream of the flash mix tank to allow automatic blending of a portion of the Contaminated Mine Water stream.

The three sets of flash mix and neutralization reactors will operate independent of each other in all respects.

Operating level in the flash mix and neutralization tanks should provide approximately 2 feet of freeboard and allow gravity flow to the softeners.

The details of the engineering calculation for the flash mix and neutralization reactors and all subsequent design calculations are presented in "Water Treatment Facility Revised Engineering Report Computations" (CH2M HILL, 1986).

Contaminated Mine Water System

Flash Mix Design Flow: (2 + 271) gpm (based on 1,550 gpm) = 273 gpm

Influent Design Flow: 1,265 gpm x 1.2 (design factor) = 1,550 gpm

Required Capacity: 2 min x 273 gpm = 546 gal (flash mix)
20 min x 1,550 gpm = 31,000 gal (neutralization)

Selected Tank Sizes:

Flash Mix: 5 ft diameter by 6 ft high, operating volume = 590 gal (operating level = 4.0 ft)

Neutralization: 18 ft diameter by 17.5 ft high, operating volume = 31,200 gal (operating level = 15.5 ft)

Recycle Water System

Flash Mix Design Flow: (1 + 210) gpm (based on flow of 1,200 gpm) = 211 gpm

Influent Design Flow: 1,000 gpm x 1.2 (design factor) = 1,200 gpm

Required Capacity: 2 min x 211 gpm = 422 gal (flash mix)
20 min x 1,200 gpm = 24,000 gal (neutralization)

Selected Tank Sizes:

Flash Mix: 5 ft diameter by 5 ft high, operating volume = 440 gal (operating level = 3.0 ft)

Neutralization: 16.5 ft diameter by 17.5 ft high, operating volume = 24,800 gal (operating level = 15.5 ft)

Intercepted Groundwater System

Flash Mix Design Flow: (2 + 200) gpm (based on flow of 1,000 gpm) = 202 gpm

Influent Design Flow: 850 gpm x 1.2 (design factor) = 1,000 gpm

Required Capacity: 2 min x 202 gpm = 404 gal (flash mix)
20 min x 1,000 gpm = 20,000 gal (neutralization)

Selected Tank Sizes:

Flash Mix: 5 ft diameter by 5 ft high, total volume = 440 gal (operating level = 3.0 ft)

Neutralization: 15 ft diameter by 17.5 ft high, operating volume = 20,500 gal (operating level = 15.5 ft)

NEUTRALIZATION TANK AIR BLOWER

Air sparging may be required to oxidize ferrous iron to ferric iron, which will then precipitate and be removed in the lime/sulfide or lime/soda softeners.

Air requirement: Assume that all iron is present as Fe^{+2} and that O_2 is also required to saturate the water. Additionally, assume that 20 percent of thiosulfate $(S_2O_3^{-2})$ present will be oxidized.

Fe^{+2}:

O_2 req'd =

$$\frac{[(0.653\ mg/L)(1{,}550\ gal/min)+(1.53\ mg/L)(1{,}200\ gal/min)+(0.71\ mg/L)(1{,}000\ gal/min)](3.785\ L/gal)(10^{-3}\ g/mg)}{(56\ g/mole\ Fe^{+2})\ (4\ moles\ Fe^{+2}/mole\ O_2)}$$

= 0.060 g-mole/min = 0.00013 lb-mole/min

$S_2O_3^{-2}$:

O_2 req'd =

$$\frac{[(85.3\ mg/L)(1{,}550\ gal/min)+(361\ mg/L)(1{,}200\ gal/min)+(0\ mg/L)(1{,}000\ gal/min)](3.785\ L/gal)(10^{-3}\ g/mg)(0.20)}{(112\ g/mole\ S_2O_3^{-2})\ (1\ mole\ S_2O_3^{-2}/2\ mole\ O_2)}$$

= 7.64 g-mole/min = 0.0168 lb-mole/min

O_2 for Saturation:

O_2 req'd =

$$\frac{(5\ mg/L\ req'd\ for\ saturation)\ ([1{,}550 + 1{,}200 + 1{,}000]\ gal/min)\ (3.785\ L/gal)\ (10^{-3}\ g/mg)}{32\ g/mole\ O_2}$$

= 2.22 g-mole/min = 0.0049 lb-mole/min

Total O_2 req'd =

$$(0.0013 + 0.0168 + 0.0049)\ lb\text{-}mole\ O_2/min \times \frac{359\ scfm}{lb\text{-}mole\ O_2} \times \frac{1}{0.21}\ \frac{mole\ air}{mole\ O_2} = 39\ scfm\ air$$

Assume ten times stoichiometric requirements = 390 scfm

Size: 8 psig at 390 scfm = 25 hp

LIME AND LIME-SODA SOFTENERS (REACTOR CLARIFIERS)

The lime/sulfide and lime-soda softening systems will be designed using three solids contact-type clarifiers. This type of unit combines rapid mixing, flocculation, sedimentation, and solids recycle in one piece of equipment. It has been assumed that complete clarifier/flocculator mechanisms will be purchased and installed in field-erected tanks. All units will operate independent of each other.

Contaminated Mine Water System:

Design Flow: 1,265 gpm x 1.2 (design factor) = 1,550 gpm

Clarification Area: 1,550 gpm ÷ 1 gpm/ft² = 1,550 ft²; requires 45-foot diameter unit. Select 46-foot diameter unit for residence time requirement.

Operating Volume: 2-hour residence time req'd. (186,500 gal). Use 15.00 ft operating water depth; 186,500 gal plus cone bottom.

Solids Loading to Clarifier = Sludge generation plus recycle solids = $(555 + 4{,}442)(\text{lb/hr})\left(\frac{1{,}265 \times 1.2}{845}\right)(24\ \text{hr/day}) =$

215,445 lb/d.

Solids Flux: $\frac{215{,}445}{1{,}662\ \text{ft}^2} = \frac{130\ \text{lb/d}}{\text{ft}^2}$

Sludge Consistency: Assume 6 percent solids (conservative, since 6-10 percent solids should be achieved with sludge recycle configuration)

Recycle Water System::

Design Flow: 1,000 gpm x 1.2 (design factor) = 1,200 gpm

Clarification Area: 1,200 gpm ÷ 1 gpm/ft² = 1,200 ft²; requires 40-foot diameter unit. Select 41-foot diameter unit for residence time requirement.

Operating Volume: 2-hour residence time req'd. (144,000 gal). Use 15.00 ft operating water depth; 148,100 gal plus cone bottom.

Solids Loading to Clarifier =
$(573 + 4{,}202)(\text{lb/hr})\left(\frac{1{,}000 \times 1.2}{800}\right)(24\ \text{hr/day}) =$

171,900 lb/d.

Solids Flux: $\frac{171{,}900}{1{,}320\ \text{ft}^2} = \frac{130\ \text{lb/d}}{\text{ft}^2}$

Intercepted Groundwater System:

Design Flow: 850 gpm x 1.2 (design factor) = 1,000 gpm

Clarification Area: 1,000 gpm x 1 gpm/ft² = 1,000 ft²; requires 36-foot diameter unit, select 37-foot unit for residence time requirement.

Operating Volume: 2-hour residence time req'd (120,000 gal). Use sidewater depth of 15.00 ft; 120,600 gal plus cone bottom.

Solids Loading to Clarifier:

$$(18 + 2{,}091)(\text{lb/hr})\left(\frac{850 \text{ x } 1.2}{350}\right)(24 \text{ hr/day}) =$$

147,509 lb/d.

Solids Flux: $$\frac{143{,}509 \text{ lb/d}}{1{,}075 \text{ ft}^2} = \frac{137 \text{ lb/d}}{\text{ft}^2}$$

SLUDGE PUMPS (LIME/SULFIDE AND LIME/SODA)

The sludge pumps will be designed for continuous operation. More than 85 percent of the pumped sludge will be returned to the flash mix tank, and the remaining sludge will be wasted to the sludge transfer tank on a timed cycle.

For normal operation, the Contaminated Mine Water, Recycle Water, and Intercepted Groundwater Systems will be equipped with 150 to 300 gpm, 150 to 300 gpm, and 70 to 200 gpm adjustable speed pumps, respectively. The adjustable speed 150 to 300 gpm recycle water pump will also be piped to the Contaminated Mine Water clarifier as a spare. A 200 gpm constant speed pump will be piped to the Recycle Water clarifier for use as required. The spare sludge transfer pump (discussed later) will spare the Intercepted Groundwater sludge pump.

Size: Maximum flow (Intercepted Groundwater System and Spare) = 200 gpm at 15 psig
At 65 percent efficiency, 2.7 BHP required; use 3 hp motor

Maximum flow (Recycle and Contaminated Mine Water Systems) = 300 gpm at 15 psig
At 65 percent efficiency, 4.0 BHP required; use 5 hp motor

SLUDGE TRANSFER TANK

A transfer tank will be provided to accumulate centrifuge wash water and batch sludge blowdowns from the lime/sulfide softeners, lime/soda softener, and brine softener and to provide enough surge to allow controlled sludge transfer to the tailings thickener underflow sump and line flushing.

This transfer tank arrangement will be provided to prevent sludge line plugging problems.

The lime/sulfide and lime/soda softeners are the primary sources of flow to the sludge transfer tank and will be blown down on a periodic basis. The sludge transfer tank will be of sufficient size to accumulate 1 hour of blowdowns from either clarifier unit at design flows.

Inflow: Contaminated Mine Water clarifier sludge =

$$18 \text{ gpm} \times \frac{1{,}265 \times 1.2}{845} = 33 \text{ gpm}$$

Recycle Water clarifier sludge =

$$19 \text{ gpm} \times \frac{1{,}000 \times 1.2}{800} = 29 \text{ gpm}$$

Intercepted Groundwater clarifier sludge =

$$0.6 \text{ gpm} \times \frac{850 \times 1.2}{350} = 1.7 \text{ gpm}$$

Size: Required tank size: 1 hr sludge volume from largest single source = 33 gpm x 60 min/hr = 1,980 gal. Select 8-foot diameter x 8-feet high (operating volume = 2,260 gal) coated steel, with mixer.

SLUDGE TRANSFER PUMPS

Two 300-gpm constant speed end-suction centrifugal, lined slurry pumps will be used to ensure adequate sludge transfer capacity to the tailing thickener underflow sump. Pump capacity will be based on the maximum instantaneous flow to the sludge transfer tank from any single lime/sulfide or lime/soda softener. Each pump will provide approximately 100 percent excess capacity under normal operating conditions. One pump will serve as an installed spare. The spare pump will also spare the Intercepted Groundwater Treatment system sludge pump. Automatic pump and discharge line flushing will be provided.

Size: Maximum flow = 300 gpm, at 20 psig.
At 65 percent efficiency, 5.4 BHP req'd; use 7.5-hp motor.

BUILDING SUMP

To avoid surging the softeners, filter backwashes and building drains will be returned to the system upstream of the neutralization reactors. Three pumped sumps will be provided to capture these streams and route them to the appropriate upstream surge tanks. To avoid cross-contamination and resulting problems in meeting discharge or recycle quality criteria, reclaim water will be isolated from contaminated mine water and intercepted groundwater throughout the plant. Floor drains and overflows will be routed to the recycle system sump.

Contaminated Mine Water System:

Sump Size: The sump holds 3 filter compartment backwash volumes (64 ft^2/filter compartment) x 15 gpm/ft^2 x 5 min = 4,800 gal

3 x 4,800 = 14,400 gallons.

At 12 ft deep; regular cross section = 15 ft x 14 ft (15,150 gal includes approximately 3 ft of freeboard and dead volume), coated concrete construction.

Recycle Water and Intercepted Groundwater Systems:

Sump Size: Each sump holds 2 filter compartment backwash volumes of 4,800 gallons.

2 x 4,800 = 9,600 gallons

At 12 ft deep, regular cross section = 15 ft x 10 ft (10,000 gal includes approximately 3 ft of freeboard), coated concrete construction.

BUILDING SUMP PUMPS

Vertical wet-pit centrifugal pumps will be provided in each compartment to transfer contents to the respective surge tank. All pumps will be specified as identical. A uninstalled spare will be provided for redundancy.

Size based on 1-1/2 filter backwash to be pumped out per 30 min:

$$\text{Pump} = \frac{1.5 \times 2 \times 4{,}800 \text{ (gal)}}{30 \text{ min}} = 480 \text{ gpm}$$

Select a 480-gpm pump at 50 psig, one per compartment. At 75 percent efficiency, 18.7 BHP req'd; use 20 hp motor.

PRE-FILTER pH ADJUST TANKS

Pre-filter neutralization with sulfuric acid will be provided, if needed, to avoid calcium carbonate deposition on the filter media. The tanks will be designed as completely mixed reactors at 10-minute residence time based on maximum expected flow rates.

Contaminated Mine Water System:

Size: 1,265 gpm x 10 min x 1.2 (design factor) = 15,180 gallons

Operating level, with 2-foot freeboard, must allow gravity flow from softeners.

Select Tank Sizes:

14 ft diameter by 16.5 ft high (operating volume = 16,700 gal), coated steel tank

Recycle Water System:

Size: 1,000 gpm x 10 min x 1.2 (design factor) = 12,000 gallons

Operating level, with 2-foot freeboard, must allow gravity flow from softeners.

Select Tank Size:

12 ft diameter by 16.5 ft high (operating volume = 12,300 gal), coated steel tank

Intercepted Groundwater System:

Size: 850 gpm x 10 min x 1.2 (design factor) = 10,200 gallons

Operating level, with 2-foot freeboard, must allow gravity flow from softeners.

Select Tank Size:

11 ft diameter by 16.5 ft high (operating volume = 10,300 gal), coated steel tank

MIXED-MEDIA FILTERS

Neutralized water will be gravity-filtered in parallel mixed-media filtration systems. The contaminated mine water filtration system will consist of 4 cells. The recycle water and intercepted groundwater systems will consist of 3 cells. Each filter cell will consist of two identical compartments. The number of filter cells represents an optimization between turndown capability and capital cost. Each filter system will be sized assuming a maximum hydraulic loading of 3.5 gpm/ft^2 with all cells in service. Dual media consisting of 18 inches of anthracite and 21 inches of silica sand will be used. This selection of media is common for all filters in the treatment systems. Each system of filters will be identical but will operate independently. A separate backwash water source will be provided to each system to avoid cross-contamination. A common air scour blower will be provided. Filter backwashing will be sequenced such that one filter compartment will be backwashed per cycle. Coated steel tanks will be used.

Typical media size for such dual media filters are as follows:

Material	Particle Diameter (mm)
Sand	0.45 - 0.55
Anthracite	0.9 - 1.1
Support Bed	0.8 - 1.2

Contaminated Mine Water System:

Size: 1,550 gpm ÷ 3.5 gpm/ft^2 ÷ 4 = 111 ft^2 per filter cell

Select 4 filters with 128 ft^2 (available as standard size). During backwash, with seven filter compartments online, hydraulic loading will be 3.5 gpm/ft^2. With one cell offline for repairs, hydraulic loading will be 4.0 gpm/ft^2.

Recycle Water Treatment System:

Size: 1,200 gpm ÷ 3.5 gpm/ft^2 ÷ 3 = 114 ft^2 per filter cell

Select three filters identical to those selected for the Contaminated Mine Water system. During backwash, with five filter compartments online, hydraulic loading will be 3.75 gpm/ft^2. With one cell offline for repairs, hydraulic loading will be 4.7 gpm/ft^2.

Intercepted Groundwater System:

Size: 1,000 gpm ÷ 3.5 gpm/ft^2 ÷ 3 = 95 ft^2 per filter cell

Select three filters identical to those selected for the other treatment systems. During backwash, with five filter compartments online, hydraulic loading will be 3.1 gpm/ft^2. With one cell offline for repairs, hydraulic loading will be 3.9 gpm/ft^2.

FILTER AIR SCOUR BLOWER

The blower will be a positive displacement type, common to all filters.

Size: $3.8\ \text{scfm/ft}^2 \times 64\ \text{ft}^2$ = 243 scfm at 10 psig = 20 hp

FILTER BACKWASH PUMPS

The filters will be backwashed with filter product water.

Horizontal, end-suction centrifugal type pumps will be provided to backwash the filters, one for each set of three or four filters.

Size: $15\ \text{gpm/ft}^2 \times 64\ \text{ft}^2$ = 960 gpm at 25 psig.

At 70 percent efficiency, 20 BHP req'd; use 25-hp motor.

POST-FILTER pH ADJUST TANKS AND FILTER CLEARWELLS

Post-filter neutralization with sulfuric acid will be provided to further reduce pH as required for discharge or reverse osmosis (RO) feedwater criteria. Effluent from the filters will flow by gravity into a concrete sump arrangement that will include neutralization tanks with mixing compartments and filter clearwells with filter backwash compartments (to provide water for filter backwashing), all constructed with common walls. The compartments will be connected in series and segregated for either discharge or RO feedwater service. Intermediate sluice gates between contaminated mine water and recycle water sides will be provided to allow common use if desired. Similarly, sluice gates will be provided between intercepted groundwater and contaminated mine water sides. A source of treated water will provide supplementary backwash water to the clearwell for startup and off-normal conditions.

Criteria:

- Two-minute mixing compartment followed by 8-minute neutralization tank for each stream to allow two-step feedback pH control for potentially unbuffered waters.
- Separate backwash compartments in clearwells to allow relatively constant level in surge tanks for feedback level control of softener inlet valves.
- Common wall construction
- Gravity flow
- Provide 2-foot freeboard

Contaminated Mine Water System:

Mixing Compartment Size: 2 minutes x 1,550 gpm = 3,100 gal. At 15 feet deep, regular cross section = 6 feet x 6 feet, operating volume = 3,500 gal.

Neutralization Compartment Size: 10 minutes (includes mix compartment residence time) x 1,550 gpm = 15,500 gallons. At 15 feet deep, cross section = 13 feet x 13 feet, operating volume = 16,400 gal.

Clearwell Surge Tank Size: 5 minutes x 1,550 gpm = 7,750 gal. At 15 feet deep, cross section = 7 feet x 13 feet, operating volume = 8,200 gal.

Clearwell Backwash Compartment Size: 4 filter compartment backwashes = 19,200 gallon. At 15 feet deep, cross section = 17 feet x 13 feet, operating volume = 19,800 gal.

Note: Surge tank and backwash compartment contain extra "dead" volume below pump suction lines.

With a 2-inch nozzle between the surge tank and backwash compartment to allow slow filling and emptying, the resulting rate of flow changes through the softener will be acceptable.

Recycle Water System:

Mixing Compartment Size: 2 minutes x 1,200 gpm = 2,400 gallons. At 15 feet deep, regular cross section = 5 feet x 5 feet, operating volume = 2,400 gal.

Neutralization Compartment Size: 10 minutes (includes mixing compartment residence time) x 1,200 gpm = 12,000 gallons. At 15 feet deep, regular cross section = 13 feet x 10 feet, operating volume = 12,600 gal.

Clearwell Surge Tank Size: 5 minutes x 1,200 gpm = 6,000 gal. At 15 feet deep, cross section = 7 feet x 10 feet, operating volume = 6,300 gal.

Clearwell Backwash Compartment Size: 3 filter compartment backwashes = 14,400 gallon. At 15 feet deep, cross section = 17 feet x 10 feet, operating volume = 15,300 gal.

Intercepted Groundwater System:

Mixing Compartment Size: 2 minutes x 1,000 gpm = 2,000 gallons. At 15 feet deep, regular cross section = 4.5 feet x 4.5 feet, operating volume = 2,000 gal.

Neutralization Compartment Size: 10 minutes (includes mixing compartment residence time) x 1,000 gpm = 10,000 gallons.

At 15 feet deep, regular cross section = 11 feet x 10 feet, operating volume = 10,700 gal.

Backwash Compartment Size: 3 filter compartment backwashes = 14,400 gallons. At 15 feet deep, regular cross section = 17 feet x 10 feet, operating volume = 15,300 gal.

INTERCEPTED GROUNDWATER DISCHARGE PUMPS

One-100 percent capacity pump will be provided to discharge the water to the excess discharge lagoon system. The spare pump on the RO low pressure pumping system will be used to spare this pump.

Pump Size: 1,000 gpm at 30 psig, at 70 percent efficiency, 25.0 BHP req'd; use 30-hp motor.

CRYSTALLIZER CONDENSER COOLING PUMPS

These pumps will allow use of RO feedwater for crystallizer condenser cooling and will permit recovery of enough heat from that unit to raise RO feedwater temperature approximately 4°F, thereby increasing RO flux rates. Two 100-percent capacity pumps will be provided.

Size: 255 gpm at 30 psig (sizing as required by vendor of crystallizer system).
At 70 percent efficiency, 6.4 BHP req'd; use 7.5-hp motor.

REVERSE OSMOSIS (RO) LOW PRESSURE FEED PUMPS

Water from the recycle water treatment system will be pumped to the reverse osmosis booster pumps. Two 100 percent capacity low pressure feed pumps will be provided to feed the four booster pumps. Because the number of RO modules online at any given time will vary, pumps will be variable speed end-suction centrifugal pumps.

Initially, filtered water from the Contaminated Mine Water Treatment system will be pumped to the Excess Discharge Lagoon System. A constant speed pump will be provided for this service. If installation of the second set of RO modules is required, the constant speed pump will be converted to a variable speed pump. The spare variable speed pump, described above, will also function as spare for this pump.

Motor requirements for both variable speed and constant speed are based on maximum flow rates.

Size: 265 to 1,200 gpm at 50 psig. At 70 percent efficiency, 50 BHP req'd; use 60-hp motor. Same motor size is required for the constant speed pump.

RO CARTRIDGE FILTERS

Four (expandable to seven) 100-percent capacity 10-micron cartridge filter vessels will precede the RO booster pumps to remove any particulates. The filter elements in these units are typically constructed of cotton fiber filter materials.

Size: 430 gpm, pressure drop = 3 psi clean, 15 psi dirty.

REVERSE OSMOSIS BOOSTER PUMPS

The RO modules will require relatively constant flow and will operate independently in parallel. Therefore, a one-to-one relationship between booster pumps and RO modules will be required. Horizontal split-case multistage centrifugal pumps will be used to provide a high degree of reliability. One installed common spare will be provided. Suction pressure requirement will be approximately 30 psig. Net applied pressure to RO modules at the end of 3 years life is 520 psig.

Size: See RO module sizing below, capacity required = 400 gpm at 550 psig for the original pumps and 430 gpm at 550 psig for the future pumps. (Note that RO low pressure pumps discharge to the suction of these pumps.) At 70 percent efficiency, 183 and 197 BHP req'd; use 200-hp motors.

REVERSE OSMOSIS MODULES

The (RO) system will consist of four modules (expandable to seven modules). Each of the original modules will be designed for a maximum feed rate capacity of 400 gpm. The future modules will be designed for 430 gpm if they prove to be necessary. Each module will be arranged with a 12:6:3 taper. The RO system will be operated to recover 80 percent of the feedwater as permeate. (With the design taper, recoveries of as high as 85 percent could be realized if water quality permits.) The remaining 20-percent reject (brine) stream will flow to the RO reject surge tank.

At this level of recovery, the dissolved solids concentration in the reject stream will be well below the solubility limits recommended by vendors and should not present any scaling or precipitation problems. However, as an added safety factor, 10 mg/L of sodium hexametaphosphate (SHMP) will be added to the feedwater to inhibit scale formation.

Membrane area requirements will be largely dictated by system temperature, pressure, and properties of the type of membrane actually selected during procurement. Above 95°F, most membranes experience unacceptable degradation by hydrolysis. The pressure limits on system components will be about

600 psi. Below these limits, membrane area requirements for RO systems operating at a given recovery on relatively low TDS waters (such as the reclaim/mine water blend) are strongly dependent on feedwater temperature. For these waters, a combination of temperature, feed water flow requirements, and membrane flux constraints will control membrane sizing.

Exxon projects that the lowest possible winter feedwater temperature to the Recycle Water Treatment System will be 4.4°C (40°F). In the proposed design, the RO feedwater will be warmed up with heat from the crystallizer condenser, raising the minimum winter temperature to 9°C (49°F). Heating the feedwater provides a capacity increase in the RO modules over that which could be realized with a 4.4°C feed. The corresponding projected minimum summer temperature to the RO system after heating is 22°C (72°F) which considerably reduces the applied pressure requirement per unit volume of permeate, or increased capacity at the same inlet pressure.

The RO system was sized for both winter and summer projected flowrates at, respectively, winter and summer projected feedwater temperatures.

The design capacity and module sizing of the RO system was cross checked against a number of potential and potential future operating modes:

Operating Mode	Approximate RO Influent Flow Rate, gpm[a]
1. Treatment of Contaminated Mine Water During Mine Development	150 gpm x 1.2 Design Factor = 180 gpm
2. Treatment of Contaminated Mine Water/Reclaim Water Blend During Mill Operation	995 gpm x 1.2 Design Factor = 1,194 gpm
3. Potential Future Treatment of Contaminated Mine Water	(1,265 - 190) gpm x 1.2 Design Factor = 1,290 gpm
4. Potential Future Treatment of all Contaminated Mine Water and Reclaim Water	(1,194 + 1,290) gpm = 2,484 gpm

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[a] Summer flowrates, which are the system's peak loads, are shown.

As a compromise among all of the potential operating modes, four 400 gpm-capacity RO modules will be installed and space will be left in the building for three additional 430 gpm modules.

This module sizing results in the following module availability:

Operating Mode	No. Modules Installed	On-Line Modules	Standby Modules
1. Treatment of Contaminated Mine Water During Mine Development	4.0 @ 400 gpm	0.50 @ 400 gpm	3.5 @ 400 gpm
2. Treatment of Contaminated Mine Water/Reclaim Water Blend During Mill Operation	4.0 @ 400 gpm	3.0 @ 400 gpm	1.0 @ 400 gpm
3. Potential Future Treatment of all Contaminated Mine Water and Reclaim Water	4.0 @ 400 gpm 3.0 @ 430 gpm	3.0 @ 400 gpm 3.0 @ 430 gpm	1.0 @ 400 gpm

The process will use spiral-wound membranes rather than hollow fine fiber. Spiral-wound membranes are considered to be less susceptible to fouling by influent collodial matter and particulates. The modules will be constructed to allow use of either cellulose acetate or polyamide membrane elements. Cellulose acetate membranes have been tentatively selected in preliminary design. Membrane selection will be examined in detailed engineering and performance testing of alternatives may be pursued after startup.

Size: Detailed sizing calculations by vendors are confidential. Preliminary design parameters are:

Maximum feedwater silt density index = 5
Operating pH range = 4 to 6.5
Maximum feedwater chlorine = 1 ppm
Salt rejection, initial = 98-99 percent
Salt rejection, final = 96-98 percent
Operating pressure, initial = 410 psig
Operating pressure, final = 520 psig
Taper = 12-6-3
Pressure vessels = 21 per module,
Recovery: Initial Modules = 80 percent
Future Modules = 85 percent

Membranes = 6 per vessel,

Skid size per module:

Initial Modules	Approx. 10 ft x 26 ft x 9 ft
Future Modules	Approx. 10 ft x 26 ft x 10 ft

Range of flow conditions per module (feed/permeate) at various operating pressures:

Initial Modules	At 9°C = 265.3/212.3 gpm
	At 22°C = 398/318.4 gpm
Future Modules	At 9°C = 430/363 gpm

At a given recovery and temperature, individual modules must be operated as relatively constant flow devices. Production increases of up to 10 percent per module can be achieved in the first year or two (assuming clean service) by simply increasing booster pump pressure. After a few years, however, the booster pumps probably will reach design pressure limits as a result of normal membrane compaction. To achieve further production increases, additional modules must be added.

Space has been provided in the building for three additional, modules to process an additional 1,290 gpm of feedwater if RO treatment of Contaminated Mine Water should ever become necessary (see Section 5.11).

RO CLEANING SYSTEM

An RO cleaning system will be provided to allow periodic batch treatment of the membranes with various chemicals for cleaning, flushing, long-term "pickling" (soaking), and short-term sterilization. Batch cleaning and flushing using mixtures of detergents, solvents, and acids (see Section 4.4) are typical practices in virtually all installations to remove the inevitable buildup of fine particulates that escape capture in pretreatment equipment. Membrane "pickling" with chemicals such as formaldehyde or sodium bisulfite is also typically done preceding long-term shutdowns. Continuous chlorination, as typically practiced for cellulose acetate RO systems, will not be possible for the Crandon treatment system because of the relatively large amount of chlorine-scavenging thiosulfate present in the RO feedwater. Therefore, shock chlorination will be required. Cleaning, pickling, and shock chlorination will be intermittent operations that should not interfere with one another and will all be sized based on the RO system volume. The nonmetallic and alloyed steel materials will be compatible with all solutions.

Solution tank size = system volume = 1,000 gallons
Solution transfer pump size = 265 gpm, 30-hp based on vendor requirements
Solution heater to heat tank contents 41°C in 2 hours = 150 kW

Solution cartridge filter size:
3 gpm/cartridge = 90 cartridges, 30 stacks, one filter vessel

REVERSE OSMOSIS PERMEATE TRANSFER TANK

An RO permeate tank will be installed to collect recovered waters. This tank will be installed during initial construction to collect water from four RO modules, one evaporator, and the crystallizer. A second tank would be installed in the future if an additional RO/VCE system is required. RO permeate tanks will be sized identically and will be piped and valved to handle flow from either RO/VCE system. A small amount of soda ash will be added to those tanks to buffer those relatively pure, alkalinity-deficient waters. The soda ash addition can also be used for pH adjustment of the RO permeate to meet pH requirements for discharge.

Maximum Influent flows:
RO permeate = 990 gpm x 1.2 design factor x 80 percent recovery = 950 gpm
Evaporator distillate = 197 gpm x 1.2 design factor x 95 percent = 225 gpm
Crystallizer condensate = 7.75 gpm x 1.2 design factor x 2 (future basis) = 19 gpm

Total = 1,194 gpm

Size: 3-minute residence time (to avoid excessive pump cycling) = 3,600 gal. Select 10-foot-diameter x 8-foot-high coated steel tank. (Same size tank will be adequate for future tank.)

REVERSE OSMOSIS PERMEATE TRANSFER PUMPS

Two 100 percent capacity pumps will be installed to transfer water to the mill treated/fresh water tank. The future permeate transfer tank contents would be discharged to the Excess Discharge Lagoon System with one additional and identical pump. One pump will spare both systems.

Size: 1,285 gpm (future basis) at 50 psig. At 70 percent efficiency, 54 BHP req'd; use 60-hp motor.

RO REJECT TANK

This tank will collect reject water from the RO modules and evaporator barometric condenser effluent and will provide surge capacity to decouple the RO system from the evaporator system. It will also be sized to handle maximum potential future flow including flows which would result from RO/VCE treatment of contaminated mine water.

Flows: Evaporator feed = 198 gpm x 1.2 = 238 gpm (Design Operation)

= 400 gpm x 1.2 = 480 gpm (Future)

Size: 12-hour residence time at design flow or 6 hours residence time in the future
238 gpm x 60 min x 12 hr = 171,000 gallons
480 gpm x 60 min x 6 hrs = 173,000 gallons
Select 36-foot diameter x 32-foot high coated steel tank = 228,000 gal (standard API tank size, also allows for freeboard and "dead" volume below pump suction). This meets both sizing criteria.

EVAPORATOR FEED PUMPS

Two 100 percent capacity pumps will be installed for the maximum design flow rate with one evaporator.

Size: 240 gpm at 30 psig. At 70-percent efficiency, 6 BHP req'd; use 7.5-hp motor.

EVAPORATOR SYSTEM

The evaporator system will recover approximately 95 percent of the water in the RO reject stream for mill reuse. The evaporator residue or brine stream will be pumped to the brine concentration system for further treatment.

It has been assumed that the entire evaporator system will be purchased and installed as a turnkey system. The system, with the exception of the evaporator feed pumps, acid feed pumps, and in-line mixers, will include all equipment and controls shown in Figure 23. All components included in the evaporator system will be sized by the vendor who designs and supplies the equipment (several vendors and configurations are available).

Because of the extremely high capital and operating cost of the evaporator, sizing of the unit is very important. As with the RO system (see previous discussion), various operating modes were considered in sizing the evaporator.

As a compromise among the sizing required for the various operating modes, a nominal 240 gpm-capacity evaporator (feed flowrate) will be installed and space will be left for a future evaporator of the same size. This sizing provides the following:

Operating Mode	No Evaporators Installed	Design[a] Influent Flow Rate (gpm)	Sizing Safety Factor
1. Treatment of Contaminated Mine Water During Mine Development Period	1	30	800%
2. Treatment of Contaminated Mine Water/ Reclaim Water Blend During Mill Operation	1	200	20%
3. Future Treatment of all Contaminated Mine Water and Reclaim Water	2	400	20%

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[a] Does not include 1.2 sizing factor.

The evaporator system will be designed to include a 240 gpm-capacity vapor compression falling-film-type evaporator sized to treat the RO reject stream. It is estimated that a maximum of 236 gpm of distillate and a minimum of 4 gpm of brine could be produced from each train. These values represent best estimates and could vary, depending on actual feedwater chemistry experienced during full scale operation and the configuration of the evaporator purchased. Distillate water quality has been estimated at 10 mg/L TDS. Brine water quality will be approximately 19-percent total solids and 18-percent dissolved solids. Only one evaporator will be required for the design condition. The second unit would be added if, at some future date, RO/VCE treatment of contaminated mine water becomes necessary.

The system will also include a boiler to provide steam for the barometric condenser, evaporator startup, and the crystallizer's brine heater. Steam condensate will be recovered from all users.

Size: Detailed calculations by vendor are confidential. Design parameters are:

Feed pH = 5.5 to 7.5
Vapor release velocity (avg.) = 4.2 fps
Weak side liquor temperature = 216°F
Strong side liquor temperature = 217°F
Heat transfer coefficient = 450 Btu/ft^2-hr-°F
Weak side boiling point rise = 2°F
Strong side boiling point rise = 10°F
Overall energy usage (max.) = 87 kWh/1000 gal. feed
Cyclone underflow = 30% TSS
Recovery = 95%
Distillate quality = 10 ppm TDS, maximum

During the short periods of time when the evaporator may be down for servicing, the recycle water treatment system can still be operated by pumping the reverse osmosis brine stream to the tailings pond via the tailings thickener underflow sump. There is sufficient excess reverse osmosis capacity to provide all of the high quality water required for mill operation. A higher dosage of scale inhibitor may be required during these periods of evaporator shutdown.

BRINE SOFTENER FEED TANK

This tank will be sized to accumulate batch brine blowdown from both the proposed and the potential future evaporators and will equalize feed to the brine softener.

Size: 9.8 gpm x 1.2 design factor x 2 evaporators = 24 gpm
100-minute residence time = 2,400 gallons
Select 8-foot-diameter x 8-foot-high coated steel tank.

BRINE SOFTENER FEED PUMPS

Two 100-percent capacity pumps will be used to provide constant flow and redundancy. Because these will be small pumps, they will be sized based on maximum potential future conditions (two-evaporators). They can be throttled back for normal operation without significant waste of energy.

Size: 9.8 gpm x 1.2 x 2 = 24 gpm at 10 psig.
At 60-percent efficiency 0.23 BHP req'd; use 0.5-hp motor.

BRINE SOFTENER

Crystallization for bulk sodium sulfate and thiosulfate salts will not be possible in the vapor compression evaporator because of unacceptable scale formation in the falling film section. Therefore, a brine concentration system will be required to dispose of brine wastes and recover these salts. The first step in this brine concentration system will consist of a brine softener for suspended solids removal and precipitation of impurities such as gypsum, calcium, silica and metals that would render the crystal products unsalable. Because of the high temperature (100°C), an insulated, covered steel tank will be required. Because the softener will be relatively inexpensive, it will be sized for the maximum potential future flow from two evaporators. The design of the clarifier assumes a solids flux limiting basis (100 ft^2/ton/day) instead of a rise-rate limitation. The major solids that were assumed to precipitate in the clarifier were: aluminum hydroxide, magnesium hydroxide, calcium carbonate, and silica.

Design future flow (two evaporator operation): 24 gpm (see calculations above)
Clarification area (very conservative): 24 gpm ÷ 0.25 gpm/ft^2 = 96 ft^2
Solids flux (very conservative): 2,701 lb/day x 100 ft^2/ton/day = 135 ft^2
Operating volume (very conservative): 3 hours residence time = 3,600 gallons
Minimum SWD: 8 feet
Solids flux and SWD dictate a 14-foot-diameter x 8-foot SWD unit
Sludge consistency = 3 to 7 percent solids

BRINE SOFTENER SLUDGE PUMPS

Two 100-percent capacity progressing cavity sludge pumps have been selected to transfer the mixture of crystals and hydrous floc in the brine softener sludge to the sludge transfer tank. It is assumed that one pump will operate 20 percent of the time (40 percent of the time if the future evaporator is installed). The average daily flow at design conditions is 2.7 gallons per minute.

Size: 13.7 gpm at 30 psig; 0.75-hp pump

BRINE CRYSTALLIZER SYSTEM

A forced circulation crystallizing evaporator will crystallize the brine into a 55-percent solids slurry consisting primarily of anhydrous sodium sulfate and sodium thiosulfate. A screen bowl centrifuge will dewater the slurry to a 80 to 95 percent solids cake. A 2-gpm washwater stream in the second stage of the centrifuge will be provided to remove readily soluble chloride from the centrifuge cake. Upon cooling, any water remaining in the cake will combine with sodium sulfate to form Glauber's salt ($Na_2SO_4 \cdot 10H_2O$). The resulting product will have no free water.

It has been assumed that the crystallizer system will be purchased and installed as a turnkey system. The system, with the exception of the brine softener, reagent feed pumps, and crystal storage bin, will be provided by the crystallizer supplier. All components included in the crystallizer system shown on Drawing 051-7-P-009 (Figure 24) will be sized by the vendor who designs and supplies the equipment. Final sizing of the crystallizer will depend on the performance guarantees obtained from the successful evaporator manufacturer. Procurement specifications for the crystallizer will be prepared sequentially, after selection of the evaporator to be installed. The design parameters given below are vendor supplied criteria for equipment in similar service. Pending receipt of final quotations from evaporator manufacturers, the crystallizer has been tentatively sized to receive a feed stream of 16 to 20 gpm.

Size: Detailed calculations by vendor are confidential. Design parameters are:

Feed pH = 5.5 to 7.5
Residence time (min.) = 37 min at 50% full
Vapor release velocity (avg.) = 2.3 fps
Heat transfer coefficient = 300 Btu/ft^2-hr-°F
Recovery (hydraulic basis) = 90% (nominal)
Distillate quality = 10 ppm TDS
Steam requirement = 9,500,000 Btu/hr

INSTRUMENT AIR RECEIVER

Instrument-quality air will be supplied to the building from the mill instrument air system. One hundred scfm at 100 psig will be required. A 25-minute receiver will be provided to dampen flow surges and provide for an orderly shutdown in case of main system failure.

SULFURIC ACID SYSTEM

Sulfuric Acid Tank

A vertical cylindrical steel tank with dished heads, supports, and a concrete containment sump will installed for sulfuric acid storage. A standard size acid storage tank has been selected.

Size: 10-foot diameter x 22 feet high (active volume = 9,700 gal). This tank will provide a 48-day supply at design consumption (204 gpd) and will feed all 16 proposed and future acid pumps.

Sulfuric Acid Pumps

Variable-speed, positive displacement, diaphragm metering pumps will be provided for all acid services, with Alloy-20 wetted parts and TFE diaphragm. These will be identical pumps, all with 0.5-hp motors.

SODA ASH SYSTEM

Soda Ash Tank

Soda ash solution will be prepared and mixed in the lime preparation building and transferred to this tank in the water treatment plant, from which it will be fed to the five users.

Size: 15.2 gpm x 8-hr x 60 min/hr = 7,296 gallons of 10 percent solution.
Use 10-foot diameter x 14.5 feet high coated steel tank, operating volume = 7,340 gal.

Soda Ash Feed Pumps

The lime-soda softeners and brine softener will use soda ash solution in the gpm range; the permeate transfer tank use will be in the gph range. Therefore, progressing cavity pumps will be provided for the first two uses and diaphragm pumps will be provided for the latter.

SHMP SYSTEM

SHMP Feed Tanks

Two identical mixed tanks are provided, each capable of making and holding a 2-day supply of 10-percent SHMP solution sufficient for six RO modules (i.e., proposed plus potential future).

Maximum Flow rate:
(400 gpm x 3) + (430 gpm x 3) = 2,490 gpm

Size: 2,490 gpm x 1,440 min/day x 10 ppm x 10^{-6} x 8.3 lb/gal = 298 lb pure SHMP/day = 359 gpd 10 percent SHMP solution; use two FRP tanks, 5-foot diameter x 7 feet high each, operating volume = 730 gal.

SHMP Feed Pumps

These pumps will be very similar to the sulfuric feed pumps except that 316SS wetted parts will be used.

POLYMER SYSTEM

Polymer Feed Tank

Two identical mix tanks will be provided, each capable of making and holding a 12-hour supply of 0.5 percent solution sufficient for feeding all four softeners at maximum feed rates.

Size for maximum dose of 5 ppm:

> (1,550 + 1,200 + 1,000 + 20) gpm x 5 ppm x 10^{-6} x 8.3 lb/gal = 0.16 lb/min polymer
> 0.16 lb/min ÷ 0.001 dilution ÷ 8.3 lb/gal = 19 gpm of 0.1 percent diluted polymer = 3.8 gpm of 0.5 percent diluted polymer.
> 12-hour supply of 0.5 percent diluted polymer = 2,713-gallon, use 7-foot diameter x 11 feet high (includes 1.5-foot freeboard) FRP tank (2,735 gallons).

Note: This will provide 2 day supply per tank at an average dose of 1.2 ppm polymer (2,735 gallons ÷ 0.90 gal/min (usage at 1.2 ppm) = 3,023 min = 2.1 days).

Polymer Pumps

A 5-gpm progressing cavity drum pump will transfer neat (as-received) polymer into the mix tanks. This pump will empty a 55-gallon drum in 11 minutes. Identical diaphragm metering pumps with a common spare will be provided for polymer feed to the lime and lime-soda softeners. Similar, smaller diaphragm metering pumps will feed polymer to the brine softener.

SODIUM SULFIDE SYSTEM

Sodium Sulfide Feed Tanks

Two identical feed tanks will be provided, each capable of making and holding a 24-hour supply of 5 percent solution sufficient for feeding all three softeners at maximum feed rates.

Size for maximum dosage of 5 ppm:

> (1,550 + 1,200 + 1,000) gpm x 5 ppm x 10^{-6} x 8.3 lb/gal = 0.16 lb/min sodium sulfide
> 0.16 lb/min ÷ 0.05 dilution ÷ 8.3 lb/gal = 0.37 gpm

24-hour supply of 5 percent diluted sodium sulfide = 540 gallons, use a 5-foot diameter x 7-foot high (730 gallon) cylindrical FRP tank.

(Note: This will provide over 5 days supply per tank at an average dosage of 1.2 ppm.)

Sodium Sulfide Feed Pumps

Variable speed positive displacement diaphram metering pumps with 316 ss wetted parts and FE diaphram will be used. These will be identical pumps with 0.5 hp motors.

ACTIVATED CARBON SYSTEM

The potential future activated carbon feed system will be designed to unload carbon from bulk containers, similar to those provided by ICI America, Inc. Since actual carbon needs and dosages will not be defined until plant startup, and will probably not actually be required, tank and pump sizes are based on rough assumptions.

Size: Nominal 2 gpm carbon slurry feed at 20 psig.
Tank sufficient for 6-hour supply.
Recirculation pump = 250 gpm; 15-hp per supplier's standard.

FERRIC SULFATE SYSTEM

Ferric Sulfate Mix Tank

Each ferric sulfate mix tank will be capable of holding a 12-hour supply of 10-percent ferric sulfate solution at maximum feed rates.

Size for maximum dose of 35 ppm:

$(1{,}550 + 1{,}200 + 1{,}000)$ gpm x 35 ppm x 10^{-6} x 8.3 lb/gal = 1.1 lb/min ferric sulfate
1.1 lb/min ÷ 0.1 dilution ÷ 8.3 lb/gal = 1.3 gpm of 10 percent solution
12-hour supply = 945-gallon, use 6-foot diameter x 6 feet high (includes 1.5-foot freeboard) FRP tanks (operating volume = 950 gal).

Note: This will provide a 1-day supply per tank at the average dose of 20 ppm.

Ferric Sulfate Pumps

These pumps will be selected and sized in a similar manner to the polymer feed pumps.

TEMPORARY HYDRATED LIME SYSTEM

A temporary lime supply will be needed for startup purposes during the mine development period before the mill milk-of-lime circuit is constructed and operating reliably. Hydrated lime will be used for handling convenience and to avoid the cost and operating difficulties associated with a temporary slaker. The system will be sized to provide lime to the contaminated mine water and intercepted groundwater lime/ lime-soda softeners at the maximum expected flowrates during the mine development period. Sizing will include a 20 percent contingency.

Hydrated Lime Storage Silo

Sized to handle a typical 20-ton truckload with silo 1/3 full = 30-ton silo.

Size: (30 x 2,000) lb ÷ 30 lb/ft^3 = 2,000 ft^3

This will provide over 2-weeks storage at design rates.

Milk-of-Lime Tank

Size: 8-hour storage at design rates.
(8 x 60) min x 2.1 gpm x 1.2 = 1,210 gallons.
Use 6-foot-diameter x 8 feet high (including 2-foot freeboard) carbon steel tank (1,270 gal).

MOL Pumps

A 25 gpm slurry pump (plus one 100 percent capacity spare) will be provided to maintain 4.5-fps velocity in the MOL piping.

Size: 25 gpm at 15 psig.
At 60-percent efficiency; 0.4 BHP required; use 0.5-hp motor.

EXCESS DISCHARGE LAGOON SYSTEM

Excess Discharge Lagoon

The Excess Discharge Lagoon System will be sized to provide 24-hour residence time at the maximum anticipated effluent discharge flow rates during mill operations. The two lagoons will operate in series.

Intercepted Groundwater Flow Rate = (850 gpm x 1.2) = 1,000 gpm
Contaminated Mine Water Flow Rate = (1,265 - 190 gpm) x 1.2 = 1,290 gpm

$$\text{24-hour volume} = (1{,}000 + 1{,}290)\ \frac{\text{gal}}{\text{min}} \times \frac{1{,}440\ \text{min}}{\text{day}} = 3.3 \times 10^{6}\ \text{gal}$$

Use two cells, with 1.65 million gallons capacity per cell

Size: 75 ft x 233 ft with 4 ft sidewater depth and 2:1 sloped bottom. Use concrete sidewalls and synthetic liner on pond bottom, installed in accordance with NR213 (see Figure 31).

Excess Discharge Lagoon Bypass Pump

Treated water failing to meet discharge quality will be routed from the excess discharge lagoon system to either the Contaminated Mine Water Treatment System feed tank or tailings thickener overflow sump. An end suction centrifugal pump will be provided for this purpose.

Size: 2,550 gpm at 20 psig. At 70-percent efficiency; 43 BHP req'd; use 50-hp motor.

5.4 UTILITY REQUIREMENTS AND CHEMICAL CONSUMPTION RATES

Daily chemical and utility consumption rates are shown in Table 5-2, broken down by treatment process. These rates are based on the design flows shown in the P&ID's (i.e., they do not include a 20 percent safety factor or allowance for future additional RO/VCE capacity and are based on 1,270 gpm of mine inflow). Connected power requirements are shown on the equipment data sheets (Section 5.9). The maximum projected total instrument air requirement is 100 scfm.

5.5 CONTROL PHILOSOPHY

The water treatment system is designed to operate with minimal operator attention. A central control console featuring CRT displays will be provided in the control room for monitoring system performance. It is assumed that key instrument readouts and alarms will be displayed in the mill control room as well.

The overall control system will be configured as a distributed-type system, with single-loop integrity and redundant data highways. Redundant CRT's in the control room will display all instrument readouts, process graphics, and alarms. Traditional control panels and annunciators will not be used.

The following paragraphs describe the key control features and alarm conditions of the treatment system.

Table 5-2
CHEMICAL AND UTILITY CONSUMPTION RATES

	Neutralization Reactors			Lime Soda Softeners			Prefilter & Post Filter pH Adjust & Pump Station			Media Filter			RO System	Evaporator System	Brine Softener	Crystallizer System	TOTALS
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3					
Chemicals[a,b,c,d,e]																	
Lime (90% CaO)	1,080	590	740												220		2,630
Soda Ash (98% Na_2CO_3)					12,100								100		500		12,700
Sulfuric Acid (93% H_2SO_4)							290	340	570				280	70		< 10	1,560
Ferric Sulfate ($Fe_2(SO_4)_3$)	220	200	100														520
Polymer[f]				15	15	5									<1		35
SHMP (100%)													100				100
Sodium Sulfide (Na_2S)				15		5											20
Activated Carbon (100%)																	Not Planned
RO Cleaning Solution (0.2% citric acid, 0.1% detergent, 0.01% NH_4OH)													280				280
Hypochlorite (1.5% NaOCl)													1.5				1.5
Gypsum ($CaSO_4$)														55 (seed)			55
Utilities																	
Electric Power (kW-h/day for process equipment, based on normal flows)	360	360	320	180	170	120	620	870	340	60	40	40	8,380	19,770	120	2,150	33,900
Natural Gas (cfd)														150		130,000	130,150
Instrument Air (scfm)																	100

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[a] Chemicals in pounds per day. Utilities as noted.

[b] Chemical and utility consumption rates based on average winter flow conditions.

[c] System No. 1 is the Contaminated Mine Water Treatment System.

[d] System No. 2 is the Recycle Water Treatment System.

[e] System No. 3 is the Intercepted Groundwater Treatment System.

[f] Mass balance computations in Figures 12 through 19 based on maximum polymer dose of 5 ppm, values shown here based on average polymer dose of 1.2 ppm.

INFLUENT FLOW

Intercepted groundwater, contaminated mine water and reclaim water will be pumped to the neutralization reactors from their respective tanks. Flows and blending will be controlled by cascaded level-to-flow loops which will use the levels in the respective filter clearwells to set the total influent flows to each side of the plant. Changes will be rate-limited to avoid upsetting the softeners. Once the initial blending operation is accomplished, contaminated mine water will be kept segregated from the reclaim water/contaminated mine water blend throughout the plant.

Assuming constant levels in their respective filter clearwells, contaminated mine water and intercepted groundwater influents to neutralization reactors Nos. 1 and 3 will be flow controlled directly. Similarly, the reclaim water/ contaminated mine water blend to neutralization reactor No. 2 will be flow controlled (but at a preset ratio). As any filter clearwell level changes, the set points for these flow controllers will be adjusted accordingly (on a rate-limited basis). The Recycle Water Treatment System will be designed to automatically treat enough water to satisfy the requirements of the low-pressure RO feed pump. The flow signal from each neutralization reactor influent stream will be used to pace soda ash, ferric sulfate, sodium sulfide, and polymer feeds to the respective softeners.

Influent flow to each of the three treatment systems will be automatically shut off by high water level in the softener.

NEUTRALIZATION REACTORS

The neutralization reactors will be constant-level tanks. Water will flow by gravity from the flash mix tank to the neutralization reactor and on to the lime/sulfide or lime-soda softeners. Ferric sulfate addition will be controlled in proportion to the influent water flow; lime addition will be pH controlled; recirculated sludge will be flow controlled; and air will be controlled manually. If activated carbon addition ever proves to be necessary, it will also be controlled manually.

LIME/SULFIDE AND LIME-SODA SOFTENERS AND SLUDGE HANDLING

These will be gravity-flow devices, which overflow into the prefilter pH adjust tanks. Soda ash, sodium sulfide, and polymer will be added to the centerwells on ratio flow control. The drive motor for each clarifier mechanism will be equipped with a torque indicator, high-torque alarm, and high-torque shutoff switch. pH and turbidity analyzers will monitor the softener effluents.

Sludge will be continuously recirculated on flow control, and sludge blowdown will be routed to the sludge transfer tank on an intermittent timed cycle. The density of the recycle stream will be measured, indicated, and recorded. Combined waste sludges will be pumped to the tailings thickener underflow sump in an on/off, level-controlled manner. Automatic pump and line flushes will be provided for all batch sludge transfers. High- and low-level alarms will be provided on the transfer tank.

If additional sludge is required to maintain optimum sludge settling properties in the Intercepted Groundwater Treatment System, the operator can manually waste sludge from the Contaminated Groundwater Treatment System to the centerwell of softener No. 3.

PREFILTER pH ADJUSTMENT

These tanks will also be gravity flow devices, the outflow will be distributed to the respective sets of filters. Sulfuric acid addition will be pH controlled.

MIXED MEDIA FILTERS

A microprocessor-based step sequencer will be provided for automatic filter backwash. The backwashing cycle for each filter cell will be initiated either by high water level in the filter, filter throughput since the last backwash, or on a timed cycle. High water level will activate a control valve at the filter inlet piping to shut off the flow to a filter cell. A low-level switch in the filter control system will prevent filter backwashing if the filter clearwell is empty. Each filter cell consists of two compartments. The compartments will be backwashed in sequence.

Air scouring and backwashing will be initiated automatically. Air flow will be set by a manual valve (adjustments will rarely be necessary); backwash will be flow controlled with slow opening valves.

Flow to each filter will be automatically shut off in the event of high-high water level in the filter.

POST-FILTER pH ADJUSTMENT AND CLEARWELL

Post filter pH adjustment will be controlled similarly to pre-filter pH adjustment. Because the titration curve will be steeper for the pH levels desired in the post-filter pH adjustment, separate mixing compartments will be provided to allow two-step feedback control.

Water will flow by gravity through the series of mixing, reaction, surge, and backwash compartments as described earlier in Section 5.3. Conductivity, pH and turbidity analyzers, and level controllers/alarms will be provided for each clearwell. Crystallizer condenser cooling water will be continuously withdrawn from the neutralization tank and returned to the clearwell of the Recycle Water Treatment System using manual flow control (adjustments will rarely be necessary).

EFFLUENT PUMPS, RO LOW-PRESSURE FEED PUMPS AND CARTRIDGE FILTERS

Water will flow through the plant by gravity up to this point. These pumps, to be located in the basement adjacent to the clearwell, will transfer the treated contaminated mine water and intercepted groundwater to the Excess Discharge Lagoon System and the treated reclaim water/contaminated mine water blend to the RO booster pumps via the cartridge filters. (Note that the contaminated mine water will be segregated from the reclaim water/contaminated mine water blend throughout the plant.)

Treated contaminated mine water and intercepted groundwater will be pumped to the Excess Discharge Lagoon System continuously paced by level control in the clearwell. If discharge requirements are less than design flows, the pump will be throttled automatically. The pumps will shut down automatically on low-low level in their respective clearwell.

The treated reclaim water/contaminated mine water blend will be pumped by a variable speed pump, through the cartridge filters to the RO booster pumps continuously. The RO booster pumps discharge will be pressure controlled, which will also act to adjust the speed of the RO low-pressure feed pump. This pump will be interlocked with its respective clearwell level. The 100-percent capacity spare pump will be interlocked with all three clearwell levels.

If RO treatment of contaminated mine water ever becomes necessary, a separate set of RO high pressure feed pumps would be installed to feed a separate RO train for this system.

Soda ash and SHMP addition will be flow paced with the RO feedwater flow. Sulfuric acid will be added on pH control. The cartridge filters will be operated manually. High differential pressure alarms will alert the operator to change filter cartridges.

REVERSE OSMOSIS (RO) SYSTEM

To protect the RO system, conductivity, temperature, and turbidity of the feedwater will be monitored. High conductivity will be alarmed. High turbidity in the feed stream will shut off flow to the system.

Flow to the individual RO modules will be controlled from the central control system. Individual flow control valves on the feed stream to each module will be adjusted to the desired operating pressure. The product water recovery rate from each module will be controlled by the ratio of the reject and feed stream flows. High conductivity in the reject or product water streams will be alarmed.

If RO treatment of contaminated mine water ever becomes necessary, a separate RO train would be installed for this system.

RO CLEANING SYSTEM

This will be a batch operation that will be conducted on a once-per-week to once-per-month frequency for each RO module. Controls will all be manual. Flow, temperature, level, and and pressure indicators will be provided. Actual cleaning frequency will be determined through operating experience.

RO PERMEATE TRANSFER

Water recovered from the RO, evaporator, and crystallizer systems will be accumulated in the RO permeate transfer tank and pumped to the mill treated/fresh water tank by on/off level control. A manual bypass will be provided to divert this water to the excess water discharge tank, as necessary.

If RO treatment of contaminated mine water ever becomes necessary a second RO permeate tank would be installed to receive RO-treated contaminated mine water. Water collected in the future tank would be pumped to the Excess Discharge Lagoon System on ON/OFF level control.

EVAPORATOR SYSTEM

The evaporator system, including all instrumentation and controls, will be supplied as a complete package. All control functions will be designed by the manufacturer and will be compatible with the plant distributed control system and CRT displays.

The evaporator feed will be accumulated in the RO reject tank and pumped through the feed preheater to the evaporator deaerator on flow control. Sulfuric acid will be added to the feedwater using a combination of flow and pH control, in which the flow signal will be used to adjust acid feed pump speed and the pH signal will be used to adjust pump stroke. The deaerated feed will be pumped through the feed heater on level control and will enter the primary evaporator recirculation loop, which will operate continuously.

Evaporator distillate will flow by gravity from the condenser shell to the distillate surge tank, from which it will be pumped on level control through the feed heater and feed preheater to the RO permeate transfer tank. A slipstream bypassing the feed heater will be controlled to maintain desired deaerator feed temperature. Another slipstream will be routed to the de-mister spray system on a timed cycle. Distillate conductivity will be monitored continuously.

Concentrated brine slurry will be continuously blown down from the secondary recirculation loop on evaporator level control via a hydrocyclone. This system will ensure that a sufficient solids inventory in the evaporator will be maintained for scale control. Hydrocyclone underflow will be routed to the seed tank, from which it will be pumped back to the evaporator (via the shear mixer) on level control. Hydrocyclone overflow will be routed to the brine softener feed tank, which will also be pumped out on level control.

The startup boiler will be provided with its own packaged control system to regulate gas firing and steam pressure. Steam flow to users will be flow controlled (via ejector size and condenser steam rate). A slipstream will be routed to the barometric condenser from the feed pumps on flow control.

Evaporator throughput will primarily be controlled by manually adjusting the compressor inlet guide vanes. A pressure-controlled discharge-to-suction bypass will provide trim control. Pressure, temperature, vibration, level, and density indicators, recorders, and alarms and pump interlocks will be provided per manufacturer's standard.

The future evaporator, if ever necessary, would be designed similarly.

BRINE SOFTENER

The brine softener will be a gravity-flow device, operated and controlled similarly to the lime-soda softener. Soda ash and polymer additions will be paced to the feed flow rates and sludge will be pumped batch-wise to the sludge transfer tank.

CRYSTALLIZER SYSTEM

The brine crystallizer system, including all instrumentation and control, will be supplied as a complete package. All control functions will be designed by the manufacturer and will be compatible with the plant distributed control system.

The brine softener will overflow by gravity to the crystallizer feed tank. Sulfuric acid will be added on pH control, and the neutralized feedwater will be pumped to the crystallizer recirculation loop on tank level control.

Crystallizer pressure will be maintained by controlled venting of noncondensibles. Vapors will be condensed and accumulated in the vapor condensate tank and pumped to the permeate transfer tank on level control. Condensate conductivity will be recorded and alarmed.

A portion of the brine slurry will be pumped to the centrifuge on crystallizer level control. Mother liquor will flow back to the crystallizer feed tank by gravity, and the wet crystals will drop into the storage bin. Cake wash water will be added continuously by manual flow control, and the resulting contaminated wash water will flow to the sludge transfer tank by gravity.

Steam to the feed heater will be flow controlled. (The crystallizer level controller will be used to adjust the steam flow controller set point so that the crystallizer system can handle evaporator blowdown over a wide flow range.) The resulting condensate will be accumulated in the steam condensate tank and pumped back to the boiler on level control. Pressure, temperature, vibration, level, and density instruments and pump interlocks will be provided per manufacturer's standard.

SULFURIC ACID FEED SYSTEM

The 14 (16 in future) acid feed pumps (eleven different services) will all draw acid from the sulfuric acid storage tank and discharge to their respective users. Each pump will be pH controlled via an SCR drive. Automatic stroke control will also be provided for the pumps associated with the RO and evaporator systems to allow two-step control on these alkalinity-deficient waters. Pulsation dampeners and back pressure control valves will be provided on each discharge line, and low-level shutoff protection will be provided for each pump.

SODA ASH SYSTEM

The seven (eight in future) soda ash pumps (five services) will all draw soda ash solution from the soda ash tank. Each pump will be flow paced using an SCR drive. Pulsation dampeners and back pressure control will be provided for the diaphragm pumps; low-level shutoff protection will be provided for each pump.

SHMP SYSTEM

A skid-mounted prepackaged system (including controls) will be provided for SHMP mixing and feeding. SHMP will be flow paced to the RO feedwater using an SCR drive. Pulsation dampeners and back pressure control will be provided. The tanks will serve as mix and day tanks. SHMP makeup and switching between tanks will be manual. Low-level alarms and low-level shutoff protection will be provided for each tank and pump. Space will be provided in the skid for a future SHMP pump for the future RO system.

FERRIC SULFATE SYSTEM

The ferric sulfate system will be a skid-mounted packaged unit very much like the SHMP system, except that there will be three users instead of two and there will be an additional common spare pump for redundancy.

SODIUM SULFIDE SYSTEM

The sodium sulfide system will also be a skid mounted package (complete with controls). Pump controls will be similar to previously described systems. Two operating pumps and one standby pump will be provided. The standby pump will be piped to provide sodium sulfide feed to lime/soda softener No. 2, which does not normally use sodium sulfide, but possibly could under alternate operation modes.

POLYMER SYSTEM

The polymer system will also be a skid-mounted package (complete with controls) much like the SHMP and ferric sulfate systems. Pump controls and protection will also be similar. Treated water will be added automatically to the discharge lines at preset rates when the pumps operate.

TEMPORARY HYDRATED LIME SYSTEM

The temporary hydrated lime system will also be a packaged unit, including system controls. Silo filling will be a manual operation using the delivery truck's pneumatic conveying system. The bin vent bag filter will operate automatically. Silo high- and low-level alarms will be provided. A low-level switch in the MOL tank will activate the fill cycle, during which the bin air stimulator, rotary valve, and treated water makeup will all operate automatically at preset rates until high level is reached. High- and low-level alarms will also be provided. The MOL feed line will operate as a long recycle loop to maintain minimum line velocities and minimize scaling. MOL feed will be withdrawn at the points of use via pH-controlled pinch valves.

ACTIVATED CARBON SYSTEM

Because the actual need for carbon and dosage requirements are unknown, the activated carbon system is shown on the drawings as a manual operation at this time. Low-level shutoff protection will be provided for the feed pump.

BUILDING SUMP

The building sump pumps will operate automatically in an on/off mode based on sump level. High-level alarms will be provided.

5.6 BUILDING LAYOUT AND ARRANGEMENT

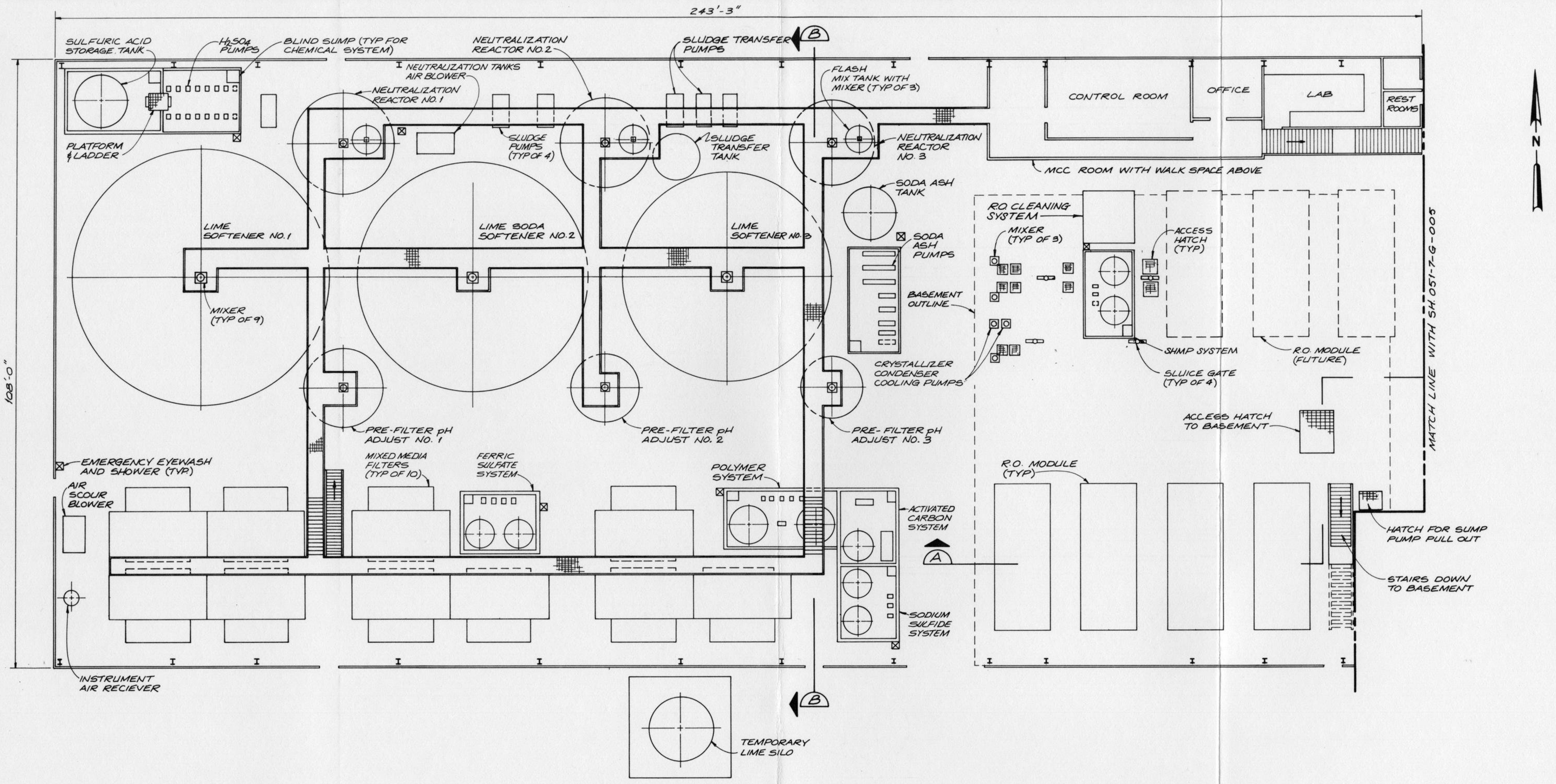
The water treatment plant building will be located between the lime plant and the plant water tank and will be oriented in an east-west direction. Figures 28, 29 and 30 (Drawings 051-7-G-004 and -005, and -006) show the general arrangement of equipment in the water treatment building. All water treatment system equipment shown on the P&ID's will be located within the building, except as noted below:

- The vapor compression evaporator will be located immediately adjacent to and east of the building. The future evaporator, if ever necessary, will be located similarly.
- The RO reject tank will be located approximately 40 feet to the east of the building.
- The temporary lime silo will be located immediately adjacent to and south of the building.

Equipment will be situated such that influent water enters on the north side of the west end of the building and flows roughly north to south through the softening and filtration processes. Water treated in the RO/VCE processes will be pumped from west to east through the rest of the building. Most chemical feed systems will be located in a common area along an aisle near the center of the building, close to the point of supply and as close as possible to the point of use, to minimize operator travel. Because the H_2SO_4 tank will be large, and would restrict line-of-sight if located centrally, it will be positioned in the northwest corner of the building. The SHMP and RO cleaning systems will be located near the RO system (along the south wall of the motor control center). The control room, lab, and MCC will be clustered together in the middle of the building to maximize operator access to equipment and minimize cable run length. The control room will be positioned on top of the MCC to provide operator line-of-sight to the entire treatment building. An elevated walkway from the control room will provide operator access to all tanks in the softening and filtration systems.

Most of the valves, pumps, vessels, and tanks associated with the RO system will be located in a basement area between the filter clearwells and the building sump to minimize noise in the upper floor and conserve building area and plot space. An access hatch will be provided to remove this equipment for maintenance.

Figure 31 (Drawing 051-7-G-007) shows a conceptual design of the Excess Discharge Lagoon System, which will be located immediately east of the tailings thickener.



FLOOR PLAN

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING.
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1	10.18.85	MRH	GENERAL REVISIONS
REVISED	DATE	BY	DESCRIPTION

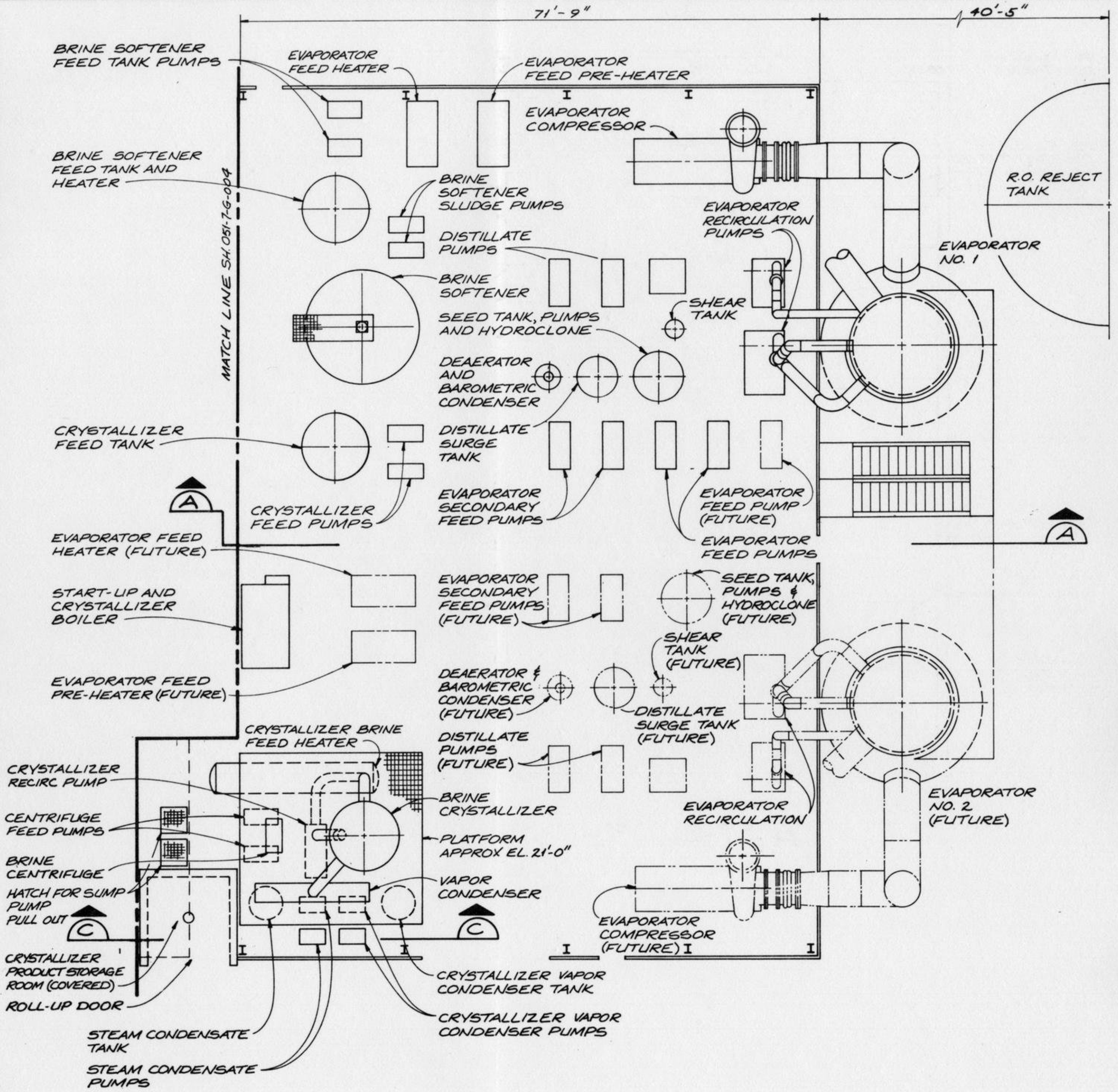
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

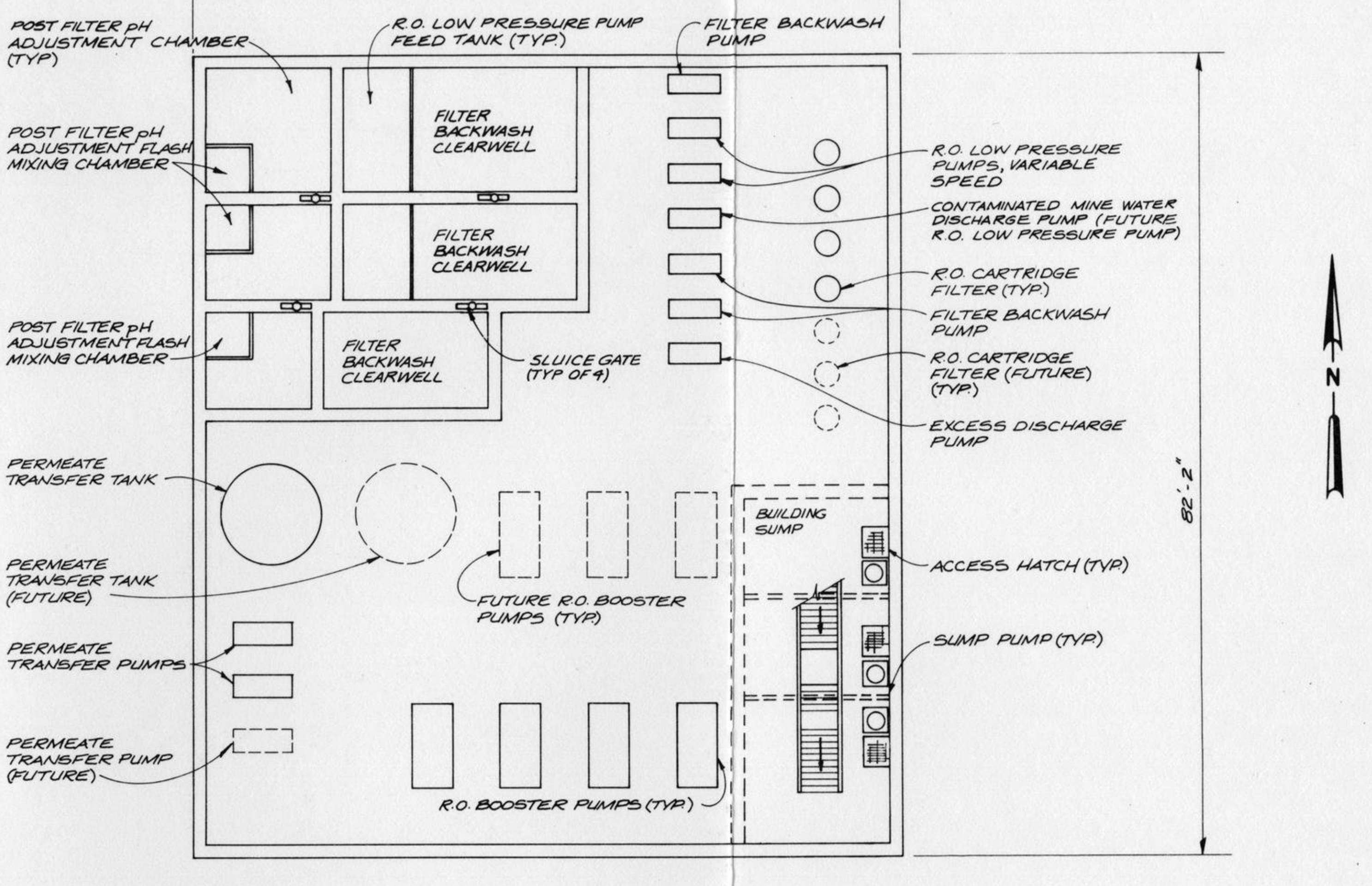
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY GENERAL ARRANGEMENT

GENERAL ARRANGEMENT

SCALE 1:100	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY MJL	DATE 7-16-84	CHECKED BY MTI		DATE 7-17-84	
APPROVED BY	DATE	APPROVED BY MRH		DATE 7-18-84	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO 051-7-G-004	FIGURE 28	SHEET OF		REVISION NO. 1	





BASEMENT PLAN

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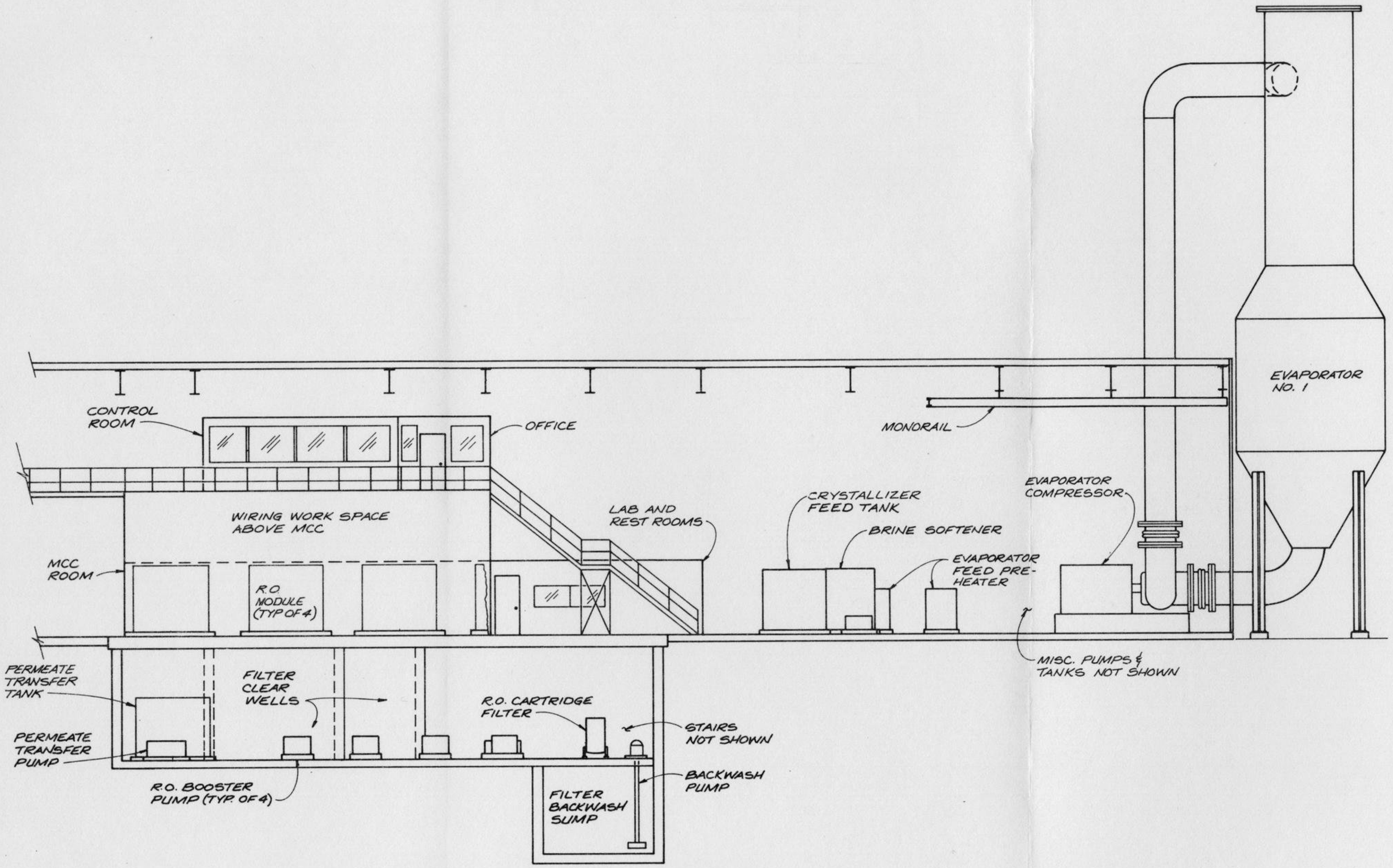
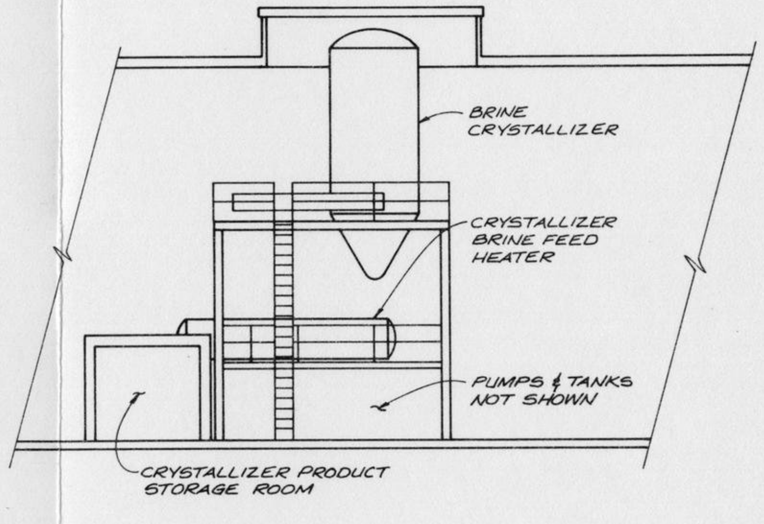
TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

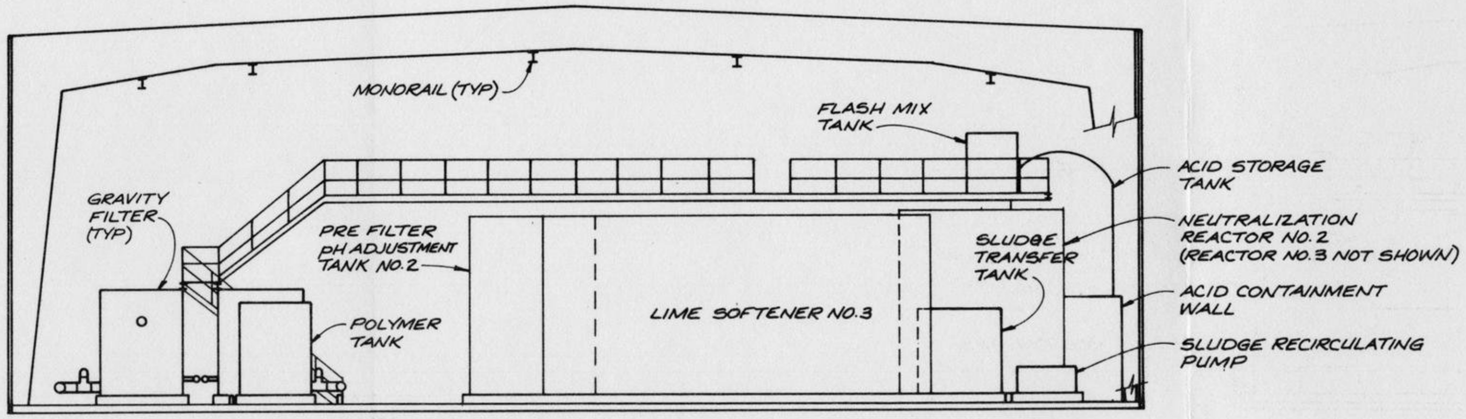
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
PRELIMINARY
GENERAL ARRANGEMENT
GENERAL ARRANGEMENT
SCALE 1:100 STATE WISCONSIN COUNTY FOREST
DRAWN BY MJL DATE 7-15-84 CHECKED BY MTI DATE 7-17-84
APPROVED BY DATE APPROVED BY MRH DATE 7-18-84
APPROVED BY DATE EXXON DATE
DRAWING NO 051-7-G-005 **FIGURE 29** SHEET OF REVISION NO 1



SECTION (A)



SECTION (C)



SECTION (B)

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TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
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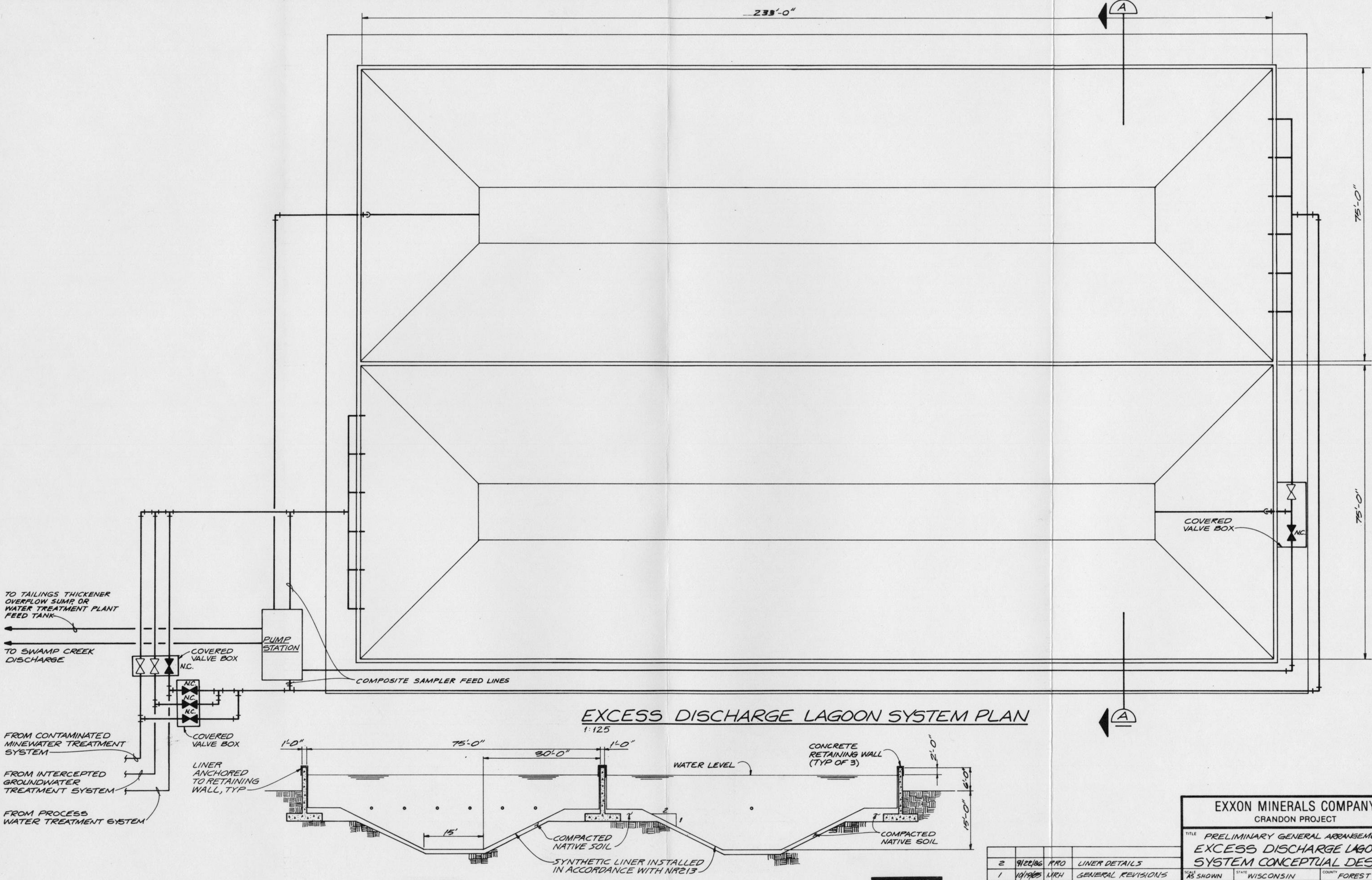
TITLE
PRELIMINARY
GENERAL ARRANGEMENT
SECTIONS

SCALE 1:100	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY MJL	DATE 7-17-84	CHECKED BY MTI		DATE 7-18-84	
APPROVED BY	DATE	APPROVED BY MRH		DATE 7-18-84	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO 051-7-G-006	**FIGURE 30**	SHEET OF		REVISION NO 1	



EXCESS DISCHARGE LAGOON SYSTEM PLAN
1:125

SECTION (A)
1:125

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REVISED	DATE	BY	DESCRIPTION
2	9/22/86	RRO	LINER DETAILS
1	10/19/85	MRH	GENERAL REVISIONS

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY GENERAL ARRANGEMENT
EXCESS DISCHARGE LAGOON
SYSTEM CONCEPTUAL DESIGN

SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY MJL
DATE 7/15/84
CHECKED BY MRH
DATE 7-15-84
APPROVED BY
DATE
APPROVED BY MRH
DATE 7-18-84
APPROVED BY
DATE
EXXON
DATE
DRAWING NO 051-7-G-007
FIGURE 31
SHEET
OF
REVISION NO 1

Figures 32 and 33 (Drawings 051-7-A-003 and -004 show the architectural plan and elevations of the building. The building will be a standard metal frame structure with insulated walls and roof. Overall building area, including basement, will be approximately 34,000 feet^2.

To facilitate maintenance on large equipment items, five one-ton monorails will be located above the neutralization reactors, lime and lime-soda softeners, prefilter neutralization tanks and filters, and a 5-ton monorail will be located above the evaporator area. Lifting eyes will be located above other individual pieces of equipment as needed.

The water treatment building will be heated to a minimum of 50 to 60°F year-round. Air conditioning will not be required during summer months. The building's control room, office, and laboratory will have additional heating for operator comfort. During final design of the building, air conditioning should be considered in these areas.

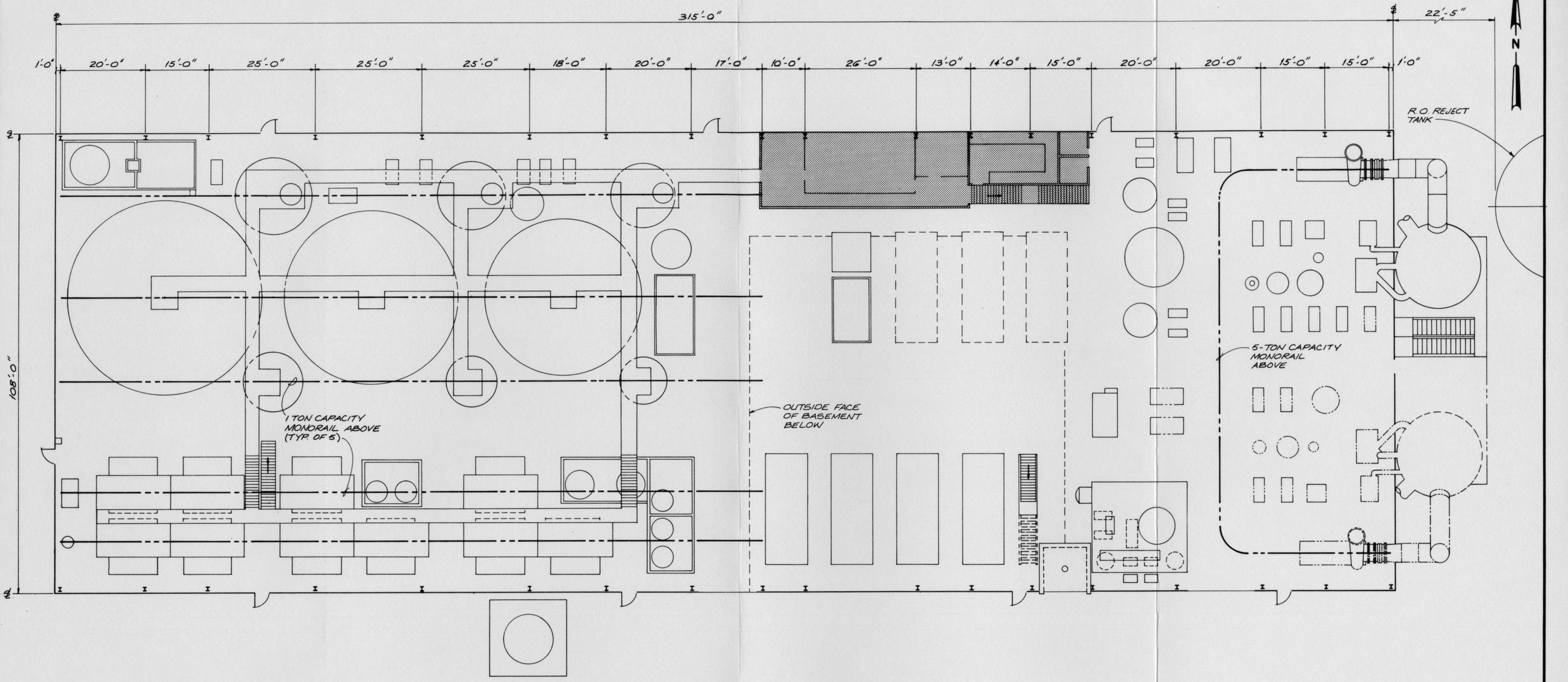
The building will be provided with toilet facilities, hot and cold running water, and safety showers. A laboratory area will be included in the layout and will be equipped to run routine process control tests and other compliance monitoring tests that are not done elsewhere. The laboratory sink drain will be routed to the neutralization reactor of the Recycle Water Treatment System. Toilet drains will be routed to the sanitary wastewater treatment facility.

5.7 HYDRAULIC PROFILE

Figure 34 (Drawing 051-7-L-001) presents a preliminary hydraulic profile for the main streams through the plant at design rates. Water will flow by gravity through the flash mix tanks, neutralization reactors, lime and lime-soda softeners, prefilter pH adjust tanks, dual-media filters, and post-filter pH adjust tanks and clearwells. Treated intercepted groundwater and contaminated mine water will be pumped from their respective filter clearwells to the Excess Discharge Lagoon System. The treated reclaim water/contaminated mine water blend will be pumped from its filter clearwell to the RO plant. RO permeate will be pumped to reuse; RO reject will be pumped to the evaporator system. Evaporator distillate will be pumped to reuse; evaporator brine will be pumped to the brine softener, from which it will flow by gravity to the crystallizer system. Crystallizer feed and products will all be pumped. Building drains and filter backwash will flow by gravity to the building sumps, from which they will be pumped back to their respective surge tanks for reprocessing.

5.8 ELECTRICAL SYSTEM

The overall system will be supplied from the local electric



FLOOR PLAN

NOTES:
1. $\mathbb{S}$ - STRUCTURAL LINE (THE EXTERIOR FACE OF THE STRUCTURALS TO WHICH THE PANELS ATTACH)

2. SHADED AREAS SHOWN NOT SUPPLIED BY PREFABRICATED METAL BLDG. MFR.

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1	10-1985	MRH	GENERAL REVISIONS
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TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY ARCHITECTURAL FLOOR PLAN

SCALE 1:125	STATE WISCONSIN		COUNTY FOREST		
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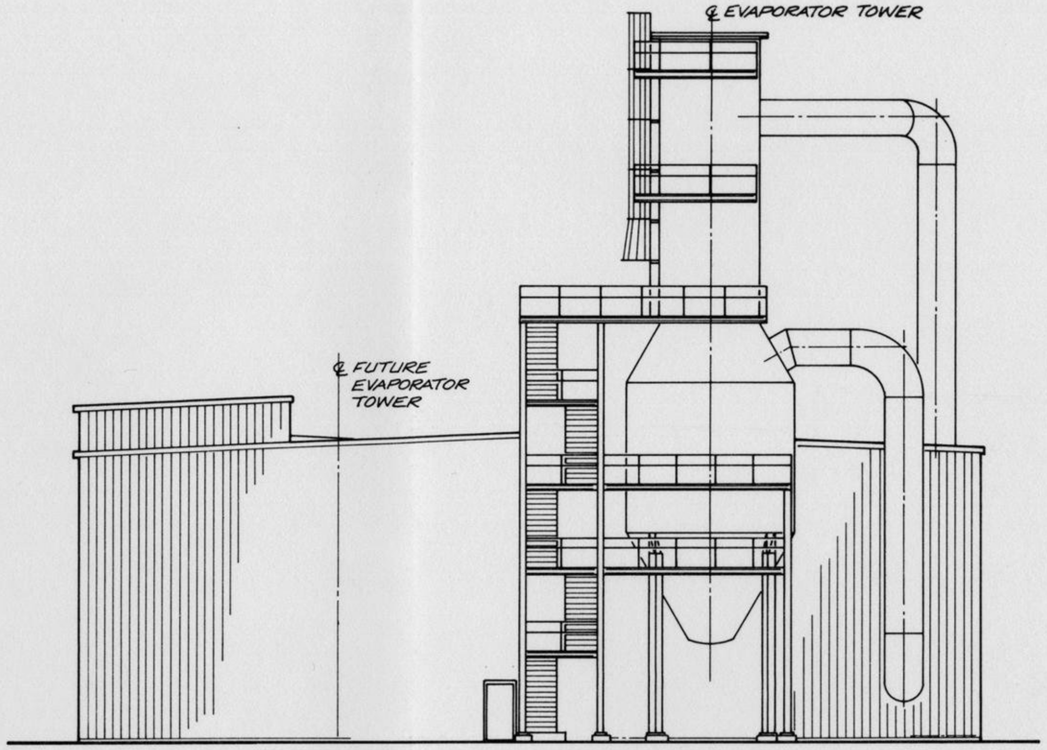
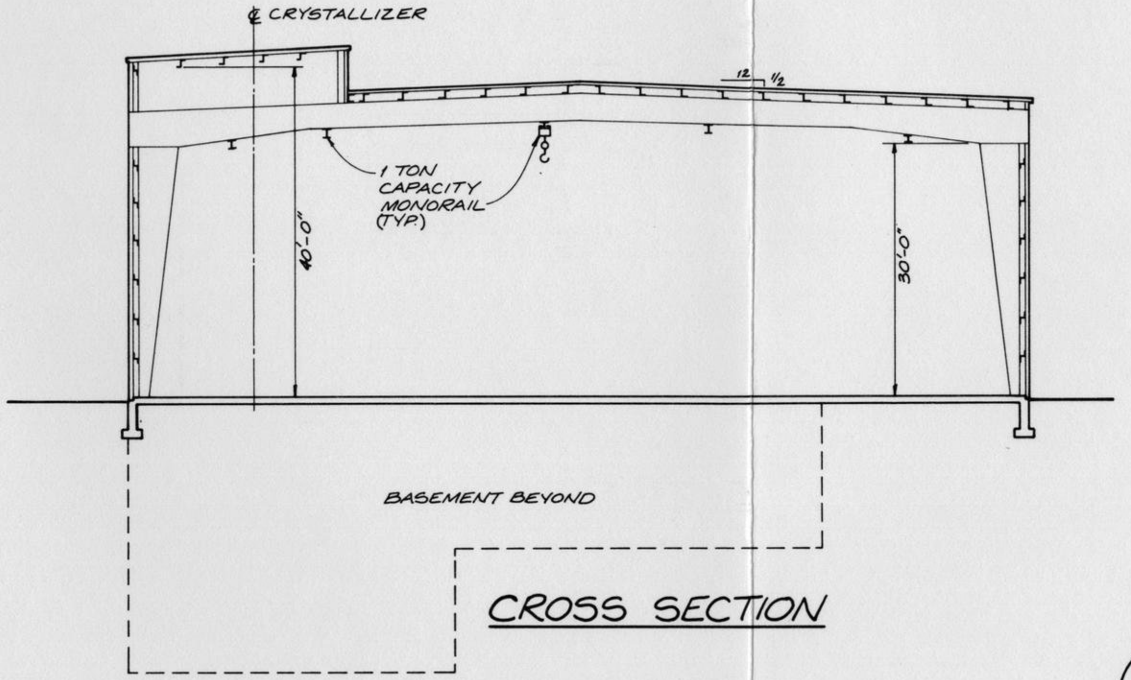
APPROVED BY	DATE	APPROVED BY MRH		DATE 7-18-84	
APPROVED BY	DATE	EXXON		DATE	
DRAWING NO 051-7-A-003	FIGURE 32	SHEET OF		REVISION NO 1	

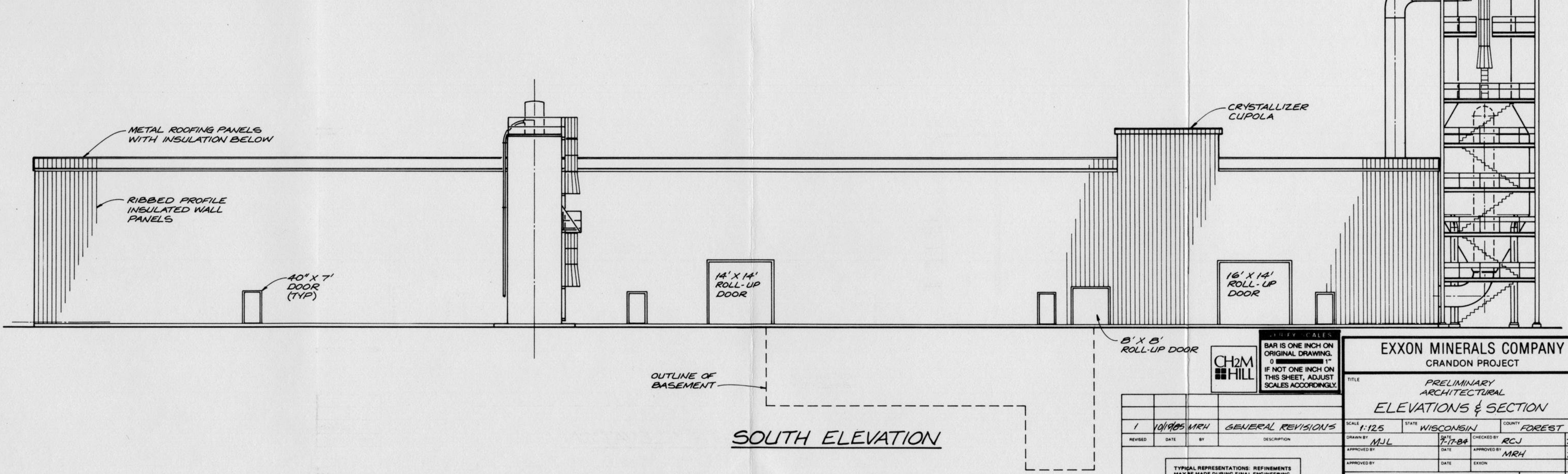
G88 5/19?



EAST ELEVATION



CROSS SECTION



SOUTH ELEVATION

CH2M HILL

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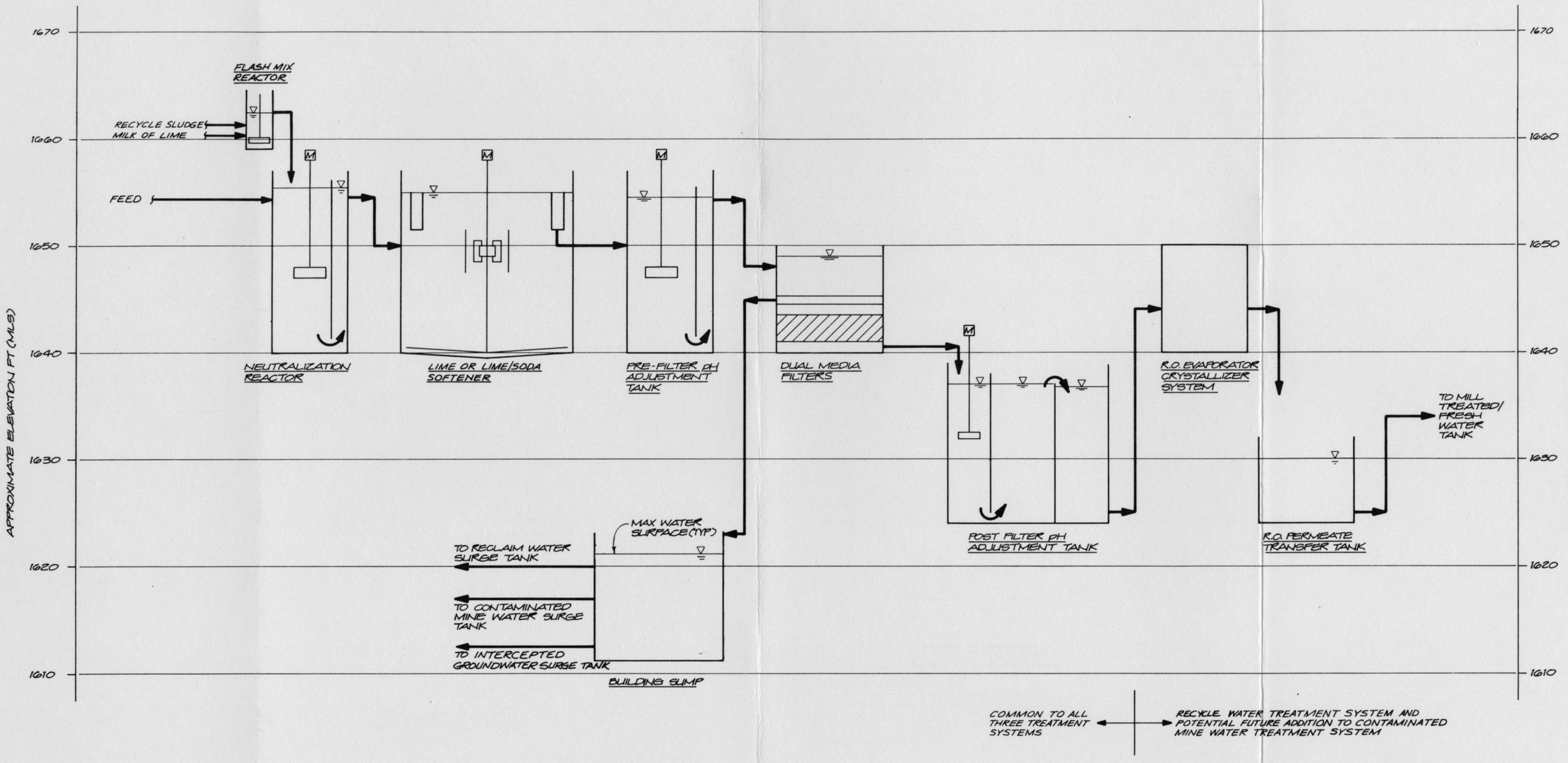
REVISED	DATE	BY	DESCRIPTION
1	10/19/85	MRH	GENERAL REVISIONS

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
PRELIMINARY
ARCHITECTURAL
ELEVATIONS & SECTION

SCALE 1:125	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY MJL	DATE 7-17-84	CHECKED BY RCJ	DATE 7-17-84
APPROVED BY	DATE	APPROVED BY MRH	DATE 7-18-84
APPROVED BY	DATE	EXXON	DATE
DRAWING NO 051-7-A-004	FIGURE 33	SHEET OF	REVISION NO 1



NOTES:

1. ONLY MAIN FLOW STREAMS ARE SHOWN.
2. FILTER BACKWASH CLEARWELL NOT SHOWN.

REVISED	DATE	BY	DESCRIPTION
2	10-1985	RRO	GENERAL REVISIONS
1	7/15/84	MRH	GENERAL REVISIONS

CH2M HILL

TYPICAL REPRESENTATIONS: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE PRELIMINARY PROCESS FLOW
HYDRAULIC PROFILE

SCALE NONE
STATE WISCONSIN
COUNTY FOREST
DRAWN BY SWB
DATE 11-18-83
CHECKED BY MTI
DATE 11-18-83
APPROVED BY MND
DATE 11-18-83
APPROVED BY
DATE
APPROVED BY
DATE
EXXON
DATE
DRAWING NO. 051-7-L-001
FIGURE 34
SHEET
OF
REVISION NO. 2

DESIGN PRODUCTS CO.

utility by a 115,000-volt transmission line. The line is projected to have an average outage rate of about one hour annually. Two main 25,000 KVA basic-rated transformers will be connected to this line through separate primary circuit breakers. The 13,800-volt secondaries of the transformers will supply a double-ended selective switchgear assembly with a normally-open tie breaker. In the event of an outage of one main transformer, the secondary tie breaker will be closeable and the site can be maintained at full capacity.

13,800-volt feeders will be provided to serve the plant distribution system. Some of these feeders will be transformed to 4,160 volts for large-horsepower motors. Other feeders will be transformed to 480 volts to serve the balance of the plant power needs.

The 480-volt service will be designed to provide redundancy for the three separate treatment systems. If a failure or loss of power is experienced on any of the separate systems, the remaining systems will continue to operate unaffected.

Backup and critical process equipment will be supplied by separate electrical distribution equipment. Automatic transfer equipment will be incorporated to connect critical equipment to an emergency power system supplied by a diesel-fueled engine generator.

5.9 EQUIPMENT LISTS AND DUTY SPECIFICATIONS

Table 5-3 illustrates preliminary sizing and duty specifications for all pumps, tanks, mixers, heat exchangers, and other miscellaneous process equipment items which will be required for the water treatment plant.

5.10 EQUIPMENT SPARING

The water treatment plant will be designed to operate 24 hours per day, essentially year-round. Critical equipment and process elements will, where necessary, be provided with a standby unit to increase system availability. Sparing philosophy for each major unit process is summarized in Table 5-4. Note that since the entire water treatment plant will be designed to process more than normal flows (see Table 5-1), spare capacity is available in each equipment item.

5.11 ADDITIONAL RO/VCE CAPACITY

As evidenced by the layout and process design for the water treatment system, space will be provided for future installation of additional RO/VCE capacity.

Although not contemplated at this time, it is possible that contaminated mine water will have to be treated to higher

Table 5-3 (Page 1 of 8)
EXXON CRANDON - WASTEWATER TREATMENT PLANT
EQUIPMENT NUMBERS

PUMP SCHEDULE

Equipment No.	Service/Name	Size	Specification	Material	Motor Power (typ. for multiple units)
709-1101-00 709-1102-00S 709-1103-00F	RO Permeate Transfer Pump	1,285 gpm @ 50 psig	End suction centrifugal	Ductile iron	60 hp
709-1104-00 709-1105-00	Lime Softener Sludge Pumps	150-300 gpm @ 15 psig	End suction, centrifugal, lined, slurry pump	Cast iron case with rubber lining	5 hp
709-1117-00S		200 gpm @ 15 psig			3 hp
709-1198-00		70-200 gpm @ 15 psig			3 hp
709-1106-00 709-1107-00S 709-1108-00	Lime Softener Soda Ash Feed Pump	13 gpm @ 20 psig	Positive displacement; progressing cavity; variable speed	Chrome plated 316 SS rotor with viton stater	1.0 hp
709-1109-00	Polymer Drum Pump	5.0 gpm @ 10 psig	Positive displacement; progressing cavity	Chrome plated 316 SS rotor with viton stater	1.0 hp
709-1111-00 709-1112-00S 709-1113-00 709-1197-00	Lime Soda Softener Polymer Feed Pump	1.7 gpm @ 50 psig	Positive displacement; diaphragm metering pump variable speed	316 SS wetted parts & TFE diaphragm	0.5 hp
709-1114-00 709-1115-00S 709-1116-00 709-1196-00	Prefilter pH Adjustment Acid Feed Pump	0.10 gpm @ 50 psig	Positive displacement; diaphragm metering pump, variable speed	Alloy-20 wetted parts & TFE diaphragm	0.5 hp
709-1119-00 709-1120-00 709-1195-00	Filter Backwash Pump	960 gpm @ 25 psig	End suction centrifugal	Ductile iron	25 hp
709-1121-00	Contaminated Mine Water Discharge Pump (Future Low Press Feed Pump if necessary)	1,550 gpm @ 50 psig	End suction centrifugal	Ductile iron	20 hp
709-1122-00 709-1123-00	RO Low Pressure Feed Pump	265-1,200 gpm @ 50.0 psig	End suction centrifugal variable speed	Ductile iron	60 hp
709-1124-00 709-1125-00 709-1110-00US 709-1194-00	Building Sump Pump	480 gpm @ 50 psig	Vertical wet-pit centrifugal; single speed	Ductile iron	20 hp
709-1126-00 709-1127-00S 709-1193-00F	SHMP Feed Pump	0.15 gpm @ 50.0 psig	Positive displacement; diaphragm metering pump, variable speed	Manufacturer's standard	0.5 hp
709-1128-00 709-1129-00S 709-1406-00F	RO Acid Feed Pump	0.02 gpm @ 100.0 psig	Positive displacement; diaphragm metering pump, variable speed	Alloy-20 wetted parts & TFE diaphragm	0.5 hp
709-1130-00	Reverse Osmosis Cleaning Solution Transfer Pump	265 gpm	End suction centrifugal	316 stainless steel	30 hp

Note: S = Spare
F = Future (if necessary)
US = Uninstalled spare

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 2 of 8)
PUMP SCHEDULE

Equipment No.	Service/Name	Size	Specification	Material	Motor Power (typ. for multiple units)
709-1131-00 709-1132-00 709-1133-00 709-1134-00S	Reverse Osmosis Booster Pump	400 gpm @ 550 psig	Multistage horizontal splitcase pump	316 or 316L stainless steel	200 hp
709-1135-00F 709-1136-00F 709-1192-00F		430 gpm @ 550 psig			200 hp
709-1137-00 709-1138-00S 709-1139-00F	Evaporator Feed Pump	240 gpm @ 30 psig	End suction centrifugal	316 or 316L stainless steel	7.5 hp
709-1140-00F 709-1141-00S 709-1142-00	Evaporator Acid Feed Pump	0.10 gph @ 50.0 psig	Positive displacement; diaphragm metering pump, variable speed	Alloy-20 wetted parts & TFE diaphragm	0.5 hp
709-1143-00 709-1144-00S 709-1145-00F 709-1179-00F	Evaporator Secondary Feed Pump	PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS			10 hp
709-1146-00 709-1147-00S 709-1148-00F 709-1182-00F	Distillate Pump	PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS			10 hp
709-1149-00 709-1150-00 709-1183-00F 709-1184-00F	Evaporator Recirculation Pump	PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFCATIONS			50 hp 75 hp 50 hp 75 hp
709-1151-00 709-1152-00F	Seed Tank Transfer Pump	PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS			5 hp
709-1153-00 709-1154-00S 709-1409-00F	Effluent Neutralization Soda Ash Pump	0.1 gpm @ 50.0 psig	Positive displacement; diaphragm metering pump, variable speed	Manufacturer's standard	0.5 hp
709-1155-00 709-1156-00S	Brine Softener Soda-Ash Feed Pump	2 gpm @ 20 psig	Positive displacement; progressing cavity; variable speed	Chrome plated 316 SS rotor with viton starter	0.75 hp
709-1157-00 709-1158-00S	Brine Softener Sludge Pump	13.7 gpm @ 30 psig	Positive displacement; progressing cavity, high temperature	Chrome plated 316 SS rotor with viton starter	0.75 hp
709-1159-00 709-1160-00S	Brine Neutralization Acid Feed Pump	0.07 gph @ 50 psig	Positive displacement; diaphragm metering pump; variable speed	Alloy-20 wetted parts and TFE diaphragm	0.5 hp
709-1161-00 709-1162-00S	Crystallizer Feed Pump	20 gpm @ 30.0 psig	End suction centrifugal; high temperature	316 SS	3 hp
709-1163-00 709-1164-00S	Steam Condensate Pump	PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS			5 hp
709-1165-00	Crystallizer Recirculation Pump	PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS			50 hp
709-1166-00 709-1167-00S	Crystallizer Vapor Condensate Pump	PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS			5 hp

Note: S = Spare
F = Future (if necessary)
US = Uninstalled spare

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 3 of 8)
PUMP SCHEDULE

Equipment No.	Service/Name	Size	Specification	Material	Motor Power (typ. for multiple units)
709-1168-00 709-1169-00S	Centrifuge Feed Pump	PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS			3 hp
709-1170-00 709-1171-00S	Brine Softener Polymer Pump	0.2 gpm @ 50.0 psig	Positive displacement; diaphragm metering pump; variable speed	316 SS wetted parts and TFE diaphragm	0.5 hp
709-1172-00 709-1173-00S 709-1174-00 709-1191-00	Post Filter pH Adjustment Acid Feed Pump	0.9 gph @ 50 psig	Positive displacement diaphragm metering pump, variable speed	Alloy-20 wetted parts & TFE diaphragm	0.5 hp
709-1118-00 709-1175-00S 709-1176-00 709-1401-00	Ferric Sulfate Feed Pump	0.3 gpm @ 50 psig	Positive displacement diaphragm metering pump; variable speed	316 SS wetted parts and TFE diaphragm	0.5 hp
709-1177-00 709-1178-00S	Sludge Transfer Pump	300 gpm @ 15 psig	End suction centrifugal lined slurry pump	Cast iron casing with rubber lining	7.5 hp
709-1180-00 709-1181-00S	Temporary MOL Feed Pump	25 gpm @ 15 psig	End suction centrifugal lined pump	Ductile iron rubber lined	0.5 hp
709-1185-00 709-1186-00S	Brine Softener Feed Pump	24 gpm @ 10 psig	End suction centrifugal; high temperature	316 SS	0.5 hp
709-1187-00 709-1188-00S	Crystalizer Condenser Cooling Pump	255 gpm @ 30 psig	Vertical centrifugal pump	Ductile iron	7.5 hp
709-1189-00	Activated Carbon Slurry Recirculation Pump	250 gpm @ 60 psig	End suction centrifugal	Cast iron casing with rubber lining	15 hp
709-1190-00	Activated Carbon Slurry Feed Pump	2 gpm @ 20 psig	Positive displacement; progressing cavity; variable speed	Chrome plated 316 SS rotor with viton starter	1 hp
709-1402-00	Discharge Lagoon Bypass Pump	2,550 gpm @ 20 psig	End suction centrifugal	Ductile iron	50 hp
709-1403-00 709-1404-00 709-1405-00	Sodium Sulfide Feed Pump	0.12 gpm @ 50 psig	Positive displacement diaphram metering pump; variable speed	316 SS wetted parts and TFE diaphragm	0.5 hp
709-1411-00	Intercepted Groundwater System Discharge Pump	1,000 gpm @ 30 psig	End suction centrifugal	Ductile iron	30 hp

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Note: S = Spare
F = Future (if necessary)
US = Uninstalled spare
Pump Number 709-1408-00 was not used.

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 4 of 8)
TANK SCHEDULE

Equipment No.	Service/Name	Size/Operating Volume	Specification/Material
709-3301-00	Brine Crystallizer	Per Manufacturer's specification. (5'-6" dia x 10' straight side and 60° conical bottom head)	Forced circulation type crystallizer to crystallize maximum of 20 gpm of softened evaporator brine; solids production of 30,000 lb/d.
709-3401-00	Mixed Media Filter	2 compartments each 8' x 8' for a total of 128 ft^2 Filter media depth = 39 in	Carbon steel tank with underdrains, air scouring, backwashing, piping collection troughs and flow control valves; mixed media filter with 2 layers: anthracite coal and sand; coal tar epoxy coated tank; package includes automatic backwashing controller.
709-3402-00			
709-3403-00			
709-3404-00			
709-3405-00			
709-3406-00			
709-3430-00			
709-3431-00			
709-3432-00			
709-3433-00			
709-5101-00	Temporary Lime Silo	12 ft dia single compartment 60° bottom cone; Vol = 2,000 ft^3	Carbon steel storage bin.
709-5422-00	Flash Mix Tank No. 1	5' dia x 6' height, Volume = 590 gal	Steel tank; coal tar epoxy coated.
709-5423-00	Flash Mix Tank No. 2	5' dia x 5' height, Volume = 440 gal	
709-5424-00	Flash Mix Tank No. 3	5' dia x 5' height, Volume = 440 gal	
709-5401-00	Neutralization Reactor No. 1	18.5' dia x 17.5' height, Volume = 31,200 gal	Steel tank; with mixer support bridge; coal tar epoxy coated, baffled.
709-5402-00	Neutralization Reactor No. 2	16' dia x 17.5' height, Volume = 24,800 gal	
709-5421-00	Neutralization Reactor No. 3	15' dia x 17.5' height, Volume = 20,500 gal	
709-5403-00	Softener No. 1	46' dia x 15' height, Volume = 186,500 gal	Steel tank; coal tar epoxy coated. Tank will accommodate solids contact reactor clarifier mechanism. Mechanism will include sludge scrapper, flocculator section, internal sludge recycle turbine, weir, and launders.
709-5404-00	Softener No. 2	41' dia x 15' height, Volume = 148,100 gal	
709-5420-00	Softener No. 3	37' dia x 15' height, Volume = 120,600 gal	
709-5405-00	Acid Storage Tank	10' dia x 22' height, Volume = 9,700 gal	Cylindrical carbon steel tank; dished top and bottom supported on 4 legs.
709-5406-00	Prefilter pH Adjust Tank No. 1	14' dia x 16.5' height, Volume = 16,700 gal	Cylindrical steel tank with mixer support bridge; coal tar epoxy coated.
709-5407-00	Prefilter pH Adjust Tank No. 2	12' dia x 16.5' height, Volume = 12,300 gal	
709-5421-00	Prefilter pH Adjust Tank No. 3	11' dia x 16.5' height, Volume = 10,300 gal	
709-5408-00	Reverse Osmosis Reject Tank	36' dia x 30' height, Volume = 171,000 gal	Carbon steel tank, concrete pad, erected in place; coal tar epoxy coated.
709-5409-00	Brine Softener	14' dia x 8' SWD, Volume = 9,200 gal	Insulated steel tank with solids contact reactor clarifier mechanism; manufacturer's supplied mechanism to include sludge scraper, flocculator section, internal recycle sludge recycle turbine, weirs, launders and cover; conical bottom tank with coal tar epoxy coating.
709-5410-00	Steam Condensate Tank	Per Manufacturer's specification.	As supplied with brine crystallizer.
709-5411-00	Milk-of-Lime Feed Tank	6' dia x 8' height, Volume = 1,270 gal	Cylindrical carbon steel tank with mixer.
709-5412-00	Sludge Transfer Tank	8' dia x 8' height, Volume = 2,260 gal	Cylindrical carbon steel tank coated with coal tar epoxy, with mixer.
709-5413-00	Brine Softener Feed Tank	8' dia x 8' height, Volume = 2,400 gal	Carbon steel tank closed top, insulated and coated with coal tar epoxy, with mixer.
709-5414-00	Instrument Air Receiver Tank	3' dia x 6' height, Volume = 300 gal	Cylindrical steel pressure tank.

Note: F = Future (if necessary)

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 5 of 8)
TANK SCHEDULE

Equipment No.	Service/Name	Size/Operating Volume	Specification/Material
709-5415-00	Soda Ash Feed Tank	10' dia x 14.5' height, Volume = 7,340 gal	Cylindrical carbon steel tank, open top, coal tar epoxy coated.
709-5416-00 709-5419-00F	RO Permeate Transfer Tank	10' dia x 8' height, Volume = 3,600 gal	Cylindrical steel tank erected in place coal tar epoxy coated, covered top.
709-5417-00	Crystallizer Feed Tank	8' dia x 8' height, Volume = 2,200 gal	Cylindrical steel tank; insulated and coated with coal tar epoxy; covered top with provisions for mixer support.
709-5418-00	Activated Carbon Slurry Feed Tank	5' dia x 7' height, Volume = 720 gal	Cylindrical carbon steel tank; coated with coal tar epoxy; with mixer
709-4107-00 709-4108-00F	Evaporator Body	--------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------	
709-5601-00 709-5602-00F	Deaerator	--------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------	
709-5603-00 709-5604-00F	Distillate Surge Tank	--------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------	
709-5605-00 709-5606-00F	Seed Tank	--------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------	
709-5607-00 709-5608-00F	Shear Tank	--------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------	
709-5609-00	Vapor Condensate Tank	Per manufacturer's specification	As supplied with brine crystallizer.
709-5701-00	RO Cleaning Solution Tank	1,000 gal	Cylindrical fiberglass reinforced plastic tank; open top.
709-5702-00 709-5703-00	Polymer Feed Tanks No. 1 & 2	7' dia x 12.5' height, Volume = 2,735 gal each	Cylindrical fiberglass reinforced plastic tank; open top.
709-5704-00 709-5705-00	SHMP Feed Tank	5' dia x 7' height, Volume = 730 gal	Cylindrical fiberglass reinforced plastic tank; open top.
709-5706-00 709-5707-00	Ferric Sulfate Feed Tank Nos. 1&2	6' dia x 6' height, Volume = 950 gal	Cylindrical fiberglass reinforced plastic tank; open top.
709-5801-00 709-5802-00 709-5807-00	Post Filter pH Adjust Tank No. 1 Post Filter pH Adjust Tank No. 2 Post Filter pH Adjust Tank No. 3	13' x 13' x 15' deep, Volume = 16,400 gal 13' x 10' x 15' deep, Volume = 12,600 gal 11' x 10' x 15' deep, Volume = 10,700 gal	Rectangular concrete tank with mixer, coal tar epoxy coated, with mixing compartment.
709-5708-00 709-5709-00	Sodium Sulfide Feed Tank	5' dia x 7' height, Volume = 730 gal	Cylindrical fiberglass reinforced plastic tank, open top.
709-5803-00 709-5804-00 709-5806-00	Filter Clearwell No. 1 Filter Clearwell No. 2 Filter Clearwell No. 3	20' x 13' x 15' deep, Volume = 28,000 gal 24' x 10' x 15' deep, Volume = 21,600 gal 17' x 10' x 15' deep, Volume = 15,300 gal	Rectangular concrete tank; coal tar epoxy coated. Includes RO low pressure feed pump clearwell. Rectangular concrete tank; coal tar epoxy coated.
709-5805-00	Building Sump	15' x 14' x 9' deep = 15,150 gal for compartment 1 (3' freeboard) 15' x 9' x 9' deep = 10,000 gal for compartments 2 & 3 (3' freeboard)	Below grade rectangular concrete tank; coal tar epoxy coated. Divided into three compartments.

Note: F = Future (if necessary)

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 6 of 8)
MIXER SCHEDULE

Equipment No.	Service/Name	Size/Type	Specification	Shaft and Prop. Mat.	Motor Power
709-3501-00 709-3502-00 709-3534-00	Neutralization Reactor Mixer Nos. 1 & 2 Neutralization Reactor Mixer No. 3	56 rpm; 50 in dia impeller	Single impeller axial flow; top entering	316 SS shaft and impeller.	10.0 hp 7.5 hp
709-3503-00 709-3504-00 709-3533-00	Softener Mixer No. 1 Softener Mixer No. 2 Softener Mixer No. 3	Turbine agitator; variable speed 3.3 to 13.3 rpm	Variable speed drive with reducers 4 to 1 variation; as supplied with	Manufacturer's standard softener mechanism	3 hp
709-3505-00 709-3522-00	Polymer Feed Tank Mixer	350 rpm; 10 in dia impeller	Single propeller, clamp mounted mixer	316 SS shaft and propeller.	0.5 hp
709-3506-00	Prefilter pH Adjustment Tank Mixer No. 1	56 rpm; 46 in dia impeller	Single impeller axial flow; top entering	316 SS shaft and impeller.	7.5 hp
709-3532-00 709-3507-00	Prefilter pH Adjustment Tank Mixer Nos. 2 & 3	56 rpm; 46 in dia impeller	Single impeller axial flow; top entering	316 SS shaft and impeller.	5 hp
709-3508-00 709-3511-00	SHMP Mix Tank Mixer	350 rpm; 10 in dia impeller	Single propeller clamp mounted mixer	316 SS shaft and propeller.	0.3 hp
709-3509-00 709-3538-00F	In-Line Mixer (RO feed)	12 in dia in-line static mixer	Turbulent flow in-line mixer	Fiberglass reinforced plastic.	- - - - - - -
709-3510-00	RO Cleaning Solution Tank Mixer	350 rpm; 10 in impeller	Single impeller, clamp mounted		0.3 hp
709-3512-00 709-3513-00F	Seed Tank Mixer	- - - - - - - - - - PER EVAPORATOR MANUFACTURER'S SPECIFICATION			1 hp
709-3514-00 709-3515-00F	Evaporator Feed In-Line Mixer	152 mm (6 in) dia in-line static mixer	Turbulent flow in-line mixer	316 SS	- - - - - - -
709-3516-00 709-3517-00F	Shear Tank Mixer	- - - - - - - - - - PER EVAPORATOR MANUFACTURER'S SPECIFICATION			5 hp
709-3518-00	Brine Softener Mixer	Turbine agitator; variable speed 3.3 to 13.3 rpm	Variable speed drive with reducers; 4 to 1 variation; as supplied with softener mechanism	Manufacturer's Standard.	3 hp
709-3519-00	Crystallizer Feed Tank Mixer	56 rpm; 38 in dia impeller	Single impeller axial flow; top entering	316 SS shaft and impeller.	2 hp
709-3520-00 709-3521-00 709-3535-00	Post Filter pH Adjustment Tank Mixer	56 rpm; 38 in dia impeller	Single impeller axial flow; top entering	316 SS shaft and impeller	2 hp
709-3523-00 709-3524-00	Ferric Sulfate Mix Tank Mixer	350 rpm; 10 in dia impeller	Single propeller, clamp mounted mixer	316 SS shaft and propeller	0.3 hp
709-3525-00	Milk-of-Lime Feed Tank Mixer	Per lime system Supplier specification	Dual propeller, clamp mounted mixer	316 SS shaft and propeller	2 hp
709-3526-00	Brine Softener Feed Tank Mixer	56 rpm; 38 in dia impeller	Single impeller axial flow top entering	316 SS shaft & impeller	2 hp
709-3527-00	Sludge Transfer Tank Mixer	420 rpm; 10 in dia impeller	Clamp on single impeller	316 SS shaft & impeller	1 hp
709-3528-00 709-3529-00 709-3531-00	Flash Mix Tank	420 rpm; 10 in dia impeller	Single impeller; clamp mounted	316 SS shaft & impeller	1.5 hp
709-3530-00	Carbon Slurry Feed Tank Mixer	420 rpm; 10 in dia impeller	Single propeller, clamp mounted	316 SS shaft & propeller	1 hp
709-3536-00 709-3537-00	Sodium Sulfide Feed Tank Mixer	350 rpm; 10 in dia impeller	Single propeller, clamp mounted mixer	316 SS shaft & propeller	0.3 hp

Note: F = Future (if necessary)

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 7 of 8)
HEAT EXCHANGER EQUIPMENT SCHEDULE

Equipment No.	Service/Name	Size/Material	Specification
709-4101-00 709-4102-00F	Feed Preheater	Per evaporator manufacturer's specification	240 gpm maximum flow capacity; plate and frame type heat exchanger; titanium plates capable of working pressures of 150 psig.
709-4103-00 709-4104-00F	Barometric Condenser	Per evaporator manufacturer's specification	Barometric condenser utilizing feed water as the cooling medium; condenser will provide vacuum for the feed deaerator.
709-4105-00 709-4106-00F	Feed Heater	Per evaporator manufacturer's specification	240 gpm maximum flow capacity; plate and frame type heat exchanger; titanium plates capable of working pressures of 150 psig.
709-4107-00 709-4108-00F	Evaporator No. 1 Evaporator No. 2	Per evaporator manufacturer's specification	240 gpm maximum flow; evaporator body with shell-and-tube type condenser utilizing vapor recompression evaporation in a falling film configuration; titanium tubes and tube sheets; vapor body 316 stainless steel.
709-4109-00	Brine Feed Heater	Per crystallizer manufacturer's specification	Double pass heat exchanger utilizing steam energy and compatible with forced circulation crystallizer.
709-4110-00	Vapor Condenser	Per crystallizer manufacturer's specification	Double pass heat exchanger suitable for condensing steam from the brine feed heater.
709-4201-00	Startup Boiler	Per evaporator and crystallizer manufacturer's specification	Boiler will be used for evaporator startup or crystallizer feed heater; natural gas fired boiler with rated capacity of 16,700 lbs/hr; operating capacity 13,300 lbs/hr.
709-4111-00	RO Cleaning Solution Tank Heater	Per reverse osmosis Manufacturer's specification	Electrical heater.
709-4112-00	Crystallizer Feed Tank Heater	Per crystallizer manufacturer's specification (assume 30 kW)	

Note: F = Future (if necessary)

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-3 (Page 8 of 8)
MISCELLANEOUS EQUIPMENT SCHEDULE

Equipment No.	Service/Name	Size/Material	Specification
709-0401-00 709-0402-00 709-0403-00 709-0404-00 709-0405-00 709=0406-00 709-0407-00 709-0408-00 709-0409-00 709-0410-00F 709-0411-00[a] 709-0412-00[b] 709-0413-00[c]	Composite Sampler	Manufacturer's standard	Automatic sampler provided with all necessary instrumentation for time proportional and flow proportional sampling.
709-1201-00 709-1202-00F	Compressor	Per evaporator manufacturer's specification	Single stage centrifugal type vapor compressor with electric drive motor and adjustable inlet guide vanes (1,500 Bhp).
709-3407-00 709-3408-00F	Hydrocyclone	-------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION --------	
709-3409-00	Brine Centrifuge (5 hp)	Per crystallizer manufacturer's specification	Screen bowl centrifuge for dewatering 100°C brine crystallizer slurry to 80 percent solids.
709-3410-00 709-3411-00 709-3412-00 709-3413-00 709-3414-00F 709-3423-00F 709-3424-00F	Reverse Osmosis Cartridge Prefilter	Disposable 10 micron cartridge filters capable of filtering 430 gpm	Feed water stream to reverse osmosis units filtered as required by RO supplier; cartridge core and filter casing 316 stainless steel.
709-3415-00 709-3416-00 709-3417-00 709-3418-00	Reverse Osmosis Module	4 modules each rated for 400 gpm maximum flow; modules spiral wound, cellulose acetate membranes	The modules will be skid mounted and housed in corrosion-resistant pressure vessels designed for quick isolation for cleaning, system flushing and maintenance; system sized for a maximum of 80 percent water recovery at 10°C.
709-3419-00F 709-3421-00F 709-3422-00F		3 modules each rated for 430 gpm maximum flow, same construction as above	
709-3420-00	Reverse Osmosis Cleaning Solution Cartridge Filter	Per manufacturer's standard	10 micron polypropelene in 316 SS housing.
709-1203-00	Air Scouring Blower For Filters	243 scfm @ 10 psig, 20 hp	The blower will be skid mounted complete with inlet and discharge silencer.
709-1204-00	Neutralization Tank Air Blower	380 scfm @ 8 psig, 25 hp	The blower will be skid mounted complete with inlet and discharge silencer.
709-1205-00	Air Compressor for Temporary Lime System	Per lime system manufacturer's specification	
709-8101-00	Distributed Control System	Per manufacturer's standard	A microprocessor-based control system to provide process control, data display, alarming, and data acquisition.

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[a] Not part of water treatment facility, located on contaminated mine water surge tank.
[b] Not part of water treatment facility, located on intercepted groundwater surge tank.
[c] Not part of water treatment facility, located on reclaim surge tank.

Note: F = Future (if necessary)

Refinement of equipment selection and sizing may be made during final engineering.

Table 5-4 (Page 1 of 5)
EQUIPMENT SPARING PHILOSOPHY

Unit Process	Installed Spare Provided	Remarks
1. Neutralization reactors		
Reactor tanks	None	Low-maintenance item.
Reactor mixers	None	Low-maintenance item.
Air blower	None	May not be needed. Low-maintenance item, easily replaced.
2. Lime/sulfide and lime-soda softeners reactor-clarifiers and mechanisms	None	Remarks similar to those under No. 1 above.
Sludge pumps	One installed spare	Also, softeners could operate for short periods without sludge recyle. Installed spare for systems Nos. 1 and 2. Spare sludge transfer pump also spares the sludge pump for System 3.
Sludge transfer pumps	One at 100% capacity	Critical operation.
Sludge transfer tank and mixer	None	Low-maintenance items. Could get by with temporary tank for short periods.
3. Building sumps	None	Low-maintenance items. Could temporarily route all wastes to one or two sumps.
Sump pumps	None	Shelf spares provided.
4. Pre-filter pH adjust		
Tanks	None	Remarks similar to those under No. 1 above.
Mixers	None	Low maintenance, easily replaced.

Table 5-4 (Page 2 of 5)

Unit Process	Installed Spare Provided	Remarks
5. Mixed-media filters		
Filter compartments	None	Low-maintenance item. Conservatively sized. Multiple units, so could valve extra unit into RO service and run discharge units at high rates for short periods.
Backwash pumps	None	In use only approximately one hour per day. Identical pumps; are valved to allow common use for short periods.
Air scour blowers	None	Low-maintenance item, easily replaced. Could run without air scour for short periods.
6. Post-filter pH adjust	None	Same as No. 4 above. Valved for common service if necessary.
7. Filter clear wells	None	Same as No. 6 above.
8. Crystallizer condenser cooling pumps	One at 100% capacity	Critical service to ensure RO capacity in winter months.
9. RO low-pressure feed pumps	One at 100% capacity	Common to all three systems. (Also acts as spare for effluent pumps.)
10. RO system		
Cartridge filters	None	Normally out of service only a few hours per month. Sized conservatively. Cartridges can be run at high rates for short periods.
RO booster pumps	One at 33% capacity	One-to-one relationship to RO modules, with one common spare.
RO modules	One at 33%	Some additional excess capacity also available initially. Room for three additional future modules. Vessels are low-maintenance items; membranes can be replaced easily.
RO cleaning system	None	Low-maintenance item, only used once per week. System elements typically not spared.

Table 5-4 (Page 3 of 5)

Unit Process	Installed Spare Provided	Remarks
11. RO permeate transfer tank; RO reject tank	None	Low-maintenance items. Could get by with temporary tanks for short periods.
12. RO permeate transfer pumps	One at 100% capacity	Critical service.
13. Evaporator system		
Evaporator feed pumps	One at 100% capacity	Critical service.
Feed preheater and feed heater	None	Low-maintenance items, typically not spared. Plates easily replaced.
Deaerator	None	Low-maintenance item, typically not spared. Packing easily replaced.
Evaporator secondary feed pumps	One at 100% capacity	
Distillate pumps	One at 100% capacity	
Primary recirculation pump, secondary recirculation pump, compressor, evaporator body	None	Expensive, typically not spared. Shelf spares provided for 10 percent of evaporator tubes, compressor wheel, primary and secondary recirculation pumps. Note that room is provided for another complete future evaporator system.
Distillate surge tank, hydroclone, seed tank, seed transfer pump, shear tank, barometric condenser, startup boiler	None	Low-maintenance items, typically not spared. Shelf spare hydroclone.
14. Brine softener		
Brine softener feed tank	None	Low-maintenance item. Could use temporary tank or bypass for short periods.

Table 5-4 (Page 4 of 5)

Unit Process	Installed Spare Provided	Remarks
Brine softener feed pumps	One at 100% capacity	Critical service.
Brine softener	None	Remarks similar to No. 2 above.
Brine softener sludge pumps	One at 100% capacity	Critical service.
15. Crystallizer		
Crystallizer feed tank, steam condensate tank, condenser, vapor condensate tank	None	Low-maintenance items, typically not spared.
Crystallizer feed pumps, steam condensate pumps, crystallizer vapor condensate pumps	One at 100% capacity each	Critical service.
Brine feed heater, crystallizer recirc. pump, brine crystallizer, product centrifuge	None	Expensive, typically not spared. Replacement parts for routine maintenance will be stocked.
16. Sulfuric acid system		
Sulfuric acid storage tank	None	Remarks similar to No. 11 above.
Sulfuric acid feed pumps	One at 100% capacity for each service	Critical service. Common spares used for similar flows.
17. Soda ash system		
Soda ash tank	None	Remarks similar to No. 11 above.
Soda ash feed pumps	One at 100% capacity for each service	Critical service.
18. SHMP system		
SHMP feed tanks	One at 100% capacity	Batch system.

Table 5-4 (Page 5 of 5)

Unit Process	Installed Spare Provided	Remarks
18. SHMP system		
SHMP feed tanks	One at 100% capacity	Batch system.
SHMP feed pumps	One at 100% capacity	Critical service.
19. Polymer system		
Polymer feed tanks	One at 100% capacity	Batch system.
Polymer feed pumps	One at 100% capacity	Common spare used for similar flows.
20. Ferric sulfate system		
Ferric sulfate feed tanks	One at 100% capacity	Batch system.
Ferric sulfate feed pumps	One at 100% capacity	Common spare used for similar flows.
21. Sodium sulfide system		
Sodium sulfide feed tanks	One at 100% capacity	Batch system.
Sodium sulfide feed pumps	One at 100% capacity	Common spare piped to process train which normally does not use sodium sulfide.
22. Activated carbon system	None	Need and dosages unknown. Can provide spares later if warranted.
23. Temporary hydrated lime system		
Silo, vent filter, MOL tank	None	Low-maintenance items, typically not spared.
MOL pumps	One at 100% capacity	Critical service.
24. Control system		
CRT's	One at 100% capacity	Critical service.
PLC's	None	Shelf spare cards, easily replaced.
Field elements	None	Shelf spares for most.
Control valves	None	Most have bypass provisions and can be operated manually for short periods.

quality than achievable with the proposed system. The need for such additional treatment will be assessed during the mine development period through full-scale treatment in the lime/sodium sulfide treatment system. If, as expected, the effluent meets the DNR's limitations, the RO/VCE/crystallizer systems installed in the plant will be used as part of the Recycle Water Treatment System. If (after optimization of treatment operations during the mine development period) treated effluent does not meet DNR's limitations, it is possible that the Contaminated Mine Water Treatment System will have to be expanded to include RO and VCE unit operations. This requirement would add tremendously to both the capital and long-term O&M cost of water treatment.

With use of the lime and sodium sulfide precipitation process (see Section 6), it is believed that the system will achieve compliance with effluent limitations. It is not considered likely that the additional RO/VCE capacity will be required. CH2M HILL and Exxon, however, jointly agreed that the water treatment facility should be designed with sufficient floor space for the additional capacity should it ever be required. This decision may result in unused floor space, but is the only practical way to ensure a sensible equipment arrangement if the need does arise to install the additional equipment.

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SECTION 6
Influent and Effluent Water Quality

Section 6
INFLUENT AND EFFLUENT WATER QUALITY

6.1 INFLUENT WATER QUALITY

Influent to be treated in the Crandon Project water treatment system will consist of three streams:

- o Intercepted groundwater
- o Contaminated mine water
- o Reclaim pond water

These three streams will be treated in the three water treatment systems as described earlier.

The Crandon Project Water Use Model and recent analyses of groundwater by Exxon were used to generate an estimate of the quality of these three streams. CH2M HILL's Phase III Water Management Study (December 30, 1982) provides an extensive discussion of how the model works and of data used to develop predictions of water quality in specific streams.

An additional brief description of the Water Use Model and updates of model runs are presented in "Water Model Projections of Effluent Composition from the Water Treatment Facility" (Exxon Minerals Company, 1985).

INTERCEPTED GROUNDWATER

The intercepted groundwater quality used in the Water Use Model and used for the treatment system design is shown in Table 6-1. This composition is based on the analysis of water from well 211, which had among the highest heavy metal concentrations of all the wells tested. Well 211 was in the oxidized portion of the ore body. Hence, the actual intercepted groundwater to be encountered under steady state conditions is expected to have a higher quality than that shown in Table 6-1.

CONTAMINATED MINE WATER

Contaminated mine water quality is summarized in Table 6-2. As shown in Table 6-2, contaminated mine water has three components: mine seepage, potable water, and backfill drainage. The water model combines these streams in the proportions shown in Table 6-2.

According to the discussion in the Phase III Water Management Report (CH2M HILL, 1982), mine seepage water quality is based on data from the report "An Investigation of Column Water Leaching of Crandon Project Samples," Lakefield Research Canada, Progress Report No. 28.

Table 6-1
WATER QUALITY OF INTERCEPTED GROUNDWATER[a]

Constituent[b]	Concentration
Cations	
Ag	<0.001
Al	<0.01
Ba	<0.01
Ca	28
Cd	0.039
Cr	<0.001
Cu	0.20
Fe (Total Iron)	0.71
Hg	<0.0001
K	1.3
Mg	16
Mn	0.045
Na	4.7
Pb	0.04
Se	0.018
Zn	0.44
Anions	
As	0.51
CO_3	<1
Cl	12
CN	<0.001
F	0.48
HCO_3	130
NO_3	2.0
PO_4	0.28
SO_4	15
S	<0.01
S_2O_3	<1
CO_2	2.0
Miscellaneous	
SiO_2	8.2
Hardness	150
pH	7.1
TDS	160
TSS	50
Flow	
GPM	350

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[a] Projected concentrations are based on summer conditions.

[b] All values except pH and flow are mg/L.

Table 6-2
WATER QUALITY OF CONTAMINATED MINE WATER[a]

Constituent[b]	Mine Seepage	Utility Water	Backfill Drainage	Total Contaminated Mine Water
Cation				
Ag	0.01	0.001	0.02	0.01
Al	0.53	0.53	1.9	0.75
Ba	0.02	0.02	0.015	0.019
Ca	45	30	510	120
Cd	0.07	0.002	0.013	0.061
Cr	0.10	0.002	1.8	0.56
Cu	0.10	0.007	0.59	0.25
Fe^{2+}	1.7	1.7	0.11	1.5
Fe^{3+}	< 0.01	< 0.01	0.19	0.03
Hg	0.0004	0.0001	0.0002	0.0004
K	1.3	1.3	17	3.7
Mg	19	12	2.2	17
Mn	0.42	0.42	0.05	0.37
Na	4.1	4.1	290	48
Pb	0.34	0.01	0.10	0.30
Se	0.001	0.001	0.60	0.11
Zn	20	0.05	2.8	18
Anions				
As	0.01	0.001	0.17	0.047
CO_3	< 1	< 1	10	1.6
Cl	4.0	4.0	4.4	4.1
CN	0.001	0.001	0.06	0.01
F	0.20	0.20	4.6	0.9
HCO_3	30	150	5.8	27
NO_3	1.6	1.6	0.8	5.6
PO_4	< 0.01	0.06	0.8	0.12
SO_4	200	9	1,400	390
S	< 0.01	< 0.01	0.04	0.006
S_2O_3	< 1	< 1	560	85
CO_2	2.0	< 1	2.5	2.1
Miscellaneous				
SiO_2	9.0	15	15	9.9
Hardness	230	44	1,300	390
pH	5.7	7.7	11.3	5.8
TDS	370	65	2,300	660
TSS	50	0	7,700[c]	1,200
Flow				
GPM	870[d]	5	160	1,035

---

[a] To match the flowsheets shown in Section 5, the water chemistry shown in this table is for winter average operating conditions. Under these conditions the model predicts no precipitation of metals in the reclaim pond, thus predicting worst case water quality in the backfill drainage water.

[b] All values except pH and flow are mg/L.

[c] Includes all solids picked up in the mine.

[d] 50 gpm of mine seepage (see Figure 3) exits with ore hoisted to the surface.

Water seepage will pass through ore rock and hanging wall rock. Water passing through the ore rock has been assumed to have a quality similar to a 60-day water leach through a 1:1:1 mixture of stringer ore, massive ore, and massive pyrite. Seventy-five percent of the water seeping into the mine has been assumed to be of this quality. The remaining 25 percent has been assumed to seep through hanging wall rock and have a water quality similar to the quality of the 60-day leach tests of this rock. The two seepage streams were then summed proportionately to compute the mine seepage water quality.

Utility water comprises only 5 gpm out of the approximately 1,035 gpm of contaminated mine water. It will be close in composition to that of average groundwater quality. The composition used was from the Dames and Moore Environmental Baseline Study.

The quality of backfill drainage is calculated by the water model. It is assumed to have the same quality as water in the mine backfill.

It is believed that the water qualities used in the engineering to date are conservative in at least one way. The 60-day leach time assumed for mine seepage is probably several times longer than that which will actually be experienced by the water seeping into the mine.

RECLAIM POND WATER

Table 6-3 shows the water quality of reclaim pond water as predicted by the water use model. This quality is the predicted steady state concentration of reclaim pond effluent water during winter operation of the mine/mill.

6.2 TREATED CONTAMINATED MINE WATER QUALITY

Effluent from the Contaminated Mine Water Treatment System will be discharged to Swamp Creek via the Excess Discharge Lagoon System and the excess water discharge pipeline.

Based on the results of tests by Exxon (see Appendix), it is predicted that effluent quality will meet all of the projected effluent limitations shown in Table 2-1.

6.3 TREATED INTERCEPTED GROUNDWATER QUALITY

Intercepted groundwater will be treated in a separate treatment system but with the same treatment processes as described for contaminated mine water. Based on the results of tests by Exxon (see Appendix) it is predicted that effluent quality will meet all of the projected effluent limitations shown in Table 2-1.

Table 6-3
WATER QUALITY OF RECLAIM POND WATER[a]

Constituent[b]	Reclaim Pond Water
Cations	
Ag	0.02
Al	1.8
Ba	0.016
Ca	480
Cd	0.013
Cr	3.6
Cu	1.0
Fe^{2+}	0.12
Fe^{3+}	0.22
Hg	0.0002
K	16
Mg	3.0
Mn	0.06
Na	290
Pb	0.12
Se	0.61
Zn	4.8
Anions	
As	0.20
CO_3	0.055
Cl	4.1
CN	1.3
F	4.3
HCO_3	8.9
NO_3	0.89
PO_4	0.93
SO_4	1,400
S	0.037
S_2O_3	460
CO_2	0.47
Miscellaneous	
SiO_2	14
Hardness	1,200
pH	7.5
TDS	2,200
TSS	50
Flow	
GPM	610[c]

---

[a] To match the flowsheets shown in Section 5, the water chemistry shown in this table is for winter average operating conditions. Under these conditions, the model predicts no precipitation of metals in the reclaim pond, thus predicting worst case water quality in reclaim pond effluent.

[b] All values except pH and flow are mg/L.

[c] Volume routed to Recycle Water Treatment System.

6.4 TREATED SANITARY WASTEWATER QUALITY

The projected average composition of the treated sanitary wastewater is shown in Table 6-4. The details of the calculations for this projection are presented in "Facilities Plan for the Exxon Minerals Company Mine/Mill Complex Sanitary Wastewater, Crandon, Wisconsin" (CH2M HILL, 1985).

6.5 DISCHARGE WATER QUALITY

Water discharged from the Crandon Project will consist of a blend of treated effluents from the Contaminated Mine Water Treatment System, Intercepted Groundwater Treatment System and Treated Sanitary Sewage.

The projected composition of the combined effluent stream is shown in Table 6-5. Because of the large difference in flowrates between the treated mine water and treated sanitary water (1,175 and 10 gpm, respectively), the effect of combining the two streams is negligible. The composition of the combined streams is essentially the same as the treated mine water alone.

The daily average effluent concentrations presented in Table 6-5 represent the expected monthly average of the daily values. These values are estimated based on: 1) the water treatment testing on synthetic mine water using the proposed water treatment methods, 2) the results of water model projections of the water treatment system effluent concentrations, and 3) conservative estimates of the differences that may occur between pilot plant/laboratory conditions and actual daily plant operations. Based on these conservative calculations, all chemical parameters are expected to be below the DNR effluent limitations.

The concentrations described as minimum values expected in Table 6-5 are based on the water model projections of the effluent composition for normal operating conditions and hand calculations for parameters not calculated by the model. The results of water model projections for the water treatment plant effluent composition under various conditions are presented in "Water Model Projections of Effluent Composition from the Water Treatment Facility," as previously referenced.

The concentrations described as the maximum value expected in Table 6-5 are based on the DNR's daily maximum effluent concentrations. These values are appropriate since the effluent concentrations could approach these values on a short-term basis due to a temporary upset at the water treatment facility. However, these values would not be exceeded, even on a short-term basis, as the discharge lagoons would allow for recycle of water that contained contaminants that exceeded the DNR's daily maximum values.

Table 6-4
PROJECTED WATER QUALITY OF TREATED SANITARY WASTEWATER

Constituent	Concentration[a]
BOD_5	30
COD	75
TSS	30
TDS	200
Settleable Matter	<1
Phosphorous	8
Ammonia Nitrogen	15
Turbidity (NTU)	10
Formaldehyde[b]	<0.5
Residual Chlorine	0.25
pH (standard units)	7
Average Flow (gpm)	10[c]

---

[a] All values are in mg/L unless otherwise indicated.
[b] Based on transmittal from CH2M HILL to EMC 2/17/86.
[c] This flowrate is based on average employment figures. Under peak employment this flowrate would rise to about 15 gpm.

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Table 6-5

PROJECTED WATER QUALITY OF COMBINED EFFLUENT STREAMS

	Effluent (mg/l)		
Parameter	Daily[a,b] Average	Minimum Value Expected	Maximum Value Expected
Cyanide	0.006	<0.006	<0.096
Fluoride	2	1	<12.5
Arsenic	0.05	0.025	<1.48
Barium	0.03	0.016	<2
Cadmium	0.0006	0.00028	<0.074
Chromium III	0.06	0.03	<11.1
Chromium VI	0.012	<0.012	<0.059
Copper	0.01	0.005	<0.025
Iron	0.4	0.2	--
Lead	0.04	0.02	<0.6
Mercury	0.00017	<0.00017	<0.002
Selenium	0.06	0.027	<1.0
Silver	0.003	0.0017	<0.007
Zinc	0.06	0.032	<0.44
TDS	700	<700	<1,055

Based on the presence of the substances noted below the ore, it is possible that they could be present in the effluent. Industry experience and geochemistry, however, would suggest that they will probably be present in mine seepage at near or below the standard (AA) detection limits. If they are present at more elevated concentrations, the literature and our investigations indicate that the maximum effluent concentrations would be as follows:

Nickel	<0.02
Antimony	<0.05[d]
Boron	<0.1
Cobalt	<0.02
Molybdenum	<0.05
Tin	<0.02[d]
Bismuth	<0.05
Platinum	<0.01[d]

---

[a] Monthly average of daily values.

[b] Some concentrations are flow dependent. Presented here for 1,175 gpm.

[c] BOD_5 concentrations will be less than 15 mg/l for discharge flows greater than 1,300 gpm.

[d] Inductively coupled Plasma Emission Spectroscopy detection limit.

Source of Table: WPDES Permit Application (December 1985)
(Revised October 1986)

There may be a small difference in the discharge water quality between summer and winter. This is due only to a change in the water quality of backfill drainage which becomes part of the contaminated mine water. Since backfill drainage is only a small part of the contaminated mine water, the difference in the quality of the effluent between summer and winter is not appreciable. Thiosulfate may be present at a somewhat higher concentration in the effluent in the winter than in the summer. The average thiosulfate concentration may range from 20 to 60 mg/L over the year.

As noted in Table 6-5, some effluent concentrations in the discharge to Swamp Creek will be sensitive to the flowrate of mine seepage. The components that are introduced into the contaminated mine water through backfill drainage will have flow sensitive concentrations. These components include chromium (VI), cyanide and total dissolved solids. The calculated concentrations of these three components at three mine inflow rates are shown below:

	Calculated Swamp Creek Effluent Concentration (mg/L)		
	Total Mine Seepage Flow (gpm)		
Component	950	1,270	2,000
Chromium (VI)	0.016	0.012	0.008
Cyanide	0.008	0.006	0.004
Total Dissolved Solids	800	700	600

Additionally, the BOD concentrations in the effluent to Swamp Creek will be slightly affected by variations in mine seepage rate. Since the treated sanitary effluent will be diluted to a lesser extent at low mine inflows. However, at a low mine inflow of 950 gpm, the addition of sanitary effluent containing 30 mg/l of BOD at a flow of 15 gpm to the mine water would increase the overall BOD concentration in the combined effluent by less than 0.5 mg/l.

As discussed in this section, the final effluent quality is predicted to meet all of DNR's proposed effluent limitations. If, for some unanticipated reason, effluent quality does not meet effluent limitations during the mine development period, the RO/VCE/crystallizer systems will be available to provide additional treatment until process optimization can be completed. Provisions have likewise been made for installation of additional RO/VCE capacity should these unit operations be required in the long-term.

The maximum water discharge quantity is estimated to be 3,000 gpm. Discharge at this rate assumes maximum mine flows occur simultaneously with seepage from backfill sands. These events are combined with the assumption that the mill is not operating and that mill circuit water is being discharged after treatment to reduce reclaim pond water level. It is very unlikely that this discharge flow would be realized on a long-term basis. Although this maximum discharge is conceivable, the water quality would meet the discharge effluent standards for Swamp Creek below Rice Lake.

An estimate of the make-up of the maximum water discharge value is presented below:

Source	Flow (gpm)	
Intercepted Groundwater	1,200	
Contaminated Mine Water	1,360	(includes 160 gpm backfill sand seepage)
Treated Reclaim Pond Recycle Flow	440	
Total	3,000	

The volume of precipitation that would accumulate in the tailings ponds and reclaim ponds from a 25-year 24-hour rainfall event could be treated and discharged in 33 days at a flowrate of 440 gpm. Alternatively if the 190 gpm of mine water normally added to the recycle water treatment system was discontinued and only reclaim pond water was used as the feed to this treatment system, the water from this rainfall event could be handled by treating 250 gpm of reclaim pond water for discharge for the 33 day period. In either approach, the duration of treating and discharging reclaim pond water to remove excess rainfall could be varied by increasing or decreasing the treatment rate.

6.6 TREATED PROCESS WATER QUALITY

In addition to the precipitation/sedimentation and filtration unit processes in the Contaminated Mine Water Treatment System, the Recycle Water Treatment System includes additional processes for removal of virtually all inorganic salts. These additional unit processes (RO and VCE) are extremely expensive (both capital and annual O&M) but are necessary to meet NSPS requirements for zero discharge from the process water circuit.

In certain circumstances it is possible that water may have to be treated for discharge through the Recycle Water Treatment System. For example, if there is an extremely high rainfall during a single season, the freeboard in the reclaim ponds may be decreased. In such a case, it may be necessary to discharge excess water through the Recycle Water Treatment System. The Water Use Model projection for the steady-state composition the RO/VCE treated mine water/process water blend is presented in Table 6-6. The blend used in this projection was 190 gpm mine water and 610 gpm

Table 6-6
PROJECTED WATER QUALITY OF RO/VCE TREATED MINE WATER/RECLAIM WATER BLEND[a]

Constituent	Concentration[b,c]
Cations	
Ag	0.0007
Al	<0.001
Ba	0.0007
Ca	1
Cd	0.0008
Cr	0.002
Cu	0.0008
Fe (Total Iron)	<0.001
Hg	<0.0001
K	1
Mg	0.2
Mn	0.001
Na	30
Pb	0.0008
Se	0.005
Zn	0.002
Anions	
As	0.004
CO_3	<1
Cl	0.2
CN	0.0008
F	2
HCO_3	9
NO_3	0.3
PO_4	0.2
SO_4	60
S	0.002
S_2O_3	2
CO_2	20
Miscellaneous	
SiO_2	2
Hardness	3
pH	7
TDS	100
TSS	<1

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[a] Blend = 190 gpm mine water and 610 gpm reclaim water.
[b] All values except pH are mg/L.
[c] Projected concentrations are based on water use model predictions under summer conditions.

Source of Table: "Water Model Projections of Effluent Composition from the Water Treatment Facility" (Exxon Minerals Company, 1985) reclaim pond water which represents the average influent to the RO/VCE circuit. This projection is based on summer conditions as this would be the most likely time that excess water would need to be discharged.

The water use model used for the Crandon Project does not predict any organics removal in either the RO or VCE unit operations. This assumption was based on the fact that if influent organics become a problem, powdered activated carbon would be added at the neutralization reactor to remove organics prior to the RO. The assumption of zero removal is conservative because the RO would, in fact, remove most of the high molecular weight reagents used in the mill. Of the reagents or decomposition products which are retained by the RO membranes, those compounds with boiling points above about 215° would primarily stay in the VCE/crystallizer brine product. Because of both process pretreatment requirements and incidental removals, the concentration of organics in effluent from the RO/VCE will be very low.

A blend of RO/VCE treated process water and lime/sulfide treated mine water is projected to be of a higher quality than the treated mine water alone. This can be seen by comparing Tables 6-5 and 6-6.

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SECTION 7
Sludge Generation and Disposal

Section 7
SLUDGE GENERATION AND DISPOSAL

Sludge will be generated by five unit operations within the plant: contaminated mine water lime softener, intercepted groundwater lime softener, reclaim/contaminated mine water lime/soda softener, brine softener, and crystallizer centrifuge. The first four sludges will be routed to a common sludge transfer tank, combined with centrifuge washwater and various line flushes, and pumped to the tailing thickener underflow sump for disposal in the tailings pond.

Dewatered brine from the crystallizing evaporator/centrifuge will be essentially pure sodium sulfate and sodium thiosulfate with minor calcium, magnesium, silica, and chloride impurities. The dewatered brine will be discharged to a storage bin. At this point it will be very warm and will still contain 5 to 20 percent water by weight. As the brine cools, it will solidify into a mixture of anhydrous sodium sulfate (Na_2SO_4), sodium sulfate decahydrate ($Na_2SO_4 \cdot 10\ H_2O$) and some sodium thiosulfate ($Na_2S_2O_3$). Depending on the humidity of ambient air, some moisture will be absorbed by the brine as it cools. No "free" water will remain.

Once the mill is started up and operation of the treatment system stabilizes, there is a possibility that the solidified brine product can be sold as a sodium sulfate byproduct. (Sodium sulfate is used in the kraft pulp and paper process and in detergent manufacturing). Provisions have been made for crystal washing in the centrifuge to remove chlorides and other undesirable water-soluble impurities that could exceed product specifications.

Full-scale operating experience, in-depth market analysis, and production of product from the full-scale system will be necessary before any firm market could be developed for the product. Quantities and characteristics for each of the projected sludge streams are shown on Table 7-1.

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Table 7-1
ESTIMATED SLUDGE PRODUCTION[a]

	Contaminated Mine Water Lime Softener Sludge	Intercepted Groundwater Lime Softener Sludge	Reclaim/Minewater Lime-Soda Softener Sludge	Brine Softener Sludge	Combined Sludge to Tailings Pond[b]
$CaSO_4$, lb/d				970	970
$CaCO_3$, lb/d			9,500	190	9,700
$Mg(OH)_2$, lb/d	410	160	150	130	860
$Fe(OH)_3$, lb/d	140	50	120	5	310
$Zn(OH)_2$, lb/d	270	5	130	trace	400
$Al(OH)_3$, lb/d	20	trace	40	40	110
CaF_2, lb/d	20	5	70		90
SiO_2, lb/d				20	20
Silt, Misc., lb/d	12,500	210	3,700		16,400
Total Solids, lb/d (dry basis)[b]	13,300	430	13,700	1,360	28,800
pH	10.5	10.5	10.5	10	10.5
gpm	18	0.6	19	1.8	40
% W Solids	6	6	6	5	6
Volume (cfd)	3,500	110	3,600	350	7,500

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[a] Centrifuge product = 20,700-22,600 lbs/day (based on 80-90 percent solids in product) after equilibration with ambient air (contains 18,800 lb/day anhydrous Na_2SO_4 and $Na_2S_2O_3$, plus minor impurities and water of hydration). Volume = 163 to 178 cfd at 127 lb/cf. This sludge stream will be disposed separately from the sludges routed to the tailings pond.

[b] Totals may not add due to rounding.

SECTION 8
Construction Schedule

Section 8
CONSTRUCTION SCHEDULE

Based on current projections, Exxon anticipates that construction of the mine shaft will begin early in 1988. During the first few months of actual construction, water encountered in the mine will be at very low flow rates and will be essentially uncontaminated groundwater as shaft sinking will be in the hanging wall and not within the ore body. During these first few months, mine water will be treated through an oil/water separator and discharged. The Excess Discharge Lagoon will be completed by month 9 of construction and will be available then for water storage. However, it is not expected that contaminated water will be encountered until completion of shaft sinking and beginning of lateral development which will occur about month 20 of construction. The first reclaim pond will be completed at month 20 of construction. Exxon projects that the flowrate of contaminated mine seepage water will be low throughout the construction period.

During the mine development period the entire water treatment system described in Section 5 will be constructed. The building will be built with sufficient floor space for the future addition of 3 RO modules, the second VCE, controls, and auxiliaries necessary to process both the contaminated mine water and recycle water through RO and VCE. The future facilities, however, would be installed only if necessary to meet discharge limits.

The preliminary schedule for construction of the water treatment plant was developed around the following key dates:

Start of structural excavation	Month 5 of construction
Softening, filtration, chemical feed systems construction complete	Month 19 of construction
RO construction complete	Month 22 of construction
VCE, crystallizer construction complete	Month 24 of construction

The schedule permits startup and shakedown of the entire water treatment plant prior to encountering significant quantities of mine water.

In the event that treated water from the softening/filtration system does not meet effluent limitations during the startup of the system, effluent would be recycled to the reclaim pond. Based on current projections of mine water flowrates during construction, the pond has the capacity to contain all mine water through the startup of the mill, well after projected startup of the entire treatment system.

The scope of work for construction, as reflected in the schedule, was developed from material take-offs (MTO's) quantities with appropriate take-off allowances from preliminary drawings and sketches developed by CH2M HILL.

Refinements in the approaches to accomplishing that scope are expected during final design. Major concept changes in the approach to executing the work may render the key dates unachievable.

Durations of specific activities were developed based on labor unit man-hours provided by Exxon Minerals Company.

8.1 ASSUMPTIONS

- Serious abnormal weather conditions may occur, such as severe winter storm conditions. If such conditions are encountered, some double-shifting will be necessary to meet the schedule shown.
- Any permits necessary will be granted in a timely and expeditious manner.
- No construction contract multiple shifting or extended overtime is incorporated in scheduled contract durations.
- Extensive craft labor strike disruptions will not occur. Availability of craft labor will not cause delays. Specialty crafts such as pipefitters capable of welding stainless steel and Alloy 20 were assumed to be available for the Crandon project.
- Wisconsin Department of Natural Resources (DNR) review and approval activities were not considered during the development of this schedule.

8.2 SCHEDULE DISCUSSION

Construction work will begin with the building construction. Following completion of the floor slab at grade level, equipment foundations and other concrete work will commence. As equipment foundations are completed equipment will be installed. As many as three equipment installation crews will be working concurrently. At such time as major equipment installation is approximately 65 percent complete pipe installation will commence. This schedule assumes that equipment will be ordered in adequate time to be available for installation when needed.

SECTION 9
Manpower Requirements

Section 9
MANPOWER REQUIREMENTS

9.1 OPERATION

Full-time, round-the-clock, local operator attention is required, 7 days per week. As a minimum, one operator per shift is required, with at least half-time supervisor attention on day shift, Monday through Friday. A full-time chemist will be required in the mill laboratory during the day shift to handle the routine water testing required.

Table 9-1 illustrates routine operator duties that should be assigned to the operations staff. Note that with only one operator per shift, assistance from operators in the nearby lime/soda ash building will be needed for daily makeup of polymer, sodium sulfide, ferric sulfate, and soda ash feed tanks.

At least one or two additional operators should be trained in operation of the system to perform operator functions during vacations, sick leave, etc., for the normal operations staff. All operators require a minimum of 3 to 4 weeks of training prior to plant startup to receive instruction in operation of the system. Supervision of the treatment plant will be provided and effluent monitoring and testing will be coordinated through the laboratory staff.

9.2 MAINTENANCE

Maintenance will be performed by Exxon maintenance crews or by local contractors, as appropriate. The RO system, VCE, and crystallizing evaporator processes are all relatively complex and, therefore, may require special training for mill maintenance crews.

Based on similar systems designed by CH2M HILL for electric utility and oil production industries, as many as four full-time maintenance personnel will be required, with extra help required for specialty and heavy maintenance.

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Table 9-1
WATER TREATMENT SYSTEM OPERATOR DUTIES

Item	Frequency	Remarks
Mix Polymer	Daily	Maximum one day to be mixed at any time.
Mix Ferric Sulfate	Daily	Maximum one day to be mixed at any time.
Fill Reagent Day Tanks	Daily	
Inventory and Order Fresh Chemical Supplies	Monthly	Coordinate with mill personnel.
Calibrate pH Elements	Daily	
Calibrate Conductivity Elements	Daily	
Calibrate Turbidity Elements	Daily	
Collect Influent, Effluent, Sludge Samples for Testing	Daily	
Perform Control Tests in Laboratory	2-3/shift	
Walk-Through Inspection of All Equipment	4/shift	
Inspect and Adjust Control Set Points and Pumping Rates	4/shift	
Recordkeeping	Daily	Includes changing charts, reporting and compiling data, etc.
Clean/Disinfect RO Membranes	Weekly	4-hour effort.
Preventative Maintenance and Lubrication	Daily	
Cleanup/Housekeeping	Daily	
Inspect Filter Media for Fouling	Daily	
Dried Brine Disposal	Daily	
Seed Evaporator	Twice/year	24-hour effort.

SECTION 10
References

Section 10
REFERENCES

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APPENDIXES

APPENDIX A

SUMMARY OF WATER TREATMENT TEST RESULTS

INTRODUCTION

This appendix presents a summary of the results of water treatment testing undertaken in 1984 to support engineering and permitting activities for the Crandon Project.

Section 3.0, Project Water Management, of CH_2M Hill's engineering report shows that excess mine water including contaminated mine water and intercepted ground water will have to be discharged from the Project. Excess water discharged from the Project will have to meet water quality effluent limits that will be set by the State for discharge to Swamp Creek. To meet these effluent limits, the excess contaminated mine water will require treatment and the intercepted ground water, depending on its quality, may require treatment. A portion of the water from the process water reclaim ponds will have to be treated to reduce the concentration of total dissolved solids for reuse in the mill. The proposed treatment process for the two types of mine water consists of precipitation of heavy metals followed by clarification, filtration, and pH adjustment. The proposed treatment of process water for recycle consists of lime/soda ash softening, clarification and filtration, reverse osmosis, and evaporation.

The purpose of the treatment test work described in this appendix was to provide data for process design consideration during final engineering of the water treatment plant and to demonstrate the performance of the proposed water treatment processes.

Water treatment testing for this Project was conducted by Exxon Research and Engineering (ER&E) in Florham Park, New Jersey and by the Minerals Processing Research Division (MPRD) of Exxon Minerals Company in Houston, Texas. Details of the test work are presented in the following reports:

1) Exxon Research and Engineering, 1984, Crandon Project Water Treatment Testing Program: Florham Park, New Jersey.

2) Exxon Minerals Company, Minerals Processing Research Division, 1984. Water Treatment Testing - Crandon Project: Houston, Texas.

OBJECTIVES

The overall objectives of the testing programs were as follows:

1) Investigate the effectiveness of lime precipitation and filtering in removing heavy metals from contaminated mine water and intercepted ground water;

2) Investigate potential improvements to the lime precipitation process including the use of additives such as sodium sulfide and insoluble starch xanthate; and

3) Investigate the effectiveness of lime/soda ash softening and filtration as a pretreatment process for recycle water ahead of reverse osmosis treatment.

The specific objectives for the work conducted by ER&E were as follows:

1) Determine reagent dosages for lime precipitation treatment of contaminated mine water and determine the quality of resulting effluent;

2) Determine if certain additives to the lime precipitation process would result in a better effluent; and

3) Determine lime and soda ash dosages for softening treatment of recycle water and evaluate the degree of hardness (calcium and magnesium) reduction and the suitablity of pretreated recycle water as feed for reverse osmosis.

Based on the early test results obtained by ER&E, a separate treatment testing program was developed for MPRD with the following objectives:

1) Further evaluate the use of sodium sulfide and insoluble starch xanthate as additives to the lime precipitation process for treating contaminated mine water; and

2) Determine if the lime precipitation or lime and sulfide precipitation processes are effective in treating intercepted ground water.

It was not the intent of either laboratory to optimize treatment test conditions nor to determine the best flocculant to be used in clarification processes. Truly optimum conditions can only be determined in actual plant operation. The results described in this report are laboratory results and they should be taken only as an indication. Actual plant results could be different.

SCOPE OF WORK

Since actual Project water was not available, the three types of water in question (contaminated mine water, intercepted ground water, and recycle water) were simulated for testing purposes by adding various chemicals to well water obtained from the project site. The water was simulated to reflect the projected water composition at the time of the testing. Since 1984 there has been a change in the project basis which has caused a change in the projected recycle and contaminated mine water composition. These compositional changes, however, do not affect the results or conclusions of this study.

Tests conducted by each laboratory included batch jar tests and continuous, pilot scale treatment tests. Water treatment jar tests were conducted using a standard test apparatus in which six tests could be conducted at one time. Jar tests were used primarily to determine reagent dosages, determine the effects of various flocculants on precipitate settling, evaluate the use of various additives to augment lime precipitation, and select conditions to be used in the continuous treatment tests. Jar test effluents were filtered through a 0.45 micrometer membrane filter and acidified for analysis.

The continuous treatment tests conducted by ER&E on contaminated mine water included lime precipitation, clarification, sludge recycle, and dual media (silica sand and anthracite) filtration. Samples of filtrate from the dual media filter were acidified and analyzed for metal content. Similar continuous treatment tests were conducted on recycle water utilizing soda ash in conjunction with lime for calcium and magnesium precipitation. The influent flow rate to ER&E's continuous treatment pilot unit was about 1 liter per minute.

Continuous treatment tests were run by MPRD on simulated contaminated mine water and intercepted ground water to further evaluate the use of sulfide precipitation in conjunction with lime precipitation. These tests were similar to those conducted by ER&E except that the influent flow rate was about 0.1 liter per minute and dual media filtration was not used. Samples of clarifier overflow were filtered through 0.45 micrometer membrane filters and acidified for metals analysis.

The scope of work for treatment testing of contaminated mine water and recycle water conducted by ER&E was thoroughly reviewed with the DNR at a March 1, 1984 meeting. As part of their verification effort, personnel from the DNR visited ER&E's laboratory on May 16 and 17, 1984 to observe treatment tests in progress and obtain samples of water for analysis.

RESULTS

The results of the jar testing contained in Table A-1 suggest that the lime precipitation alone might not be sufficient to insure compliance with the proposed cadmium effluent limitation. The utilization of lime and sodium sulfide jointly resulted in an improvement in heavy metal removal. The remainder of the testing program was focused upon further investigation of the lime and lime/sulfide processes in a continuous testing mode.

Other additives to lime precipitation were investigated in the jar tests conducted by ER&E. These included insoluble starch xanthate, activated carbon, clay, ferric sulfate, and soda ash. The combination of lime and starch xanthate was also successful in removing metals to concentrations below the effluent limits. However, starch xanthate is considerably more costly than sodium sulfide. The other additives that were tested did not appear to offer any advantages in improving the removal of heavy metals.

Continuous treatment tests were performed on simulated contaminated mine water by ER&E and MPRD. The objectives of these tests were to determine the effectiveness of continuous lime precipitation and to further evaluate the use of lime/sulfide precipitation. Results of the continuous treatment tests are presented in Table A-2. The continuous tests performed by ER&E used lime precipitation with sludge recycle, clarification, and dual media filtration. This testing essentially confirmed the results of the jar tests. An improved analytical technique for mercury (closed loop cold vapor AA) was employed on the effluent and the concentration was less than 0.0001 mg/l by lime precipitation.

The continuous tests performed by MPRD used lime precipitation with sludge recycle and clarification. The clarified effluent was filtered through 0.45 micrometer membrane filters and acidified prior to analysis. Comparison of results of the two laboratories and the two techniques reveals very similar results. Cadmium concentration in the MPRD effluent was substantially lower than in the ER&E results. The use of sodium sulfide in conjunction with time in the MPRD continuous testing resulted in significantly lower concentrations of heavy metals in the effluent.

The concentrations of all metals, with the exception of zinc, in the effluent were less than the detection limit for the respective analytical method used. Zinc removal was calculated to be 99.9% for both methods of precipitation. Therefore, the chemistry of lime and sulfide precipitation indicates that the effluent limits for Swamp Creek should be achieveable.

The results of continuous pilot scale treatment tests performed by MPRD on simulated intercepted ground water using lime precipitation are presented in Table A-3. These data indicate that treatment of intercepted ground water by either lime precipitation or lime and sulfide precipitation will result in an effluent chemistry which meets the DNR proposed effluent limits for Swamp Creek. Compared with lime precipitation, the use of lime and sulfide precipitation appears to offer more complete removal of cadmium, chromium, and selenium. Arsenic in the feed water was at 0.44 mg/l; the lime/sulfide precipitation effluent contained 0.36 mg/l of arsenic for only about 20% removal. Arsenic was present as the arsenite anion, $AsO_3^=$, and its main mechanism for precipitation is adsorption on other metal hydroxides, particularly iron.

Lime/soda ash softening tests were performed by ER&E on simulated recycle water. Recycle water will normally consist of about 80% water from the reclaim pond and 20% of contaminated mine water. These tests were conducted with water that represented a blend of 67% reclaim pond water and 33% contaminated mine water. This difference will have no effect on the conclusions of the testing. The specific objectives of these tests were to (1) achieve the necessary reduction in calcium and magnesium hardness to prevent scaling in the reverse osmosis process, and (2) to attain a silt density index low enough to ensure that the performance of the reverse osmosis membranes will not be affected by fouling from fine particulate matter. Data for the continuous softening test is presented in Table A-4. Calcium and magnesium were reduced to levels that will preclude scaling in the reverse osmosis membranes. The silt density index of 2 attained on the effluent from the continuous pilot scale test is well below the acceptable value of 5 for spiral wound reverse osmosis membranes. This indicates that fouling of membranes due to fine particulates should not be a problem.

SUMMARY

The following summary is based on the water treatment testing conducted by ER&E and MPRD:

1) The proposed treatment process for contaminated mine water and intercepted ground water consists of lime and sulfide precipitation, clarification and filtration. Test work reported here shows that under laboratory conditions with simulated feed, an effluent that meets the effluent limits was achieved.

2) For most heavy metal parameters, the test data (soluble metal concentrations) for lime and sulfide precipitation show substantial margin between the concentration in the test effluent and the monthly average effluent limit for Swamp Creek. The actual treatment plant may not produce an effluent with exactly the same chemistry as the test effluents; however, the difference between the effluent limit and the concentration in test effluents indicates that adequate margins exist to cover the differences that generally occur between ideal laboratory conditions and actual daily plant operations.

3) Lime/soda ash softening, clarification and filtration pretreatment testing of recycle water achieved the necessary reduction in calcium and magnesium hardness and a silt density index value characteristic of acceptable feed to reverse osmosis treatment.

TABLE A-1

JAR TESTING OF SIMULATED CONTAMINATED MINE WATER (1,2)

	Chemical Analyses, mg/l			
Constituent	Influent (Simulated)	Lime Precipitation	Lime/Sulfide Precipitation	DNR Proposed Effluent Limits for Swamp Creek(3) (mg/l)
Arsenic	< 0.015	< 0.015	(0.017)	0.55
Cadmium	0.11	(0.0026)	< 0.0001(4)	0.001
Chromium (Total)	(0.0022)	< 0.002	(0.0024)	0.216(5)
Copper	0.055	(0.0035)	< 0.001	0.02
Lead	(0.022)	< 0.009	(0.012)	0.076
Mercury	--	--	< 0.0003(6,7)	0.0002
Selenium	0.041	0.062	0.066	0.14
Silver	0.046	(0.0023)	<0.0014	0.007(8)
Zinc	12.6	(0.0029)	<0.001	0.12
Barium	0.010	0.0065	0.0055	9.2
Iron	0.090	(0.0033)	<0.002	1.6

(1) All tests performed by ER&E. Precipitation pH was 10.3. All analyses were performed by Inductively Coupled Plasma Emission Spectroscopy (ICPES) unless otherwise noted. All analyses performed on samples that were filtered at 0.45 um and then acidified.

(2) Data in parentheses indicates that value is between detection limit and 3 times the detection limit.

(3) Monthly average values for 2000 gpm discharge, except as noted.

(4) Analyzed by graphite furnace atomic absorption spectroscopy.

(5) Value for total chromium; Cr^{+3} = 0.200, Cr^{+6} = 0.016 mg/l.

(6) Analyzed by open loop cold vapor atomic absorption spectroscopy; detection limit for ER&E Laboratory was 0.0003 mg/l.

(7) Backup sample sent to Aqualab was analyzed to be <0.0001 mg/l.

(8) Allowable daily maximum; no monthly average value listed.

TABLE A-2

CONTINUOUS PILOT SCALE TREATMENT TESTS ON SIMULATED CONTAMINATED MINE WATER

Chemical Analyses, mg/l (1), (2)

	Lime Precipitation				Lime/Sulfide Precipitation		DNR Proposed Effluent Limits for Swamp Creek mg/l(6)
	MPRD (3)		ER&E (4), (5)		MPRD (3)		
Parameter	Feed(14)	Effluent	Feed(12)	Effluent	Feed(14)	Effluent	
Arsenic	0.024(7)	<0.01(7)	<0.015	<0.015	0.024(7)	<0.01(7)	0.55
Cadmium	0.052(7)	0.0002(7)	0.038	0.0028	0.052(7)	<0.0001(7)	0.001
Chromium (Total)	0.32	(0.007)	0.0044	(0.0033)	0.32	<0.005	0.016(8)
Copper	0.16	<0.005	0.010	0.0036	0.16	<0.005	0.02
Lead	0.34(7)	<0.01(7)	0.10	<0.009	0.34(7)	<0.01(7)	0.076
Mercury	<0.0001(9)	<0.0001(9)	—	<0.0001(10)	<0.0001(9)	<0.0001(9)	0.0002
Selenium	0.08(7)	<0.01(7)	0.034	(0.028)	0.08(7)	<0.01(7)	0.14
Silver	0.002(7)	<0.0005(7)	0.0019	0.0032	0.002(7)	<0.0005(7)	0.007(11)
Zinc	16.5(7)	0.023	4.44(13)	0.0078	16.5(7)	0.016	0.12
Barium	0.022	0.047	0.011	0.0098	0.022	<0.001	9.2
Iron	5.8	0.079	0.087	0.013	5.8	<0.005	1.6

Notes

(1) All Analyses were performed by Inductively Coupled Plasma Emission Spectroscopy (ICPES) unless otherwise noted.
(2) Data in parentheses indicates that value is between detection limit and 3 times the detection limit.
(3) MPRD; Mineral Processing Research Laboratory of Exxon Minerals Company.
(4) ER&E; Exxon Research and Engineering Company.
(5) Average results for two 8-hour tests.
(6) Monthly average values for 2000 gpm effluent, except as noted.
(7) Analyzed by graphite furnace atomic absorption spectroscopy.
(8) Value for total chromium; Cr^{+3} = 0.200, Cr^{+6} = 0.016.
(9) Analyzed by cold vapor, closed loop atomic absorption spectroscopy.
(10) Composite sample from two 8-hour tests that was analyzed by Exxon Minerals Company using cold vapor, closed loop atomic spectroscopy.
(11) Allowable daily maximum; no monthly average value listed.
(12) Value is for feed filtered at 0.45 micrometer.
(13) Analysis of unfiltered feed was 11.6 mg/l Zn indicating that some was precipitating in the feed.
(14) Unfiltered feed.

TABLE A-3

CONTINUOUS TREATMENT TESTS ON SIMULATED INTERCEPTED GROUND WATER (1)

	CHEMICAL ANALYSES, mg/l(2)				DNR Proposed Effluent Limit for Swamp Creek (mg/l)(4)
	Lime Precipitation(3)		Lime/Sulfide Precipitation(3)		
Constituent	Feed	Effluent	Feed	Effluent	
Arsenic	0.44(5)	0.42(5)	0.44(5)	0.36(5)	0.55
Cadmium	0.029(5)	0.0002(5)	0.029(5)	<0.0001(5)	0.001
Chromium (Total)	(0.011)	(0.007)	(0.011)	<0.005	0.216(6)
Copper	0.122	<0.002(5)	0.122	<0.002	0.02
Lead	0.026	<0.010	0.026	<0.010	0.076
Mercury	<0.0002(7)	<0.0002(7)	<0.0002(7)	<0.0002(7)	0.0002
Selenium	0.020(5)	0.015(5)	0.020(5)	<0.010(5)	0.14
Silver	<0.0005(5)	<0.0005(5)	<0.0005(5)	<0.0005(5)	0.007(8)
Zinc	0.38	<0.003	0.38	<0.003	0.12
Barium	0.018	<0.001	0.018	<0.001	9.2
Iron	0.38	<0.005	0.38	<0.005	1.6

(1) All work performed by Mineral Processing Research Laboratory of Exxon Minerals Company.

(2) All analyses were performed by Inductively Coupled Plasma Emission Spectroscopy (ICPES) unless otherwise noted. Data in parenthesis indicates that value is between detection limit and three times the detection limit.

(3) Results of single 5-hour continuous tests; results for last hour of test are reported.

(4) Monthly average values, except as noted.

(5) Analyses performed by graphite furnace atomic absorption spectroscopy.

(6) Value for total chromium; Cr^{+3} = 0.200, Cr^{+6} = 0.016.

(7) Analyzed by cold vapor, closed loop atomic absorption spectroscopy.

(8) Allowable daily maximum; no monthly average value listed.

TABLE A-4

LIME SODA ASH SOFTENING AND FILTERING TESTS ON SIMULATED RECYCLE WATER(1)

Chemical Analyses, mg/l(2)

Constituent	Jar Test Influent	 Effluent	Continuous Test(2) Influent	 Effluent
Silt Density Index(3)	--	--	--	2
Calcium	306	18.1	434	35.2
Magnesium	11.3	6.6	12.5	3.2

(1) All work performed by ER&E

(2) Average results for two 8-hour tests.

(3) Silt density index is a common parameter for determining suitability of pretreated water as reverse osmosis feed.

APPENDIX B

RECLAIM POND DESIGN AND OPERATION

The purpose of this appendix is to present the preliminary engineering plans for the water reclaim ponds for the Crandon Project. The reuse of process water will be an important feature of the Project. The use of the water reclaim ponds, along with the reverse osmosis treatment of a portion of the recycle water, will ensure the ability to successfully recycle water to the mill.

The primary functions of the reclaim ponds will be as follows:

1) Provide water surge capacity for all process-related surface facilities;
2) Allow sufficient residence time for settling of fine particulate matter;
3) Allow sufficient residence time for natural evaporation, oxidation, and biological processes to occur and thereby control the concentrations of certain chemical constituents in the water to be recycled to the mill; and
4) Utilize reclaim pond cell A for storage of mine water during construction.

Details of the pond design, water pumping systems, and pond operation are discussed below.

Reclaim Pond Design

The location and orientation of the two reclaim ponds at the north side of the mine waste disposal facility (MWDF) are shown on Figure B-1. This location will have the least operating cost and land disturbance. The ponds will serve mainly to hold and transfer water between the MWDF and the mill and a location between the two facilities will minimize the water handling system. The ponds will allow fine particulates to settle out from the water decanted from the tailings pond and from process water for recycle to the concentrator. Concentrations of organic compounds (collectors and frothers) will be reduced to levels that will allow successful recycle of water to the concentrator by aging for a sufficient time (approximately 32 days).

The retention volume in the reclaim ponds and tailings ponds will provide surge capacity for the water management system. The ponds are designed to ensure that temporary interruptions of service of any of the components in the system do not cause a complete shutdown of the mine or concentrator. When water in the reclaim ponds is at the normal operating level, there is water surge capacity in the freeboard depth of the ponds. Reclaim pond cell A has a design freeboard of 13 feet above normal operating water level and reclaim pond cell B has 10 feet. Approximately 50 percent of the freeboard volume in the reclaim ponds will hold 30 days of water flow at a rate of 1,385 gallons per minute. The freeboard in the reclaim ponds is designed to contain the volume of the probable maximum precipitation (PMP) event including the PMP volume in the largest tailing pond. The excess freeboard volume capacity, after storage of the PMP event, is still sufficient to hold approximately 20 days of mine water discharge at 1,385 gallons per minute. The two pond system will ensure adequate retention time and prevent short circuiting of water through the system.

Retention of the recycle water in the reclaim ponds will promote the natural oxidation of thiosulfate and other polythionates to sulfate. To neutralize the acid generated from thiosulfate oxidation, lime will be added to the water where it flows from pond cell B to pond cell A. As shown on Figure B-4, a mixing box will be used to assure proper mixing of the lime with the water.

On the basis of fine particulate sedimentation and surge capacity, any reclaim pond retention time in excess of a week should be adequate. Organic and thiosalt removal will require more time and can be affected by seasonal temperature changes. If one pond is temporarily removed from service, the retention time will be reduced from approximately 32 to 16 days, but there should be no long-term detrimental effect.

The operating storage volume of the two reclaim ponds is similar.

The estimated reclaim pond dimensions will be:

	Estimated Dimensions	
	Reclaim Pond Cell A	Reclaim Pond Cell B
Area Inside Crest (ac)	18	18
Bottom Area (ac)	9	9
Lined Slope Area (ac)	9	9
Maximum Depth (ft)	33	33
Max. Exterior Fill Height (ft)	35	(All in Cut)
Crest Elevation (ft) MSL	1673	1673
Storage Volume (ac-ft)*	220	264

* To normal operating water level. Does not include freeboard volume.

All embankment materials, with the exception of lining and rock slope facing materials, will consist of the soil excavated from the pond interiors. The reclaim ponds' inside embankment slopes will be 1 vertical in 4 horizontal to facilitate installing the pond lining system.

Both ponds will utilize the same lining system consisting of two 36-mil thick chlorosulfonated polyethylene (CSPE) or 40-mil thick polyethylene synthetic membranes separated by an 8-inch sand layer. The bottom membrane will be protected by placing it on a prepared subgrade or base layer as required by the supplier. An 8-inch carbonate-free sand combination underdrain and vent layer placed over the bottom membrane will protect the bottom membrane and serve as the base for the upper membrane. Then the upper membrane will be covered by 1.5 feet of sand. The lining system will be continuous across the pond bottom and sides of the pond. Riprap will be placed along the upper areas of the inside embankments to further protect the lining system and prohibit wave erosion. No leakage is expected through the upper membrane; however, in the event of any upper membrane leakage the drain and bottom membrane will provide additional assurance that no leakage will occur from the facility.

The bottom of the reclaim pond will slope gently (about 1%) from a high point in the center to the inside toe of the pond embankment. Any water entering the underdrain will be collected in a perforated perimeter pipe at the inside toe of the embankments. Six standpipes will be installed in each cell from the perimeter collection pipe to the pond embankment crest. The standpipes will be periodically checked to see if any seepage has entered the underdrain system. The standpipes will be sized to allow insertion of a submersible pump in the event any seepage has to be removed from the underdrain. The 8-inch underdrain and vent sand layer will be thickened in the area of the perimeter pipe and the embankment discharge pipes.

The drain layer will also serve as the venting mechanism for gases that might build up under the upper synthetic liner. Additional perforated pipe running through the center area of the cells, and connected to the perimeter collection pipe, will assure complete venting of the entire pond area. Final venting will be achieved through the standpipes connected to the perimeter collection pipe.

The double liner and underdrain/vent system concept was developed as a precautionary safety feature. In the unlikely event the upper synthetic liner system develops a leak, the leak will be collected in the underdrain and removed. The back-up bottom synthetic membrane will prevent leakage from the underdrain towards the underlying aquifer. Minimal leakage is expected from the upper synthetic liner. Therefore, there will be negligible seepage head on the bottom membrane and consequently negligible seepage loss from the bottom membrane and from the total system.

Two potential membrane liners for the ponds have been identified to date. Chlorosulfonated polyethylene (CSPE) and polyethylene have been suggested as potential liners. The final liner choice and thickness will be determined during final engineering based on additional wastewater and liner compatibility study and the latest available information.

In the event that the liner in one of the ponds had to be repaired, the pond would be drained and the necessary repairs made. There is flexibility in the water management system to allow operations to continue with one pond.

Details of the preliminary design of the reclaim ponds are shown on Figures B-1 through B-6. Basic preliminary material and construction specifications are included on the drawings.

The final engineering plans (construction plans) will include the information noted in the May 29, 1986 DNR letter to Exxon and also all other required information from NR 213.

Reclaim Water Pumping System

The main features of the water handling systems at the reclaim ponds are shown on Figures B-1 and B-4. Thickener overflow and the smaller stream from the tailings pond underdrain and decant systems will provide primary flow to the reclaim ponds. The inflow point to the reclaim pond cell B is shown on Figure B-1, and the water transfer location between the ponds is shown on Figure B-4. The locations were chosen to provide maximum retention time in the system. The water pumping system from pond cell A will return the reclaim water to the mine/mill site for reuse in the ore processing operations.

Vertical shaft, centrifugal pumps mounted on a floating barge approximately 15 x 15 feet in size will be used to return the reclaim water to the mine/mill site. Two 100-hp, 3,460-gallons per minute pumps, one operating and one standby, will provide the necessary pumping capacity. An access bridge will connect the barge to the pond embankment.

Reclaim Pond Operation

The two largest streams that flow to the reclaim pond will contain small amounts of particulate matter. These are estimated as follows:

	Suspended Solids
Tailing Thickener Overflow	100 to 1000 mg/l
Decant and Underdrain Water From Tailing Pond	Trace to 100 mg/l

The amount of settled solids that will accumulate in the reclaim ponds over the life of the Project has been conservatively estimated to be 140,000 cubic yards. This estimate is based on the volume of water expected to flow through the pond with an average suspended solids concentration of 415 ppm, and a settled solids density of 50 percent solids by weight. The estimated 140,000 cubic yards of sludge will consist of tailings silt and calcium carbonate, gypsum, and metal hydroxide precipitates. This volume of sludge can be contained in the reclaim pond system without affecting the operation of the ponds. The settled sludge will occupy 18 percent of the total normal operating volume and will occupy a depth of 4.8 feet if divided evenly between the two ponds.

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

If removal of settled solids from the reclaim ponds is necessary, suitable methods will be used that would not damage the pond liner and still allow continued operation of both ponds. A small floating suction dredge with depth control on the suction head could be used. In practice, a small depth of settled solids (approximately 1.0 foot) would not be removed to maintain an additional layer over the liner. If the estimated 140,000 cubic yards of settled solids were distributed evenly over the final tailings surface of pond T4, the depth of sludge would be approximately 0.8 foot. During reclamation of tailings pond T4, there will be ample time for proper management of the sludge through drying or blending with tailings or cover soil. The sludge could also be incorporated into the thick till grading layer planned as the first stope in reclamation of the tailings pond.

Retention of water in the reclaim ponds will promote the oxidation of thiosulfate and other polythionate compounds to sulfate. During warm weather, this process will occur rapidly and will slow down in the winter months. The concentrations of these compounds will generally be reduced by about 90 percent in summer and 10 percent in winter.(1) Lime will be added to the water where it flows from cell B to cell A to neutralize the acid formed as a result of thiosulfate oxidation (see Figure B-4).

Based on summer conditions, with the highest necessary pH adjustments, approximately 500 pounds per day of lime will be added in the reclaim ponds. Lime addition is not expected to be required in the winter months.

(1) Letter, B. J. Hansen, Exxon Minerals Co., to R. H. Ramharter, DNR June 2, 1982.

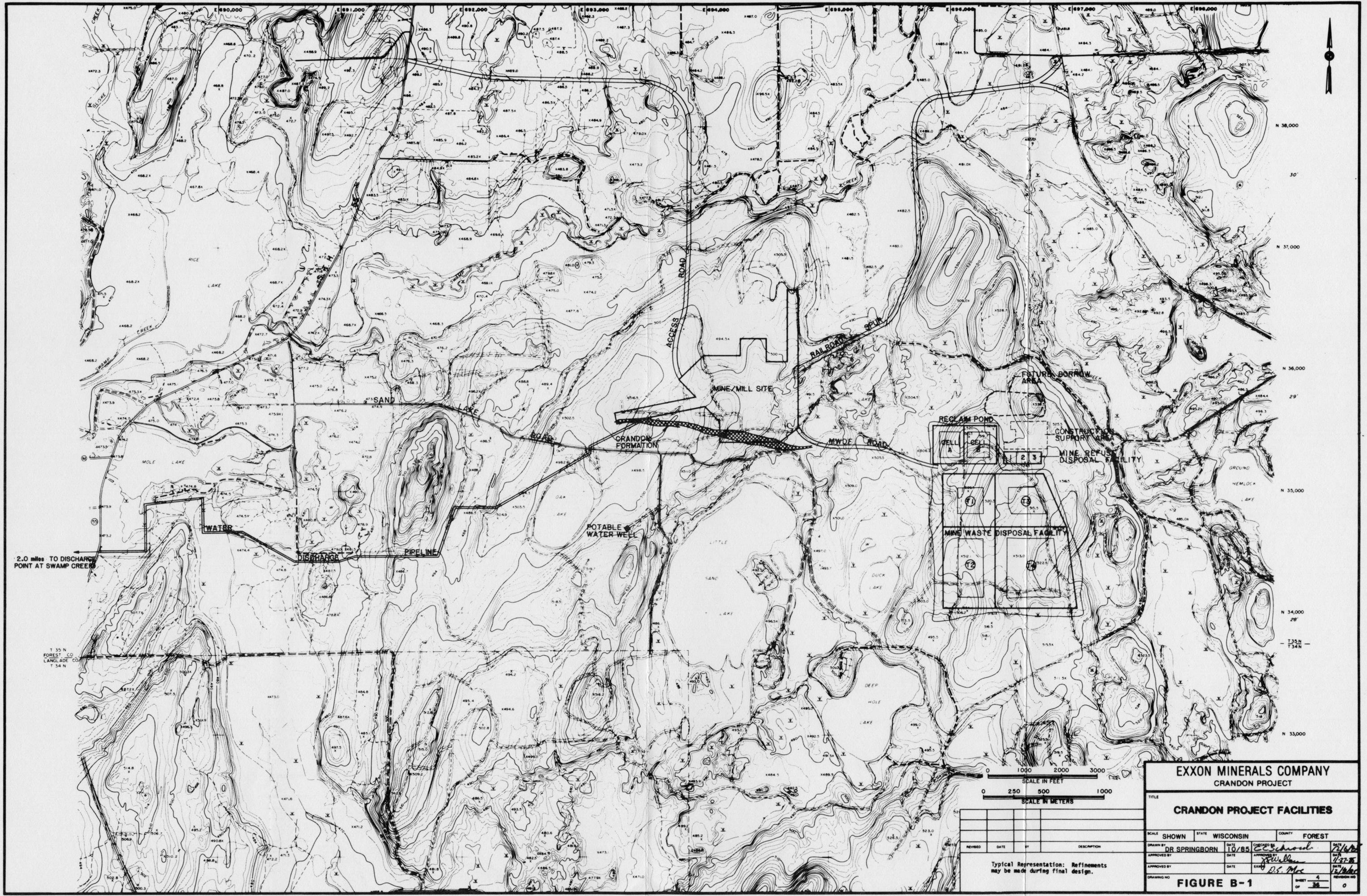
The reclaim ponds will promote oxidation processes and are designed for a normal operation depth of 23 feet or less. Therefore, it is unlikely that the deeper portions of the pond will become anaerobic. However, in the unlikely event that an anaerobic condition does exist and hydrogen sulfide is generated at depth, it would not reach the surface of the pond because it would be oxidized to thiosulfate by other polythionates. The unlikely presence of trace concentrations of hydrogen sulfide in water from the reclaim ponds would not be detrimental to either the water treatment plant or the milling process.

Most of the cyanide added in the mill process will exist in the form of an insoluble complex of ferric ferrocyanide precipitate on pyrite in the tailings pond and in backfilled stopes. The total cyanide concentration of water entering the reclaim ponds is estimated to be about 0.10 mg/l and final reclaim pond effluent is expected to contain 0.02 mg/l. Most of this cyanide will exist as complex ions rather than the toxic, free cyanide ion form. Factors causing natural degradation of cyanide include photodecomposition by sunlight, acidification, oxidation by oxygen in the air and biological action. Cyanide will be converted to hydrocyanic acid which will evaporate. When more complete oxidation occurs, carbon dioxide and ammonia (NH_3) will be formed. These processes will continue in the winter especially where there are open water areas of the ponds.

Organic compounds will be present in the water from the collectors and frothers used in the flotation process. These concentrations are expected to range from less than 1 mg/l to 20 mg/l depending on the compound in question. Natural processes of evaporation and oxidation will reduce the concentrations of these compounds by 90 percent or more; these processes will continue throughout the year. This estimate is based on data from other operations.(1)

Water will be pumped from reclaim pond cell A to the mill facilities via a pipeline system as described in subsection 1.4.4.2 of the EIR. The water will be transported to the reclaim water tank for distribution to the plant water tank and the water treatment plant.

(1) Report, Mines Noranda Limitee, Division Matagami. "A Decade of Effluent Quality Control and Tailings Revegetation at Watson Lake Tailings Disposal Area, 1970-1980". Susan S. Beaulieu (no date).



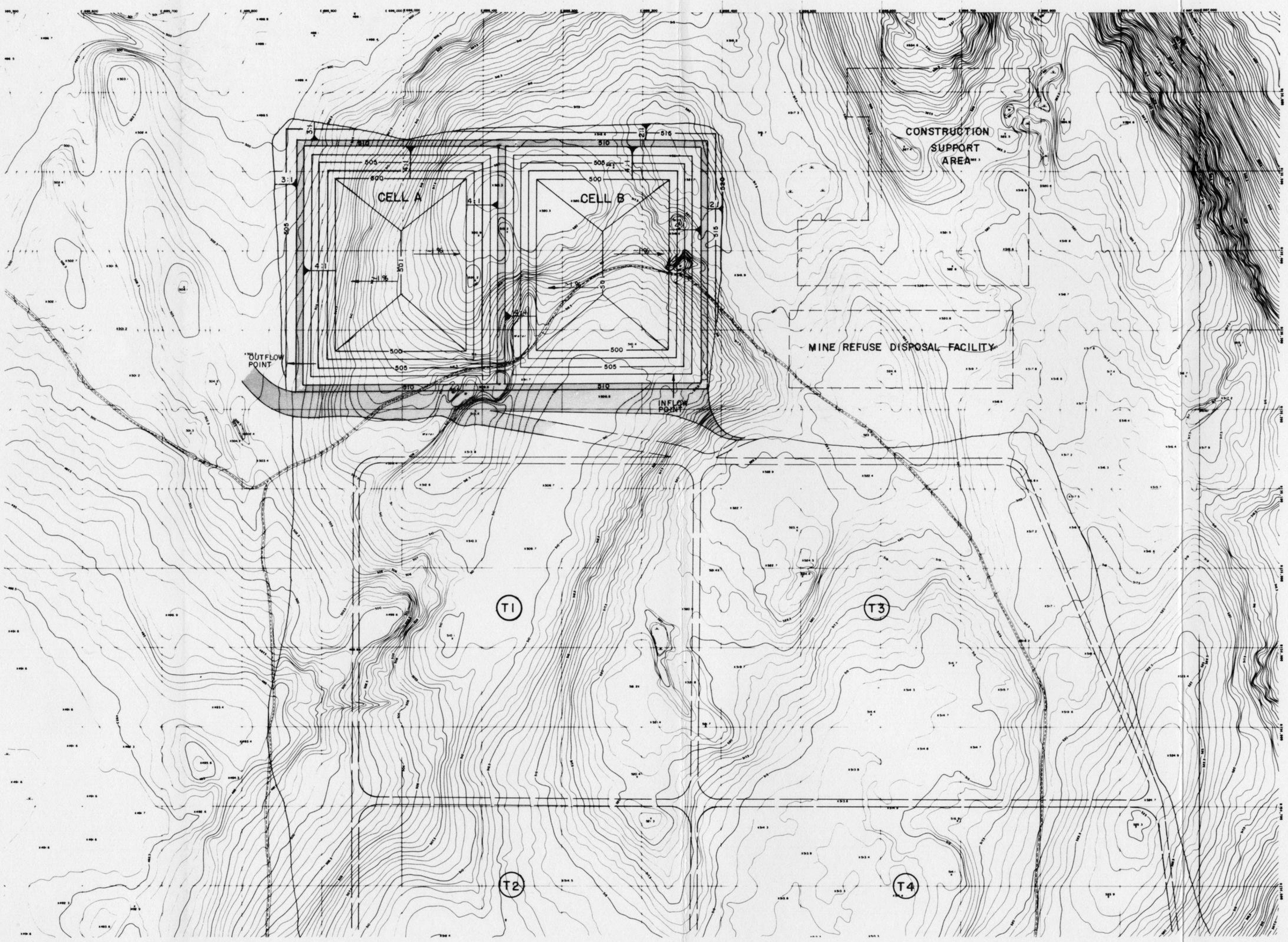
REVISED	DATE	BY	DESCRIPTION

Typical Representation: Refinements may be made during final design.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
CRANDON PROJECT FACILITIES

SCALE SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DR SPRINGBORN
DATE 10/85
CHECKED BY CC Schroed
DATE 12/6/85
APPROVED BY
DATE
APPROVED BY JF Wallen
DATE 11-27-85
APPROVED BY
DATE
EXXON D.S. Moe
DATE 12/9/85
DRAWING NO **FIGURE B-1**
SHEET 4 OF 36
REVISION NO 0



RECLAIM POND DATA NOTES		
POND DATA	CELL A	CELL B
Period of Use (yrs.)	33	30
Area Inside Crest (ac)	18	18
Bottom Area (ac.)	9	9
Lined Slope Area (ac.)	9	9
Maximum Operating Interior Depth (ft)	**20**	**23**
Maximum Exterior Fill Height (ft)	35	All in Cut
Crest Elevation (ft)	1673	1673
Lowest Bottom Elevation (ft)	1640	1640
Storage Volume to Crest (ac.ft.)	**436**	**436**
Till Excavation ($x10^6yd^3$) Both Cells	2.54	
Till Embankment ($x10^6yd^3$) Both Cells	0.16	
Upper Synthetic Liner Area (ac)	18	18
Lower Synthetic Liner Area (ac)	18	18
Rock Slope Protection Volume ($x10^6yd^3$)	0.030	0.030
Protective Cushion Above Synthetic Liner ($x10^6yd^3$)	0.047	0.047
Underdrain ($x10^6yd^3$)	0.020	0.020

NOTES:

1. BASE GRADE ELEVATIONS SHOWN ARE TO TOP OF FINAL CONSTRUCTED SURFACE. SUBTRACT ROCK, PROTECTIVE CUSHION & UNDERDRAIN THICKNESS TO DETERMINE SUBGRADE ELEVATIONS.
2. SECURITY FENCE OUTSIDE PERIMETER OF FACILITY.

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS

TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

D.E.M.

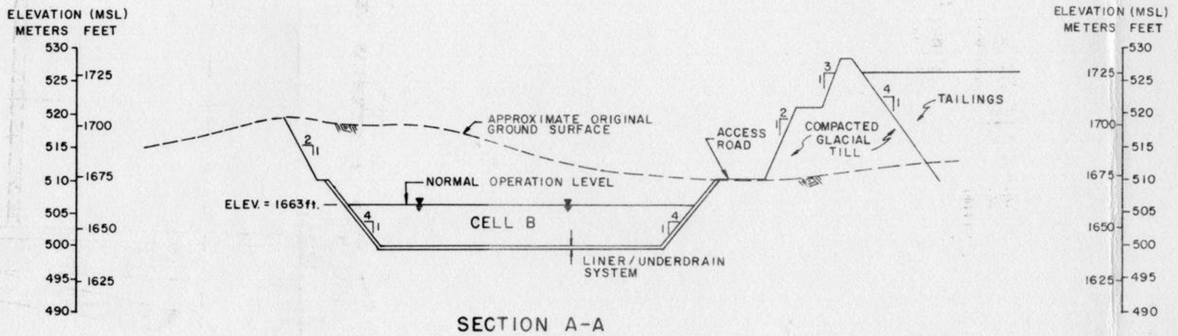
REVISED	DATE	BY	DESCRIPTION
3	7-18-86	DRS	REVISED STORAGE VOLUME TO CREST & MAX. OPERATING INTERIOR DEPTH
2	7-2-86	DRS	REPLACED TILL/BENTONITE LINER WITH SYNTHETIC LINER
1	6-12-86	DRS	REVISED INTERIOR EMBANKMENT

EXXON MINERALS COMPANY
CRANDON PROJECT

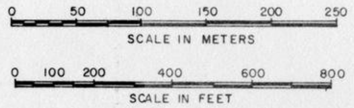
TITLE
RECLAIM POND BASE GRADE PLAN
SITE 41-114C

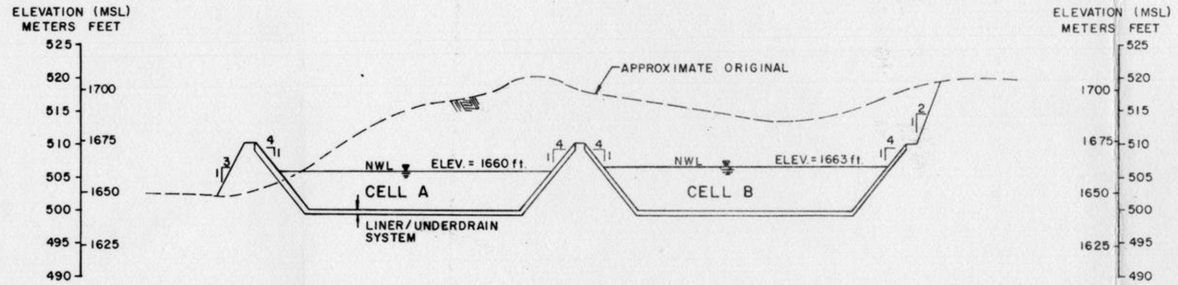
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY P. D. P.	DATE 10/21/85	CHECKED BY J.E. Wallace		DATE 11-22-85	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11-25-85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 11/27/85	
DRAWING NO **FIGURE B-2**			SHEET 1 OF 6	REVISION NO 3	

DESIGN PRODUCTS CO —

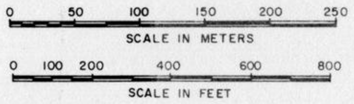


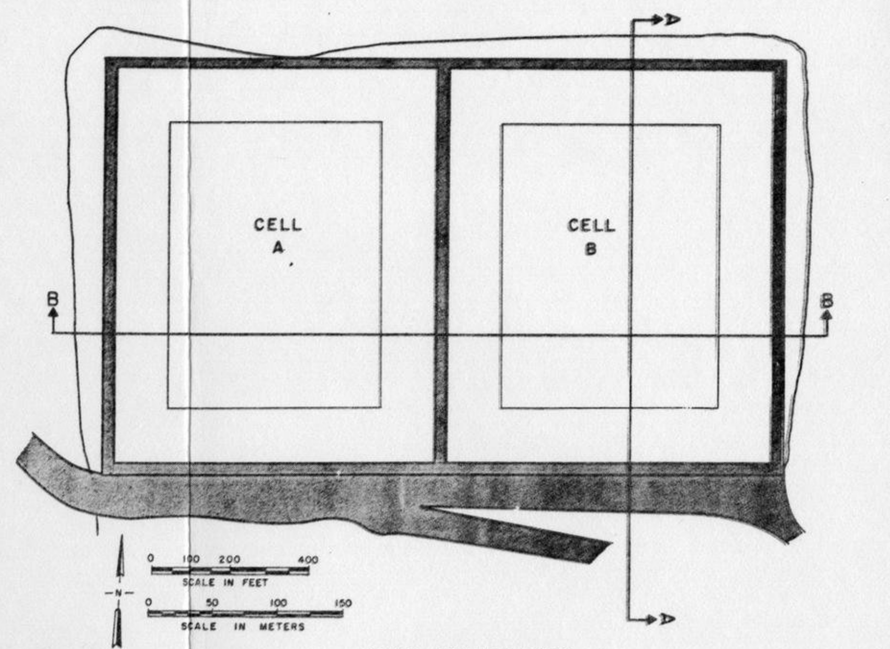
SECTION A-A





SECTION B-B





CROSS SECTION INDEX

TYPICAL REPRESENTATION: REFINEMENTS
MAY BE MADE DURING FINAL ENGINEERING

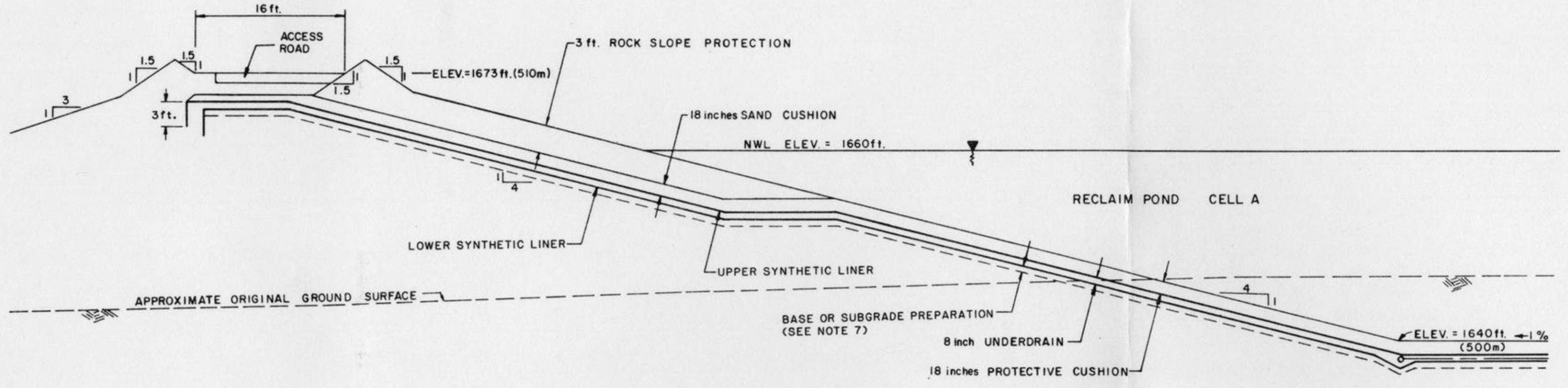
D.S.M.

1	6-12-86	DRS	Revised Interior Embankment
REVISED	DATE	BY	DESCRIPTION

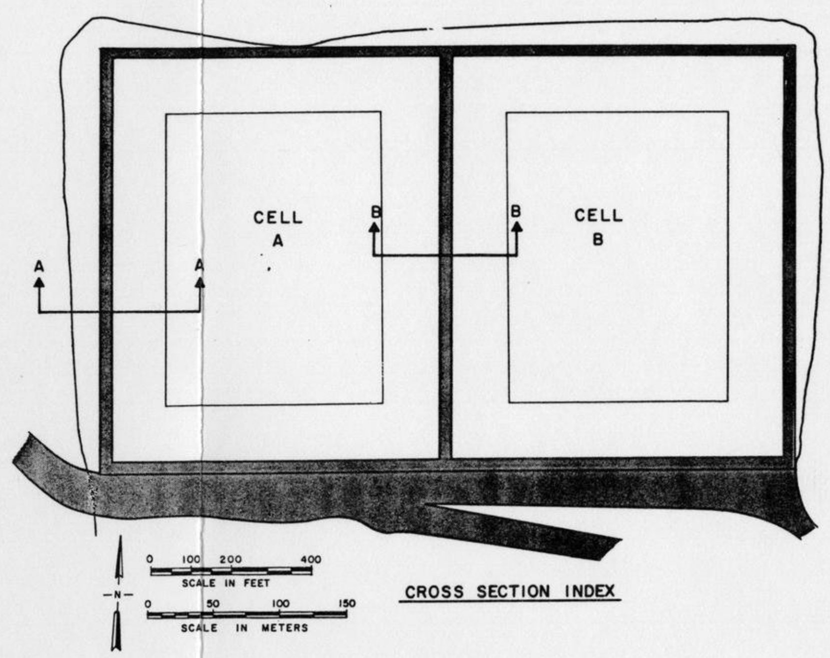
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RECLAIM POND
CROSS SECTIONS A-A & B-B
SITE 41-114C

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY P.D.P.	DATE 10-21-85	CHECKED BY J.F. Waller		DATE 11-22-85	
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11-25-85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 11/26/85	
DRAWING NO. FIGURE B-3		SHEET 2 OF 6		REVISION NO. 1	



SECTION A–A



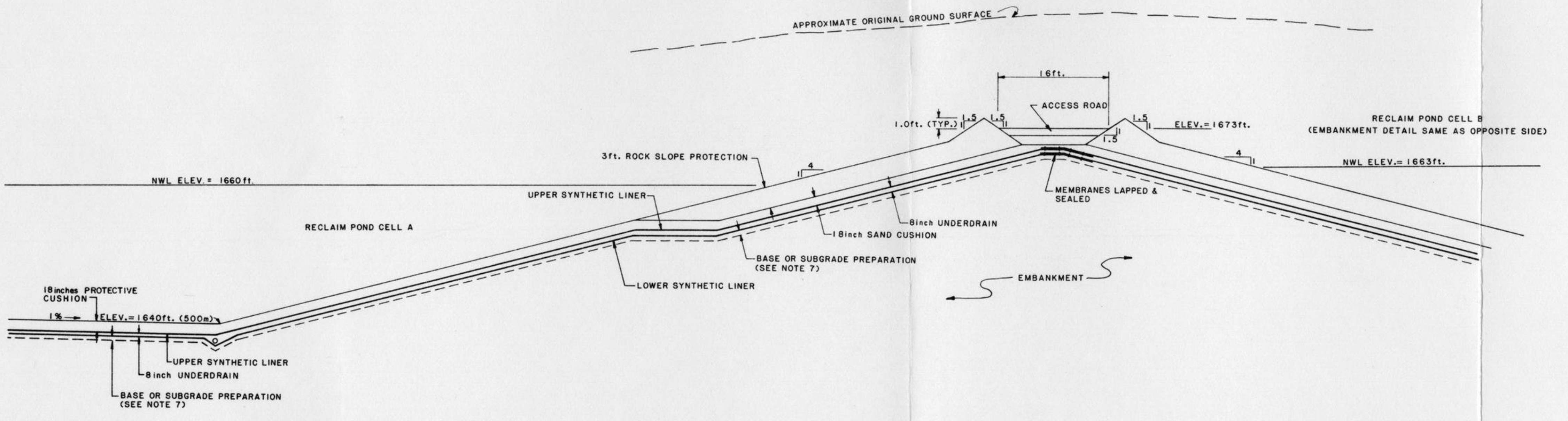
CROSS SECTION INDEX

Notes:

1. NWL - normal operation water level.
2. Section for Reclaim Pond Cell B will be similiar to Section A-A.
3. Rock slope protection to consist of pre-production waste rock.
4. Synthetic liner shall have a thickness of approximately 36 mils and be composed of either:

    a) Chlorosulfonated polyethylene (CSPE)
    b) Polyethylene, either high density (HDPE) or low density (LDPE)

5. The sand cushion (protective cushion) above the upper synthetic liner shall not be compacted and shall conform to the Manufacturers specifications.
6. The sand cushion (Underdrain) below the upper synthetic liner shall conform to the Manufacturers specifications.
7. The base or subgrade preparation below the lower synthetic liner shall conform to the Manufacturers specifications.



SECTION B–B

TYPICAL REPRESENTATION: REFINEMENTS MAY BE MADE DURING FINAL ENGINEERING

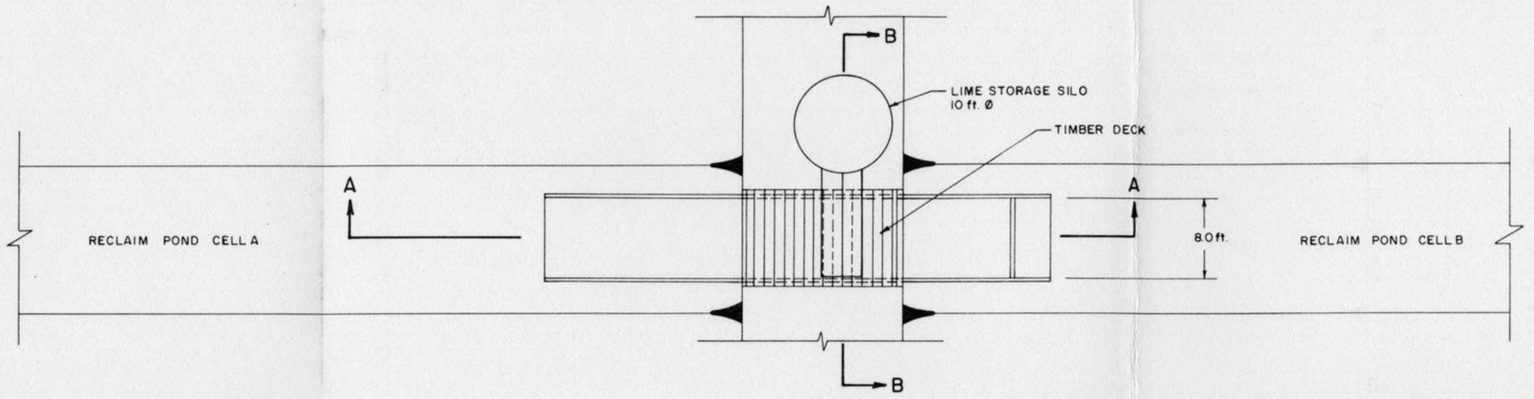
D.E.M.

REVISED	DATE	BY	DESCRIPTION
2	7-2-86	DRS	Replaced Till/Bentonite Liner With Synthetic Liner
1	6-12-86	DRS	Revised Interior Embankment

EXXON MINERALS COMPANY
CRANDON PROJECT

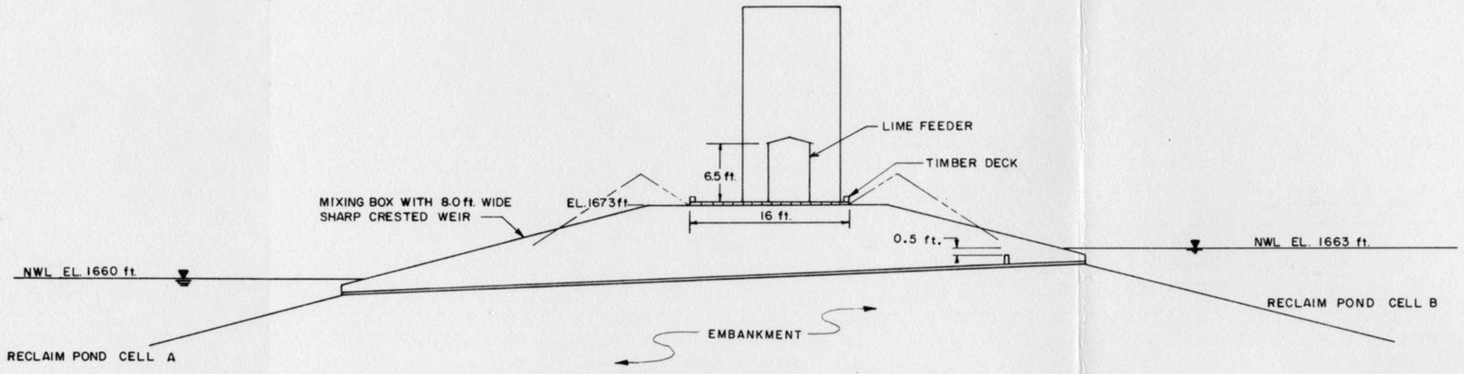
TITLE
RECLAIM POND
EMBANKMENT DETAILS

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY P. D. P.	DATE 10/24/85	CHECKED BY J.F. Wallace		DATE 11-22-85	
APPROVED BY	DATE	APPROVED BY C. C. Schroeder		DATE 11-25-85	
APPROVED BY	DATE	EXXON D.E. Moe		DATE 11/22/85	
DRAWING NO FIGURE B-4			SHEET 3 OF 6	REVISION NO 2	

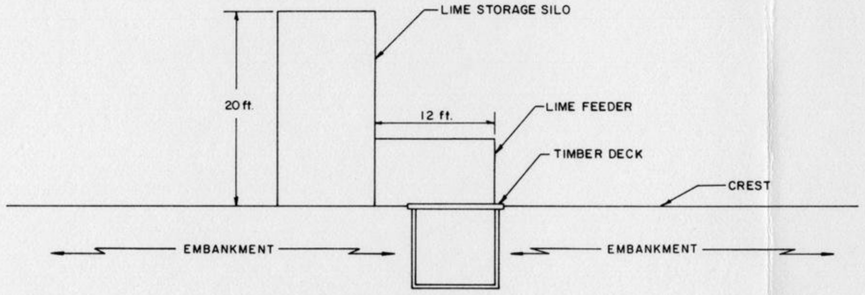


PLAN VIEW

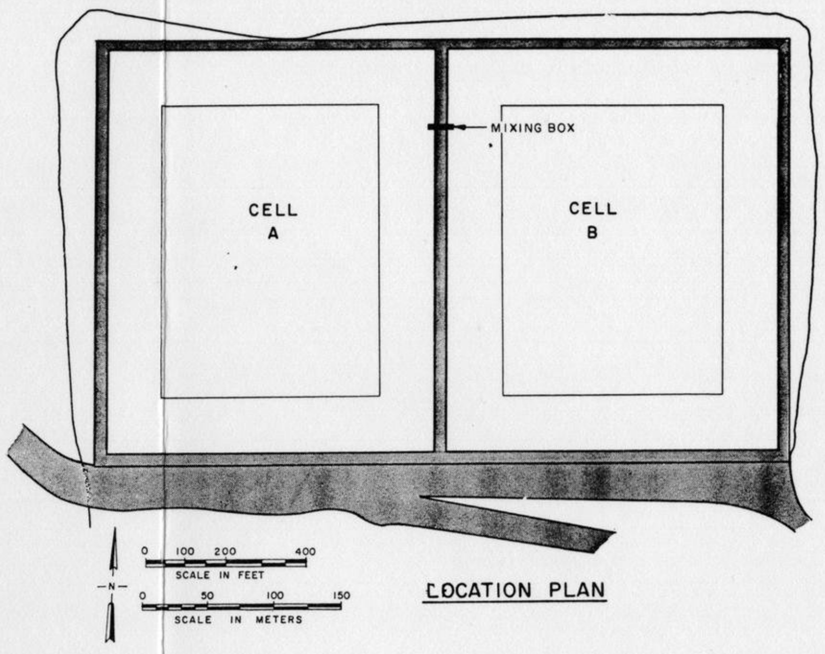
MIXING BOX BETWEEN THE TWO RECLAIM POND CELLS



SECTION A-A



SECTION B-B



LOCATION PLAN

Notes:

1. NWL - Normal operating water level

2. Details of Mixing Box

   Type: Sharp Crested, Rectangular Weir
   Width: 8.0 ft.
   Depth of Flow: 6 in.
   Depth of Tail Water: 6 in.

   The weir box should be designed for structural and mixing requirements.

0 5 10 15 20 25 30 35

SCALE IN FEET

0 1 2 3 4 5 6 7 8 9 10

SCALE IN METERS

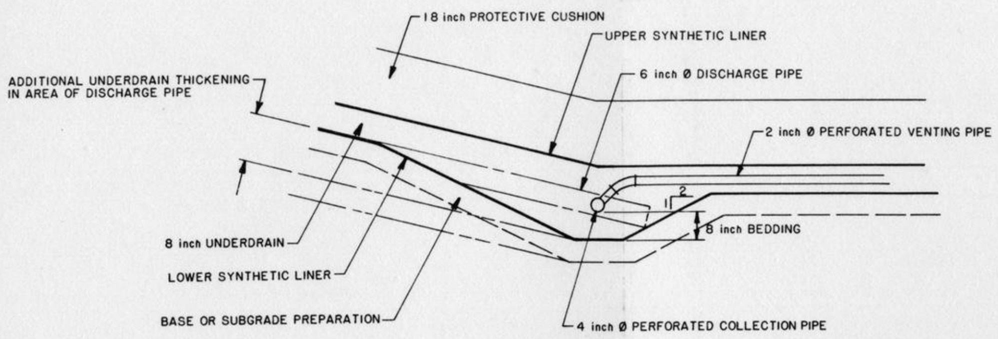
D.E.M.

1	6-12-86	DRS	Revised Interior Embankment
REVISED	DATE	BY	DESCRIPTION

TYPICAL REPRESENTATION: REFINEMENTS
MAY BE MADE DURING FINAL ENGINEERING

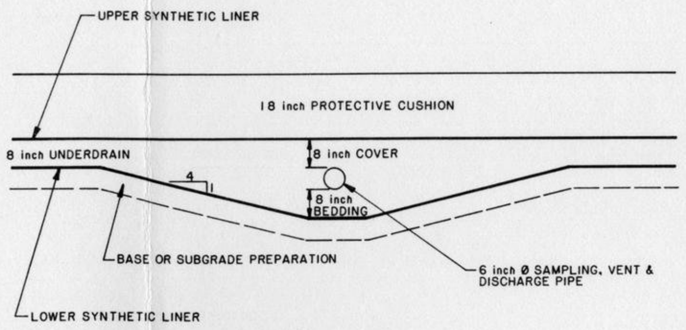
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE RECLAIM POND MIXING BOX DETAILS				
SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY J.J.T.	DATE 10-24-85	CHECKED BY J.F. Walker		DATE 11-26-85
APPROVED BY	DATE	APPROVED BY C.C. Schroeder		DATE 11-25-85
APPROVED BY	DATE	EXXON D.E. Moe		DATE 11/22/85
DRAWING NO FIGURE B-5		SHEET 4 OF 6		REVISION NO 1



DETAIL C

NOT TO SCALE



SECTION B–B

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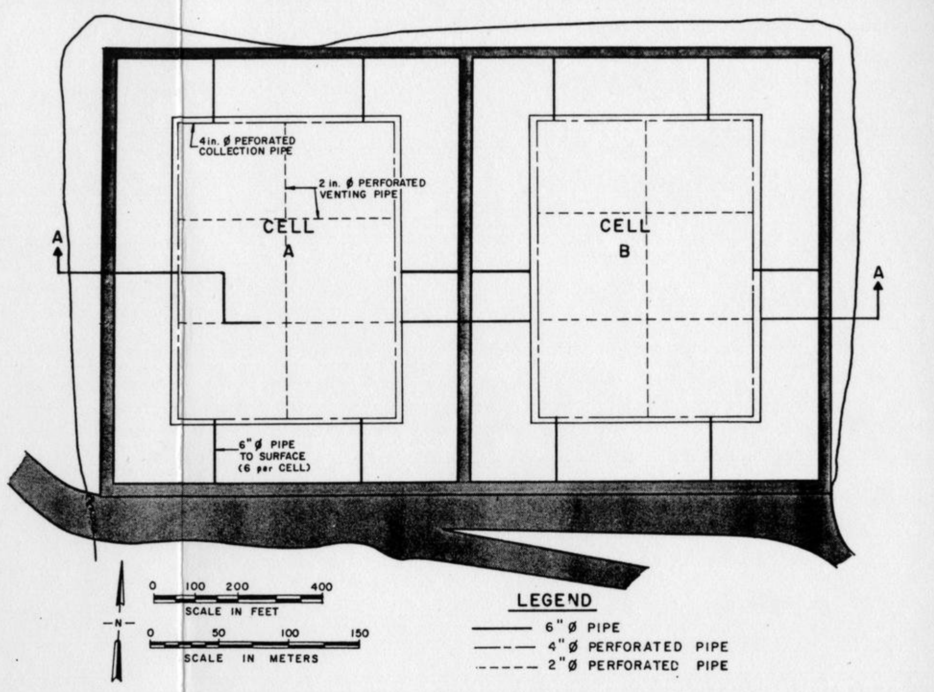

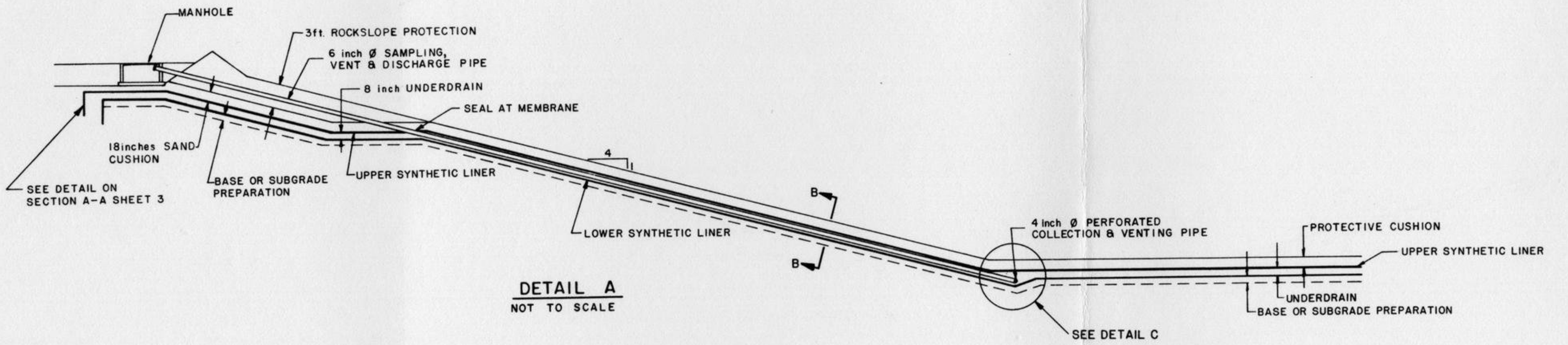

DETAIL A

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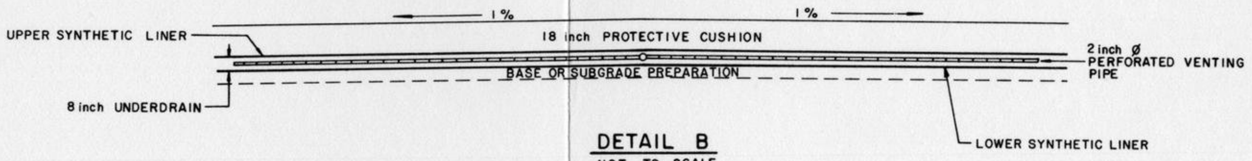
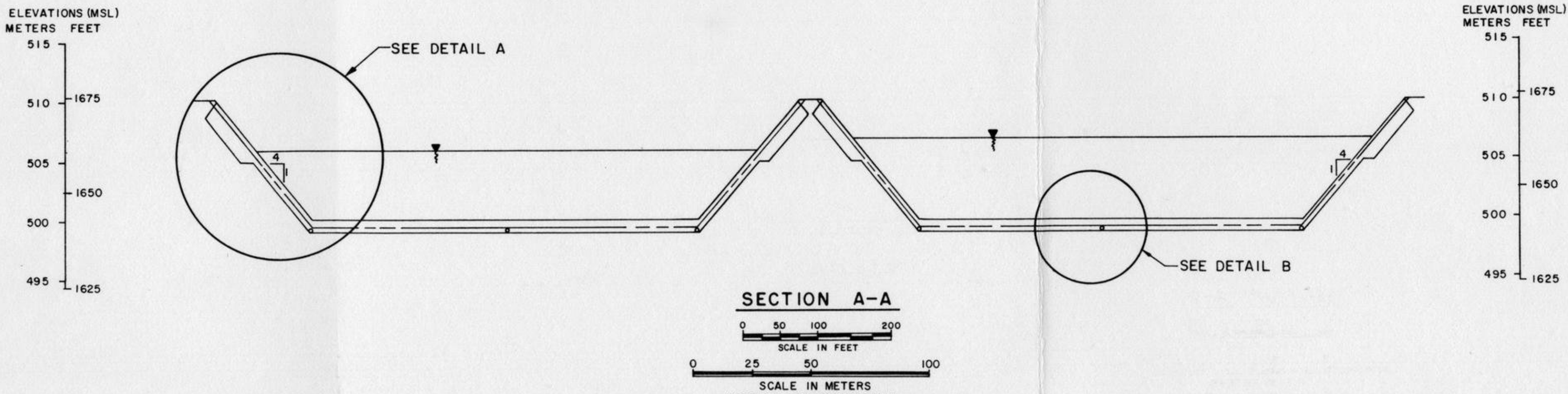


DETAIL B

NOT TO SCALE



SECTION A–A

DEM

REVISED	DATE	BY	DESCRIPTION
3	9-15-86	DRS	Added Section B-B & Detail C
2	7-2-86	DRS	Replaced Till/Bentonite Liner with Synthetic Liner
1	6-12-86	DRS	Revised Interior Embankment

TYPICAL REPRESENTATION: REFINEMENTS
MAY BE MADE DURING FINAL ENGINEERING

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
RECLAIM POND
GAS VENTING & LEAK DETECTION
PIPING SYSTEM

SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY P. D. P.
DATE 10/25/85
CHECKED BY
DATE 11 6 85
APPROVED BY
DATE
APPROVED BY D. E. Moe
DATE 11/22/85
APPROVED BY
DATE
EXXON E.C. Schroeder
DATE 11-25-85
DRAWING NO **FIGURE B-6**
SHEET 5 OF 6
REVISION NO 3

APPENDIX C

DISPOSITION OF CYANIDE AND DICHROMATE IN THE CRANDON CIRCUIT

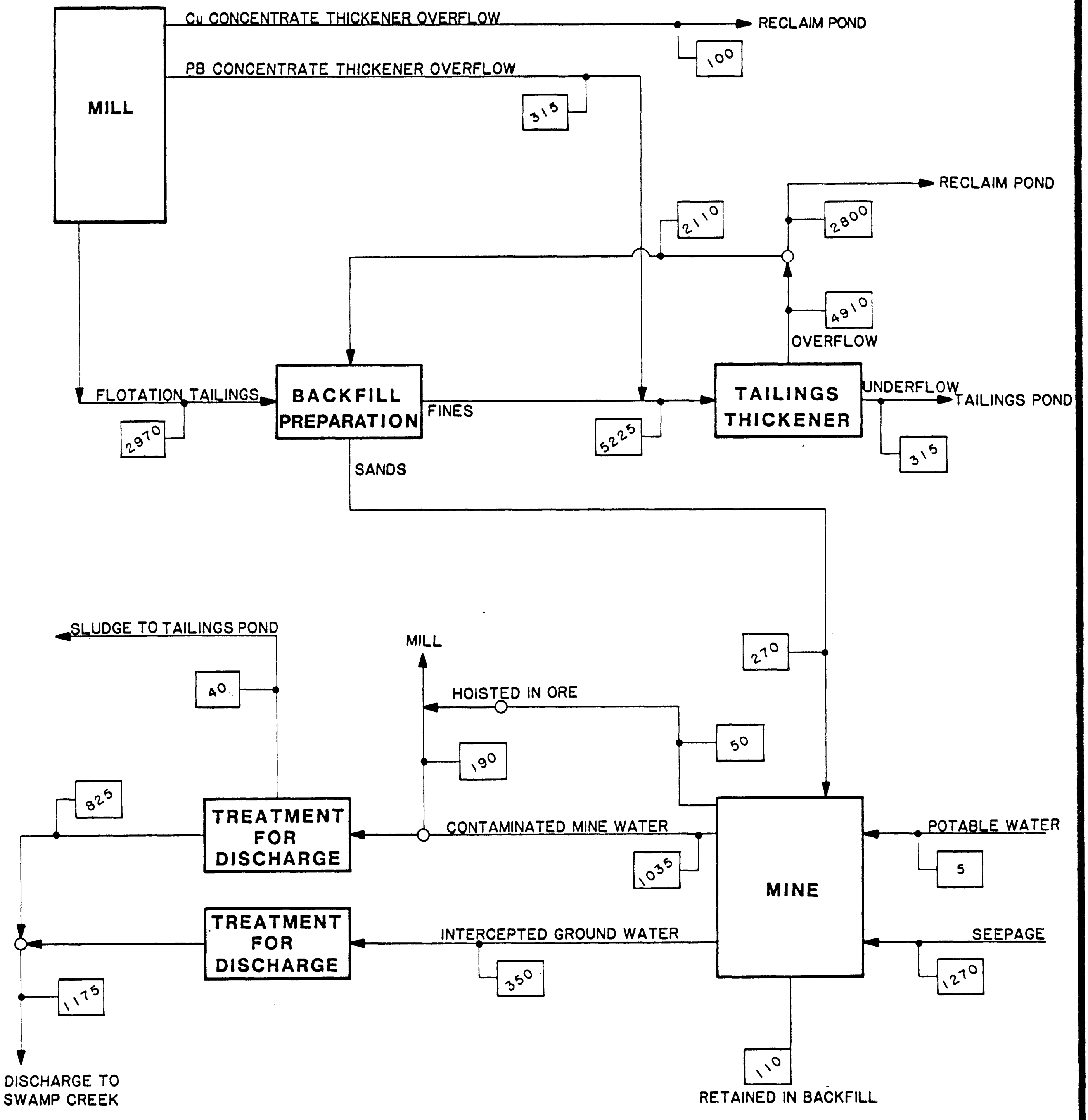
INTRODUCTION

This appendix details the disposition of sodium cyanide (NaCN) and sodium dichromate ($Na_2Cr_2O_7$) which are added in the Crandon flotation circuit. No specific treatment for the removal of cyanide or dichromate is planned as the residual concentrations of these species are expected to be well below the discharge limitations.

Sodium cyanide is added as a zinc-cyanide mixture in the flotation circuit to depress sphalerite (ZnS) while selectively floating the copper and lead minerals. Cyanide is also used to depress pyrite (FeS_2) in the lead cleaner circuit. The total sodium cyanide addition is estimated to be 21 grams per tonne of ore feed which is equivalent to eleven grams per tonne of cyanide (CN^-). Based on EPA analyses of other flotation mills that use cyanide, the chemistry of cyanide complexation, the natural degradation of cyanide, and the indirect connection between the mill and mine only through the backfill operation, the outflow concentration of cyanide at Swamp Creek is expected to be on the order of 0.006 mg/L. The discharge limitation for cyanide is 0.012 mg/L.

Sodium dichromate is added as a mixture with sodium silicate in order to depress galena (PbS) in the copper-lead flotation separation. The total sodium dichromate addition is estimated to be 32 grams per tonne of ore feed which is equivalent to 13 grams per tonne of chromium (VI) (Cr^{+6}). Based on the chemistry of chromate in the flotation circuit, laboratory test results, chromate reactions subsequent to flotation, EPA plant analyses, and the indirect connection between the mill and mine discharge, the outflow concentration of chromium (VI) is expected to be on the order of 0.012 mg/L. The discharge limitation for chromium (VI) is 0.020 mg/L for discharge flow rates of less than 1200 gpm.

Presented in Figure 1 is a flow sheet which shows the relationship between the mill circuit discharge and the final effluent discharged to Swamp Creek. This figure is a portion of the overall mill water balance presented in the body of the Water Treatment Facility Engineering Report (Figure 2). The water balance in Figure 1 was used in the calculations of cyanide and chromium (VI) concentrations at various points in the circuit. The three mill effluent streams shown in Figure 1 are the streams by which cyanide and dichromate have the potential to leave the mill. The lead concentrate thickener overflow will contain the highest concentrations of both cyanide and dichromate. This stream is combined with the feed to the tailings thickener, rather than fed directly to backfill preparation, in order to allow additional retention time for cyanide and dichromate removal and degradation prior to backfill.



KEY :

gpm VALUES ARE FOR WATER ONLY

Typical Representations: Refinements
May Be Made During Final Engineering

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
MILL/MINE BACKFILL
WATER BALANCE

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY DR SPRINGBORN	DATE 11/84	CHECKED BY		DATE	
APPROVED BY	DATE	APPROVED BY		DATE	
APPROVED BY	DATE	EXXON		DATE	

DRAWING NO **FIGURE 1**
SHEET ____ OF ____
REVISION NO 1

As shown in Figure 1, only seven percent of the water discharged from the mill is contained in the backfill sands. This water must pass through the mine backfill and the water treatment plant prior to discharge. This is the only connection between the mill circuit and the final discharge at Swamp Creek. There is a 9 to 1 dilution of the backfill drainage by uncontaminated mine water and intercepted ground water prior to treatment and final discharge.

CYANIDE

Removal During Flotation

In a study conducted by the EPA, a number of flotation mills which use cyanide were sampled.(1) These mills were from the EPA's Cu/Pb/Zn/Au/Ag/Pt/Mo category. The cyanide dosages ranged from 3 to 125 grams per tonne of ore feed with an average of 30 grams per tonne. The average cyanide concentration of 31 untreated mill tailings effluent samples was 0.28 mg/L. If there had been no consumption or destruction of cyanide in the mills, the cyanide concentration in the untreated mill tailings effluent would have been 11 mg/L. This represents an average cyanide removal of 97 percent in the mill.

The eleven grams per ton of cyanide added in the Crandon circuit would give an average effluent cyanide concentration of 3.9 mg/L if no consumption or destruction of cyanide occurred in the mill. This was calculated as follows:

$$\frac{11\ \text{g CN}^-}{\text{tonne}} \times \frac{6700\ \text{tonne}}{\text{day}} \times \frac{1\ \text{day}}{24\ \text{hr}} \times \frac{1}{792\ \text{M}^3/\text{hr}} \times \frac{1000\ \text{mg/g}}{1000\ \text{L/M}^3} = 3.9\ \text{mg/L}$$

The 792 M^3/hr represents the total of the three mill effluent streams shown in Figure 1. Assuming the cyanide removal at Crandon in the mill is the same as the EPA's average results (97 percent removal), the average mill effluent would contain 0.12 mg/L cyanide, i.e.:

$$(1-0.97) \times 3.9\ \text{mg/L} = 0.12\ \text{mg/L}$$

These EPA results demonstrate the effective removal of cyanide in flotation mills. The mechanisms responsible for cyanide removal in the flotation mills include: formation of insoluble iron, copper, and zinc ferrocyanide complexes, adsorption of cyanide complexes on pyrite and sphalerite surfaces, and formation of thiocyanates.

It is generally accepted that cyanide depresses pyrite in flotation by reacting with iron in solution to form the inert complex ferrocyanide ($Fe(CN)_6^{-4}$) via the following reaction:(2)

$$Fe^{+2} + 6CN^- \longrightarrow Fe(CN)_6^{-4}$$

This ferrocyanide then reacts on the surface at the pyrite to form ferric ferrocyanide:

$$4Fe^{+3} + 3Fe(CN)_6^{-4} \longrightarrow Fe_4(Fe(CN)_6)_3$$

The ferric ferrocyanide is present on the pyrite surface either as an adsorbed precipitate or as a chemically attached species. In either case its presence causes pyrite depression during flotation.

A saturated solution of ferric ferrocyanide contains only 0.13 mg/L total cyanide.(3) Adsorption of iron cyanide complexes on iron oxide or iron sulfide surfaces can result in an even lower cyanide concentration. Copper and zinc salts of ferrocyanide are even less soluble than ferric ferrocyanide. The cyanide in these solutions is strongly complexed in the ferrocyanide ion and is not present as free cyanide.

The low solubility of cyanide in the presence of iron and other metals was demonstrated when samples of synthetic Crandon tailings leachate were spiked with cyanide in an attempt to achieve a cyanide concentration of 0.25 mg/L.(4) The added cyanide would not stay in solution in these tests, and the resulting total cyanide concentrations were $<$0.1 mg/L either initially or after a period of months depending on the test.

Cyanide depresses sphalerite through the formation of zinc-cyanide complexes on the surface of the sphalerite.(5) A portion of the cyanide adsorbed on the sphalerite will be carried with the sphalerite to the final zinc concentrate. The cyanide which remains in solution will readily react with iron in solution to form ferrocyanide which will subsequently react to form ferric ferrocyanide or the even less soluble zinc ferrocyanide.

A large portion of the cyanide added in flotation ultimately ends up physically adsorbed on the pyrite discharged to the tailings and as such is removed from the circuit as insoluble iron cyanide complexes.(6)

An additional mechanism for removing free cyanide from solution is through its reaction with various sulfur species to form thiocyanate (SCN^-):(3)

$$S_X^{-2} + CN^- \longrightarrow S^{-2}_{(X-1)} + SCN^-$$

$$S_2O_3^{-2} + CN^- \longrightarrow SO_3^{-2} + SCN^-$$

Both polysulfides (S_X^{2}) and thiosulfate ($S_2O_3^{2}$) will be present in the mill process water from the decomposition of the sulfide minerals.

Degradation During Tailings Thickening/Impoundment

In addition to the mechanisms which can occur during flotation, cyanide is also naturally degraded during impoundment by volatilization and photodecomposition.(3)

When the pH of the solution drops, either because of CO_2 adsorption or oxidation of sulfur species, volatilization of cyanide occurs by the reaction:(3)

$$H^+ + CN^- \rightleftharpoons HCN$$

The HCN formed is readily volatilized. Because of the very low cyanide concentrations in the tailings and reclaim ponds, the concentration of HCN in the air will be minimal and poses no health problem.

Photodecomposition of complex cyanide occurs in tailings pond solutions that are exposed to the UV radiation contained in sunlight. Ferrocyanides in solution are decomposed to free cyanide by the reaction:(3)

$$Fe(CN)_6^{-4} \longrightarrow (Fe(CN)_5H_2O)^{-3} + CN^-$$

The free cyanide can then be removed by volatilization. Photodecomposition does not occur on the mineral surfaces because of the lack of light transmission in slurries or settled tailings.

A portion of the backfill preparation water (40 percent) is recycled from the tailings thickener overflow. Some degradation of the cyanide can occur in the thickener. However, the natural degradation mechanisms are most important in the tailings and reclaim ponds where these mechanisms prevent a build-up of cyanide in the water that is recycled to the mill.

An example of cyanide removal by natural degradation is the Dome Mines of Ontario gold operation where on a yearly average 65 percent of the total cyanide in the feed to the tailings basin is removed with a three-day residence time.(7) The Crandon reclaim pond has a 35-day residence time.

Removal in Backfill Stopes

The adsorption of cyanide from solution at alkaline pH on to iron sulfide surfaces (pyrite and/or pyrrhotite) is a demonstrated method of treating cyanide containing effluents.(8) Due to the high pyrite content (75 weight percent) of the backfill, it is expected that at least 50 percent of the cyanide would be removed during the backfill operation, considering the long retention time of the waters in the backfill stope. With an estimated cyanide concentration on the order of 0.12 mg/L, as calculated previously, feeding the backfill preparation, and considering the cyanide removal in the backfill (50 percent) along with the 9 to 1 dilution of the backfill drainage, the resulting final effluent at Swamp Creek is expected to be on the order of 0.006 mg/L cyanide, i.e.:

$$0.12 \text{ mg/L} \times (1-0.5)/9 = 0.006 \text{ mg/L}$$

DICHROMATE

The primary concern relating to the addition of sodium dichromate to the flotation circuit is the residual level of chromium (VI) in the discharge water. The presence of chromic ions (chromium (III)) in the flotation process water is not a major concern because the water treatment system will readily remove chromium (III) from solution.

Sodium dichromate is added to the circuit as dichromate ($Cr_2O_7^{2}$) but is present in solution primarily as chromate (CrO_4^{2}) above pH 7 as per the reaction:

$$Cr_2O_7^{-2} + 2OH^- \rightleftharpoons 2CrO_4^{-2} + 2H_2O$$

Removal During Flotation

The most widely accepted mechanism for depression of galena by chromate during flotation is through the formation of insoluble lead chromate on the galena surfaces.(9-11) The lead chromate remains on the galena surfaces and is removed from the flotation circuit with the lead concentrate. A portion of the chromate is also reduced to chromium (III) during galena depression.(9)

The following reactions are believed to be occurring during galena depression:

$$3PbS + 6O_2 \longrightarrow 3PbSO_4$$

$$3PbSO_4 + 3CrO_4^{-2} \longrightarrow 3PbCrO_4 + 3SO_4^{-2}$$

$$3PbS + 8CrO_4^{-2} + 16\ H^+ \longrightarrow 3PbSO_4 + 4Cr_2O_3 + 8H_2O$$

The most important factor that controls the residual concentration of chromium (VI) in the flotation circuit is the dichromate dosage as compared to the amount of galena in the copper-lead flotation separation. Properly controlled dichromate addition will minimize the amount of chromium (VI) in solution.

It is necessary for both metallurgical and cost control reasons that excess dichromate dosage be avoided. Higher than required dichromate dosages cause a drop in lead recovery. This occurs because the galena becomes difficult to refloat when excess chromate is used in the copper-lead separation. Sodium dichromate is a relatively high cost reagent and, as such, must be added at the minimum required dosage.

Exxon laboratory flotation tests were conducted on a Canadian copper-lead-zinc ore to evaluate the effect that variations in dichromate dosage have on flotation response and resulting water quality.(12) The results showed that the best copper-lead separation occurred at the lowest dichromate dosage tested and that improvements in the separation and resulting water quality would have been further improved at lower dichromate dosages.

The results confirmed that the best metallurgical response obtained corresponded to the lowest residual chromium (VI) concentrations. A sodium dichromate addition equivalent to a 6.4 mg/L chromium (VI) concentration was used in the copper-lead separation. This is the concentration that would have resulted if no reaction of the chromium (VI) had occurred. The resulting chromium (VI) concentrations in the copper and lead concentrate filtrates were 1.1 and 0.45 mg/L, respectively. Based on the volumes of filtrates produced, this represents an 85 percent removal of chromium (VI) from solution during flotation. It is expected that a higher removal percentage, on the order of 90 to 95 percent, will be obtained during flotation if the dichromate dosage is more properly matched to the flotation requirements.

Removal After Flotation

Dichromate is removed from process water subsequent to flotation by two mechanisms: 1) reduction of chromium (VI) to chromium (III) through reactions with reducing species in the process water and 2) additional formation of lead chromate on galena surfaces.

Chromium (VI) is reduced to chromium (III) in the presence of ferrous sulfide (FeS), sulfide ion (S^{-2}), and pyrite at neutral to slightly alkaline pH.(13-15) Chromium reduction may also occur in the presence of reducing species such as $S_2O_3^{2}$ and SO_2.(16)

Sulfide ions and ferrous ions (Fe^{+2}) are present from the decomposition of mineral phases. Sulfide ion will also be added at low levels in the water treatment plant. These species can reduce chromate via the following reactions:

$$CrO_4^{-2} + FeS + 4H_2O \longrightarrow Cr(OH)_3 + Fe(OH)_3 + S + 2OH^-$$

$$2CrO_4^{-2} + 3HS^- + 5H_2O \longrightarrow 2Cr(OH)_3 + 3S + 7OH^-$$

It has been demonstrated that chromium (VI) will be reduced to chromium (III) on pyrite surfaces by way of the following reaction:(13)

$$FeS_2 + 4H_2O + CrO_4^{-2} \longrightarrow Cr(OH)_3 + Fe(OH)_3 + 2S + 2OH^-$$

This mechanism will be effective for removing chromium (VI) from solution in the tailings thickener and in the mine backfill.

Sulfur dioxide is added to the copper circuit and $S_2O_3^{2}$ is present in most process streams. The kinetics of reduction of chromium (VI) by these species is rapid at low pH, but at neutral and alkaline pH the kinetics are much slower.

Removal of chromate will occur in the reclaim pond because $S_2O_3^{2}$ will be present. The use of SO_2 is a common method of chromate reduction.(17)

The formation of lead chromate, although initially rapid, continues to proceed over several hours.(11) Hence, chromate will continue to be removed from solutions as long as galena is present in the slurry. This mechanism is especially important in removing residual chromate in the lead feed thickener, and the lead concentrate thickener.

These methods of removal after flotation will be assisted by the fact that the process streams with higher concentrations of chromium (VI) will be combined with the tailings thickener feed. These streams will have additional residence time and, hence, additional opportunity to react prior to backfill. Also, additional contact time between the solids and solution takes place in the backfill stopes where the retention time is at a minimum a few hours and is typically many days.

A high degree of chromium (VI) removal from flotation process waters was demonstrated by an EPA study on a flotation mill using low dichromate dosages.(1) Long term analyses of the untreated effluent did not indicate the presence of total chromium in detectable concentrations.

Water treatment plants which use FeS to reduce chromium (VI) to chromium (III) are able to decrease chromium (VI) concentrations from initial concentrations of 10 to 100 mg/L to final concentrations of 0.01 to 0.4 mg/L chromium (VI). This represents removal efficiencies of over 99 percent.(13)

If a conservative removal efficiency of 70 percent is used for the combined removal/reduction of chromium (VI) by all of the processes subsequent to flotation, along with a 92 percent removal during flotation, the final discharge concentration at Swamp Creek is expected to be on the order of 0.012 mg/L. This was calculated as follows:

$$\frac{13\text{ g Cr}^{+6}}{\text{tonne}} \times \frac{6700\text{ tonne}}{\text{day}} \times \frac{1\text{ day}}{24\text{ hr}} \times \frac{1}{792\text{ M}^3/\text{hr}} \times \frac{1000\text{ mg/g}}{1000\text{ L/M}^3} = 4.6\text{ mg/L}$$

$$\frac{4.6\text{ mg}}{\text{L}} \times (1-0.92)(1-0.70)/9 = 0.012\text{ mg/L}$$

The 9 factor represents the dilution of the backfill drainage by contaminated mine water and intercepted ground water prior to final discharge.

Chromium (III) Precipitation

The chromium (III) generated from chromate reduction does not build-up in mill-reclaim pond circuit because of the precipitation of $Cr(OH)_3$. EPA sponsored research(18) indicates that for lime neutralization of acid mine drainage the chromium (III) solubility varied between 0.04 to 0.07 mg/L over a pH range of 7 to 12. Chromium precipitated in the presence of non-amphoteric metal hydroxides, $Fe(OH)_3$, does not appear to exhibit the amphoteric properties that a pure $Cr(OH)_3$-Cr^{+3} system does.

Recent water treatment studies done by Exxon Research and Engineering (ER&E) and Mineral Processing Research Division of Exxon Minerals Company report chromium (III) concentrations of 0.01 mg/L in the effluent from lime neutralization, pH = 10.3, of synthetic contaminated mine water (inffluent concentrations of 0.2 mg/L).(19,20) ER&E also reported that the chromium (III) concentration in the effluent was 0.01 mg/L for the pH range of 9.5 to 11.5. This demonstrates the effective removal of chromium (III) by the proposed Crandon water treatment method.

Conclusion

The foregoing discussion outlines the reasons why Exxon Minerals Company does not anticipate specific treatment for either cyanide or chromium in Crandon's water treatment scheme. However, if treatment for these species were ever needed, the retrofit of specific treatment of the high concentration stream (lead concentrate thickener overflow) could be accomplished within the available space.

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DECOMPOSITION OF ORGANIC FLOTATION REAGENTS

APPENDIX D

INTRODUCTION

This appendix to the Water Treatment Plant Engineering Report describes the five types of organic reagents that are planned to be used in the Crandon circuit. These reagents along with their purpose and expected dosage are presented in Table 1. These reagents are both common and typical of those used in the mining industry for concentration of sulfide minerals.

The following summarizes the degradation properties of the five organic reagents planned to be used at Crandon:

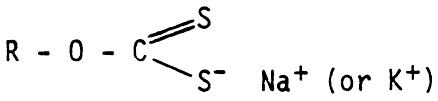
- Xanthates chemically and biologically degrade readily.
- Methyl isobutyl carbinol (MIBC) will biodegrade readily.
- Starch (carboxy methyl cellulose) will both chemically and biologically degrade but at a relatively slow rate. Carboxy methyl cellulose is a non-toxic substance commonly used as a food additive.
- Polypropylene glycol methyl ether (DF250) degrades only very slowly but is a relatively non-toxic material.
- The specific flocculant to be used at Crandon has not yet been selected. However, in general, flocculants are readily removed from solution in tailings ponds and do not build-up in recycle water.

Some of the organic reagents used in the Crandon Concentrator will end up passing through the reclaim ponds where they will be subject to degradation by natural processes such as heat and light as discussed in Section 3.4 of the Preliminary Engineering Report.

In the following sections the chemical composition, biodegradability, chemical reactions, and operational considerations controlling the dosage of each reagent are described. Also, product data safety sheets for these reagents are attached.

XANTHATES

Xanthates are among the most common collectors used in flotation. They adsorb on the mineral particle surfaces and render the particles hydrophobic. Three xanthates will be used in the Crandon flotation circuit: sodium ethyl xanthate, sodium isopropyl xanthate, and potassium amyl xanthate. Following is the xanthate formula: (1)



$$R - O - C \begin{matrix} \nearrow\!\!\!\!= S \\ \searrow S^- \end{matrix} \quad Na^+ \text{ (or } K^+\text{)}$$

where R = CH_3CH_2, $(CH_3)_2CH$, or $CH_3(CH_2)_4$.

TABLE 1

Organic Reagent Consumption in Crandon Mill Circuit

Reagent	Primary Use	Estimated Monthly Consumption (tonne)	Consumption (g/tonne of ore)
Xanthate	Collector	18	90
Methyl Isobutyl Carbinol (MIBC)	Frother	8	40
Starch	Depressant	11	55
Polypropylene Glycol Methyl Ether (Dowfroth 250)	Frother	2	10
Flocculant (type not chosen)	Flocculant	-	-

The total xanthate addition is expected to be 90 g/tonne of ore feed. The majority of the xanthate added in flotation will be adsorbed on the mineral surfaces. In many systems over 98 percent of it is adsorbed onto the mineral surfaces. (2) Any residual xanthate will either chemically or biologically decompose. The following chemical reactions can occur in aqueous solutions: (3,4)

$$ROCS_2 + H^+ \rightleftharpoons ROCS_2H$$

$$ROCS_2H \longrightarrow ROH + CS_2$$

$$3CS_2 + 6KOH \rightleftharpoons 2K_2CS_3 + K_2CO_3 + 3H_2O$$

$$ROCS_2 + OH^- \longrightarrow ROH + CS_2O$$

$$ROCS_2 + OH^- \longrightarrow ROCSO^- + SH^-$$

$$ROCSO^- + 2OH^- \longrightarrow ROH + CO_3 + SH^-$$

Xanthate and its reaction products readily biodegrade. (5, 6) Biodegradation of some xanthates may be inhibited at concentrations greater than 20-25 mg/L, but the xanthate concentration in the Crandon process water will be significantly lower than these values.

Xanthate can also oxidize to dixanthogen via the following reaction:

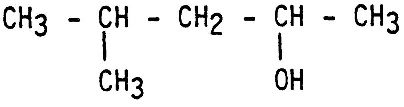
$$2ROCS_2 \longrightarrow (ROCS_2)_2 + 2e^-$$

This reaction, however, does not generally occur as a homogeneous solution reaction but occurs at the mineral particles surfaces. Dixanthogen is adsorbed on the mineral surfaces and removed from solution and, hence, does not represent a problem for either process water recycle or water quality.

Because of degradation, a build-up of xanthates in recycle waters does not generally occur. This is true even in concentrators that recycle a large fraction of their process water. However, the flotation separation efficiency is significantly affected by the xanthate dosage, and its close control is required from a metallurgical standpoint.

METHYL ISOBUTYL CARBINOL (MIBC)

MIBC is an alcohol that is used as a frother in flotation. It adsorbs at the air-water interface to lower the water surface tension. The formula for MIBC is:



$$CH_3 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$$

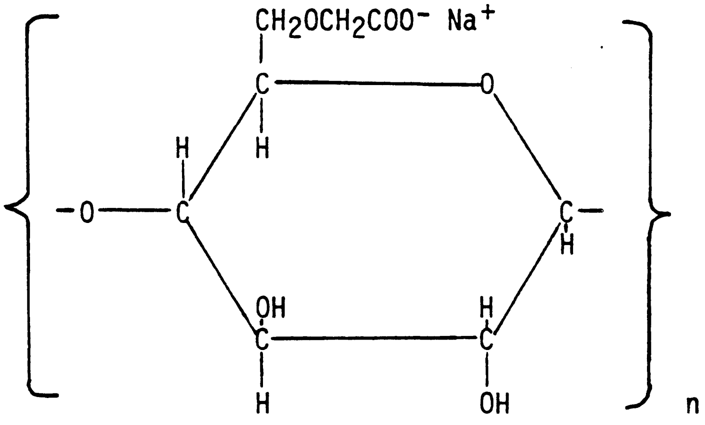
The MIBC dosage is expected to be 40 g/tonne of ore. A portion of the MIBC used in flotation may coadsorb with the collector on the mineral particles surfaces and be removed from the circuit with the final flotation concentrate. However, the majority of the frother will report to the flotation concentrate with the liquid phase.

MIBC is readily biodegradable(5) with the probable final degradation products being carbon dioxide and water. Alcohols can chemically oxidize under certain conditions (low pH and the presence of a strong oxidizer) through intermediate ketones to carboxylic acids. However, considering the ease of biodegradation of MIBC, the chemical oxidation will probably have only a minor contribution to the MIBC degradation.

Concentrators that use MIBC generally do not have difficulty with a build-up of this reagent. However, if MIBC is recycled without passing through the tailings and reclaim ponds (internal recycle) a potential exists for frother build-up in the circuit. The zinc concentrate thickener overflow at Crandon will be internally recycled. A build-up of MIBC can be readily prevented by lowering the frother addition in the zinc circuit. A build-up of frother could result in poor separation efficiency and, hence, will not be allowed to occur.

STARCH

The starch added in the Crandon circuit will be carboxy methyl cellulose (CMC). It is added in the copper-lead separation step to aid in the depression of galena by adsorbing on the galena mineral surfaces and rendering them hydrophilic. CMC has the following structure(7):



where n can have a value up to 1,000.

The CMC addition is expected to be 55 g/tonne of ore. The majority of CMC will be removed from solution by adsorption on the galena surfaces and will end up with the final lead concentrate. A small portion of the CMC may remain in the process water.

Although CMC is less susceptible to biodegradation than other types of starch, it is not immune to microbiological attack(8). CMC solution will also chemically degrade with time. The first step in the degradation is a breaking of the bonds between the individual glucose units. Oxidative degradation can occur in the presence of oxygen under alkaline pH conditions. Also, sunlight enhances degradation. These conditions will be present in the tailings pond. Additionally, CMC is removed from solution by precipitation with polyvalent cations.

Since the degradation of CMC may occur relatively slowly, its addition must be controlled to prevent CMC from returning in the recycle water. The presence of CMC in the recycled mill feed water could cause unwanted depression of galena in the copper-lead bulk flotation.

POLYPROPYLENE GLYCOL METHYL ETHER

Polypropylene glycol methyl ether is commercially available as Dowfroth 250 (DF250) and is used as a frother in flotation. It functions in the same manner as MIBC adsorbing at the air-liquid interface and lowering the water surface tension. Following is the formula for DF250(9,10):

$$CH_3 - (O\text{-}C_3H_6)n - OH$$

It has a molecular weight of approximately 250.

The DF250 dosage is expected to be 10 g/tonne of ore. As with MIBC, a small portion of the DF250 may coadsorb with the collector on the mineral particle surfaces and be removed from the circuit with the final flotation concentrate. However, most of the DF250 will remain in solution. Although DF250 is more water soluble than MIBC, the majority of it will still report to the concentrate with the liquid phase.

DF250 chemically degrades very slowly by acid, alkali, heat, light, and water contact. Oxidative breakdown is likely to result in alkoxy ketone by-products. Little or no biodegradation of DF250 is expected.(11)

DF250 is planned to be used primarily in the zinc circuit; hence, the majority of it will end up in the zinc concentrate thickener overflow. The zinc concentrate thickener overflow will be recycled directly back to the zinc circuit. This can be compensated for by a subsequent decrease in DF250 dosage. Thus, DF250 will be present in very low concentrations in the reclaim ponds.

FLOCCULANT

Three basic types of flocculants are used in mineral operations: non-ionic, anionic and cationic. These flocculants are generally synthetic polymers composed of polyacrylamides (non-ionic), acrylamide/acrylate polymers (anionic), and cationic polyacrylamides and liquid amine condensate polymers (cationic)(12).

The type and dosage of flocculant to be used at Crandon has not yet been selected; however, in this type of application dosages usually range from 5 to 100 g/tonne of ore. The majority of the flocculant added usually remains attached to the settled solids, but both the type and dosage of flocculant have an effect on its residual concentration in solution(13). The different types of flocculants degrade at different rates. In general, initial breaking of the polymer chains occurs fairly rapidly with subsequent degradation occurring more slowly. A build-up of flocculant in recycle water is not usually a problem in mineral operations.

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1988H

6-1554
(Apr. 1972)

Chemical Safety Data Sheet

DOWFROTH 200, 250,1012

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20240

METAL AND NONMETAL MINE HEALTH AND SAFETY

MATERIAL

CHEMICAL NAME	FORMULA NA	CHEMICAL FAMILY Polypropylene Glycol Methyl Ethers
TRADE NAME Dow froth 200,250, and 1012		

PHYSICAL DATA

MELTING POINT (°F)	below - 50	THRESHOLD LIMIT VALUE	-
BOILING POINT (°F.)	243 -293°C	VAPOR DENSITY (AIR=1)	-
SPECIFIC GRAVITY (H_2O=1)	0.980	VAPOR PRESSURE (mm Hg.)	-
SOLUBILITY IN WATER	Soluable	MOLECULAR WEIGHT	pH = 7.2
APPEARANCE AND ODOR	Clear liquid with odor of ether.		

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) 250, 285, 375	FLAMMABLE LIMITS	Lel -	Uel -
EXTINGUISHING MEDIA foam, CO_2, dry chemical			
SPECIAL FIRE FIGHTING PROCEDURES None			
UNUSUAL FIRE AND EXPLOSION HAZARDS None			

HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE No unusual health problems.
EMERGENCY AND FIRST AID PROCEDURES Eyes or skin: Flush with plenty of water and call a doctor.

SAFETY IS EVERYONE'S BUSINESS

REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATABILITY *(Materials to avoid)* None			
HAZARDOUS DECOMPOSITION PRODUCTS None			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Use an absorbant to pick up flush to ground, not to sewer.

WASTE DISPOSAL METHOD To ground in a restricted area.

SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION None			
VENTILATION	LOCAL EXHAUST Normal	SPECIAL	
	MECHANICAL *(General)*	OTHER	
PROTECTIVE GLOVES Yes		EYE PROTECTION Goggles	
OTHER PROTECTIVE EQUIPMENT None			

SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING Store in a cool well ventilated area.

OTHER PRECAUTIONS None

★ U. S. GOVERNMENT PRINTING OFFICE : 1972 O - 462-363

AEROFROTH® 73
Frother

AEROFROTH 73 frother, a widely used mixture of high molecular weight alcohols and hydrocarbon, produces a more brittle, less persistent froth than pine oil or cresylic acid.

Typical Properties

Appearance	Amber liquid
Specific gravity @ 20°C (68°F)	0.82
Viscosity, Brookfield*, @ 20°C	4.5 cps
Solubility in water @ 20°C	<1%
Flashpoint, open cup	45°C (113°F)
closed up	39°C (102°F)
Boiling point	128°C (262°F)
Freezing point	<−60°C (−76°F)

*UL adapter. 60 rpm

Environmental Properties

BOD_5	620 mg 0_2/g frother
BOD_{20}	1,349 mg 0_2/g frother
COD	1,937 mg 0_2/g frother

Principal Uses

AEROFROTH 73 frother is particularly useful in the flotation of nonmetallic minerals such as talc, graphite, sulfur, molybdenite and coal, as well as in the flotation of copper oxide and precious metal ores. It is exceedingly effective for improving molybdenum recovery in the flotation of copper-molybdenum ores. It can be used alone or mixed with other frothers.

Treatment Level

Suggested dosage rates are in the range of 0.05 to 0.5 lb/ton (25 to 250 g/t).

Application

As AEROFROTH 73 frother is water-insoluble, it is fed full strength to the conditioner and/or the flotation circuit.

Toxicity

The single oral LD_{50} of AEROFROTH 73 frother for young male albino rats and the LD_{50} by 24-hour contact with the clipped skin of male albino rabbits are greater than 5 ml/kg. AEROFROTH 73 is irritating to rabbit eyes but not rabbit skin.

AEROFROTH 73 contains methyl isobutylcarbinol. Methyl isobutylcarbinol is identified in Section 1910.1000 of the regulations to the Occupational Safety and Health Act. Employee exposure to methyl isobutylcarbinol as an air contaminant must be limited according to the provisions of this regulation.

CYANAMID

American Cyanamid Company
Industrial Chemicals Division
Mining Chemicals
Wayne, New Jersey 07470

Caution

Flotation reagents should not be physically mixed with each other without first obtaining the assurance of the manufacturer or manufacturers that this would not present a safety hazard.

Handling & Storage

AEROFROTH 73 frother is a stable, noncorrosive material which can be stored and handled in iron, carbon steel, plastic, PVC, copper and brass equipment.

AEROFROTH 73 frother is a combustible liquid. Follow precautions for a Class II combustible liquid. Keep away from heat and open flames. If product is spilled, remove sources of ignition. Cover with some inert absorbent material; sweep up and place in a waste disposal container. Flush area with water.

Shipping

AEROFROTH 73 frother is shipped in 55 gallon (200 liter) nonreturnable steel drums, FOB Linden, New Jersey. For information on bulk delivery, contact your Cyanamid Representative.

Technical Service

Effective mill management depends on using the best products with the latest technology in a totally balanced format. Cyanamid offers a complete system of products: collectors, frothers, flocculants, depressants, and filtering aids. Your Cyanamid Sales Representative is prepared with information and backed with technical service to aid you in applying our products.

Important Notice

CYANAMID

American Cyanamid Company
Industrial Chemicals Division
Mining Chemicals
Wayne, New Jersey 07470

8-1507 3M 4/78

CYANAMID

MSDS NO. 0290-01
CAS NO.
DATE: 08/14/82

MATERIAL SAFETY DATA

PRODUCT IDENTIFICATION

TRADEMARK:	**AERO® 350 Xanthate**
SYNONYMS:	None
CHEMICAL FAMILY:	Alkyl xanthate salt or Potassium Amyl xanth
MOLECULAR FORMULA:	n-C5H11OC(S)SK
MOLECULAR WGT.:	210

WARNING

CAUSES EYE AND SKIN IRRITATION

HAZARDOUS INGREDIENTS

COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
No Permissible Exposure Limits (PEL), have been established by OSHA				

NFPA HAZARD RATING

Not Established

HEALTH HAZARD INFORMATION

EFFECTS OF OVEREXPOSURE:	Acute oral (rat) LD50 value is between 1.0 and 2.0 g/kg. Skin or eye contact with solutions of the product may cause primary irritation. Airborne dust may cause significant eye and skin irritation or irritation of the respiratory tract. Overexposure to carbon disulfide may produce the following effects: eye or respirtory tract irritation, skin irritation or sensitization, dizziness, headache, degeneration of peripherial nerves, manic depressive pyschosis and cardiovascular disorders.
FIRST AID:	In case of skin contact, remove contaminated clothing without delay. Flush skin thoroughly with water. Do not reuse clothing without laundering. In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Refer to a physician if irritation persists. If vapor of AERO 350 Xanthate is inhaled, remove from exposure. Administer oxygen if there is difficulty in breathing.

EMERGENCY PHONE: 201/835-3100

EXPOSURE CONTROL METHODS

Utilize a closed system process where feasible. Where a closed system is not used, good enclosure and local exhaust ventilation should be provided to minimize exposure. Food, beverages, tobacco products should not be carried, stored or consumed where this chemcial is in use. Before eating, drinking or smoking wash face and hands with soap and water. Shower after completion of workshift. Launder work clothing at end of workshift prior to reuse. Store street clothing separately from work clothing and protective equipment. Work clothing and shoes must not be taken home. Where engineering controls are effective, respiratory protection is generally not required. If certain operations require respiratory protection, use a NIOSH approved respirator recommended by an industrial hygienist. Material causes eye or skin irritation on contact. A full facepiece respirator will provide eye and face protection. Wear the following as necessary to prevent skin contact; work pants, long sleeve work shirt and work gloves. For operations where eye or face contact can occur wear respiratory protection outlined above, (full facepiece) or dust proof goggles.

FIRE AND EXPLOSION HAZARD INFORMATION

FLASH POINT:	This product has no flash point of explosive limits. Carbon disulfide may be evolved; however, (see Reactivity Data) with a flash point of -22 F.
FLAMMABLE LIMITS (% BY VOL):	1.25 lower; 50.0 upper (residual carbon disulfide)
AUTOIGNITION TEMP:	248 F; 120 C (residual carbon disulfide)
DECOMPOSITION TEMP:	491-536 F; 255-280 C (residual carbon disulfide)
FIRE FIGHTING:	Use carbon dioxide or dry chemical to extinguish fires. Do not use water. Do not flush to sewers. Wear self-contained, positive pressure breathing apparatus and full firefighting protective clothing. See Exposure Control Methods for special protective clothing. Dust may be explosive if mixed with air in critical proportions and in the presence of a source of ignition. Liberates carbon disulfide slowly in aqueous solution, when heated, or in presence of moisture. Due to its high vapor density (2.2 @ 100 F) carbon disulfide may accumulate in the bottom of tanks or drums containing this product or solutions of it and create a fire or explosion hazard.

REACTIVITY DATA

STABILITY:	Unstable
CONDITIONS TO AVOID:	Heat or moisture will liberate carbon disulfide which is toxic and explosive.
POLYMERIZATION:	Will Not Occur
CONDITIONS TO AVOID:	None known
INCOMPATIBLE MATERIALS:	Acids, strong oxidizing agents, water (including atmospheric moisture).
HAZARDOUS DECOMPOSITION PRODUCTS:	Heat or moisture will liberate carbon disulfide. Thermal decomposition may produce carbon monoxide, carbon dioxide, sulfur oxides and/or carbon disulfide.

PHYSICAL PROPERTIES

APPEARANCE AND ODOR:	Yellow pellets or powder; slight, disagreeable odor
BOILING POINT:	Not Applicable
MELTING POINT:	491-536 F; 255-280 C
VAPOR PRESSURE:	Not Applicable
SPECIFIC GRAVITY:	Not Available
VAPOR DENSITY:	Not Applicable
% VOLATILE (BY VOL):	<15.0
OCTANOL/H_2O PARTITION COEF.:	Not Available
pH:	Not Applicable
SATURATION IN AIR (BY VOL):	Not Applicable
EVAPORATION RATE:	Not Applicable
SOLUBILITY IN WATER:	Appreciable

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wear NIOSH approved air purifying cartridge or canister respirator. Same protective clothing/equipment as in Exposure Control Methods. Vacuum spill instead of sweeping.

WASTE DISPOSAL

Disposal must be made in accordance with applicable governmental regulations.

SPECIAL PRECAUTIONS

HANDLING AND STORAGE/OTHER: Store in a cool, dry, well-ventilated area. Maintain good housekeeping to control dust accumulations. Areas where handling or use may result in the evolution of carbon disulfide should have fire safe practices and electrical equipment in accordance with Electrical and Fire Protection Codes (NFPA-30) governing Class I Flammable Liquids.

Marvin A. Friedman Marvin A. Friedman, Ph.D., Director of Toxicology and Product Safety

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CYANAMID

MSDS NO. 0293-01
CAS NO.
DATE: 07/29/82

MATERIAL SAFETY DATA

PRODUCT IDENTIFICATION

TRADEMARK:	**AERO® 343 Xanthate**
SYNONYMS:	Sodium isopropyl xanthate
CHEMICAL FAMILY:	Alkyl xanthate
MOLECULAR FORMULA:	$(CH_3)_2CHOC(S)SNa$
MOLECULAR WGT.:	176

WARNING

CAUSES EYE AND SKIN IRRITATION

HAZARDOUS INGREDIENTS

COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
No Permissible Exposure Limits (PEL), have been established by OSHA				

NFPA HAZARD RATING

Not Established

HEALTH HAZARD INFORMATION

EFFECTS OF OVEREXPOSURE:	Acute oral (rat) LD50 value is between 0.25 and 2.0 g/kg. Skin or eye contact with solutions of the product may cause primary irritation. Airborne dust may cause eye and skin irritation or irritation of the respiratory tract.
FIRST AID:	In case of skin contact, remove contaminated clothing without delay. Flush skin thoroughly with water. Do not reuse clothing without laundering. In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Refer to a physician if irritation persists. If vapor of AERO 343 Xanthate is inhaled, remove from exposure. Administer oxygen if there is difficulty in breathing.

EMERGENCY PHONE: 201/835-3100

EXPOSURE CONTROL METHODS

Utilize a closed system process where feasible. Where a closed system is not used, good enclosure and local exhaust ventilation should be provided to minimize exposure. Food, beverages, tobacco products should not be carried, stored or consumed where this chemcial is in use. Before eating, drinking or smoking wash face and hands with soap and water. Shower after completion of workshift. Launder work clothing at end of workshift prior to reuse. Store street clothing separately from work clothing and protective equipment. Work clothing and shoes must not be taken home. Where engineering controls are effective, respiratory protection is generally not required. If certain operations require respiratory protection, use a NIOSH approved respirator recommended by an industrial hygienist. Material causes eye or skin irritation on contact. A full facepiece respirator will provide eye and face protection. Wear the following as necessary to prevent skin contact; work pants, long sleeve work shirt and impervious gloves. For operations where eye or face contact can occur wear respiratory protection outlined above, (full facepiece) or dust proof goggles.

FIRE AND EXPLOSION HAZARD INFORMATION

FLASH POINT:	This product has no flash point or explosive limits. Carbon disulfide may be evolved; however, (see Reactivity Data) with a flash point of -22 F.
FLAMMABLE LIMITS (% BY VOL):	1.25 lower; 50.0 upper (residual carbon disulfide)
AUTOIGNITION TEMP:	248 F; 120 C (residual carbon disulfide)
DECOMPOSITION TEMP:	428-464 F; 220-240 C (residual carbon disulfide)
FIRE FIGHTING:	Use carbon dioxide or dry chemical to extinguish fires. Do not use water. Do not flush to sewers. Wear self-contained, positive pressure breathing apparatus and full firefighting protective clothing. See Exposure Control Methods for special protective clothing. Dust may be explosive if mixed with air in critical proportions and in the presence of a source of ignition. Liberates carbon disulfide slowly in aqueous solution, or when heated, or in presence of moisture. Due to its high vapor density (2.2 @ 100 F) carbon disulfide may accumulate in the bottom of tanks or drums containing this product or solutions of it and create a fire or explosion hazard.

REACTIVITY DATA

STABILITY:	Unstable
CONDITIONS TO AVOID:	Heat or moisture will liberate carbon disulfide which is toxic and explosive.
POLYMERIZATION:	Will Not Occur
CONDITIONS TO AVOID:	None known
INCOMPATIBLE MATERIALS:	Acids and strong oxidizing agents.
HAZARDOUS DECOMPOSITION PRODUCTS:	Heat or moisture will liberate carbon disulfide. Thermal decomposition may produce carbon monoxide, carbon dioxide, sulfur oxides and/or carbon disulfide.

PHYSICAL PROPERTIES

APPEARANCE AND ODOR:	Yellow pellets or powder; slight, disagreeable odor
BOILING POINT:	Not Applicable
MELTING POINT:	451-462 F; 233-239 C
VAPOR PRESSURE:	Not Applicable
SPECIFIC GRAVITY:	Not Available
VAPOR DENSITY:	Not Applicable
% VOLATILE (BY VOL):	<15.0
OCTANOL/H_2O PARTITION COEF.:	Not Applicable
pH:	Not Applicable
SATURATION IN AIR (BY VOL):	Not Applicable
EVAPORATION RATE:	Not Applicable
SOLUBILITY IN WATER:	Appreciable

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:

Where exposure level is not known, wear NIOSH approved positive pressure self-contained respirator. Where exposure level is known, wear NIOSH approved respirator suitable for level of exposure. Same protective clothing/equipment as in Exposure Control Methods. Vaccum spill instead of sweeping.

WASTE DISPOSAL

Disposal must be made in accordance with applicable governmental regulations.

SPECIAL PRECAUTIONS

HANDLING AND STORAGE/OTHER:

Store in a cool, dry, well-ventilated area. Maintain good housekeeping to comtrol dust accumulations. Areas where handling or use may result in the evolution of carbon disulfide should have fire safe practices and electrical equipment in accordance with Electrical and Fire Protection Codes (NFPA-30) governing Class I Flammable Liquids.

Marvin A. Friedman

Marvin A. Friedman, Ph.D., Director of Toxicology and Product Safety

CYANAMID

MSDS NO. 0632-01
CAS NO.
DATE: 04/28/82

MATERIAL SAFETY DATA

PRODUCT IDENTIFICATION

TRADEMARK:	**AERO® Xanthates 317, 325 and 355**
SYNONYMS:	Potassium or sodium alkyl xanthates
CHEMICAL FAMILY:	Xanthates
MOLECULAR FORMULA:	ROCS(S) Na or ROCS (S)K
MOLECULAR WGT.:	Mixture

WARNING

CAUSES EYE AND SKIN IRRITATION

HAZARDOUS INGREDIENTS

COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
No Permissible Exposure Limits (PEL), have been established by OSHA				

NFPA HAZARD RATING

Not Established

HEALTH HAZARD INFORMATION

EFFECTS OF OVEREXPOSURE:	The acute oral (rat) LD50 value for Aero Xanthate 317 is between 0.5 and 2.0 g/kg. Skin or eye contact with solutions of any of these products may cause primary irritation. Airborne dust may cause significant eye and skin irritation or irritation of the respiratory airways.
FIRST AID:	In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Refer to a physician if irritation persists. In case of skin contact, wash affected areas of skin with soap and water. Do not reuse contaminated clothing without laundering.

EMERGENCY PHONE: 201/835-3100

AMERICAN CYANAMID COMPANY, WAYNE, NEW JERSEY 07470

EXPOSURE CONTROL METHODS

Where a closed system is not used, good enclosure and local exhaust ventilation should be provided to minimize exposure. Food, beverages, tobacco products should not be carried, stored or consumed where this chemical is in use. Before eating, drinking or smoking wash face and hands with soap and water. Where engineering controls are effective, respiratory protection is generally not required. If certain operations require respiratory protection, use a NIOSH approved respirator recommended by an industrial hygienist. Material causes eye or skin irritation on contact. A full facepiece respirator will provide eye and face protection. Wear the following as necessary to prevent skin contact; work pants and long sleeve work shirt. For operations where eye or face contact can occur wear respiratory protection outlined above and dust proof goggles.

FIRE AND EXPLOSION HAZARD INFORMATION

FLASH POINT:	Not Applicable
FLAMMABLE LIMITS (% BY VOL):	Lower - 1.25 Upper - 50.0
AUTOIGNITION TEMP:	248 F(120 C) Residual Carbon Disulfide
DECOMPOSITION TEMP:	Not Available
FIRE FIGHTING:	Use carbon dioxide, dry chemical or water to extinguish fires. Heat causes decomposition to vapor of carbon disulfide. Wear self-contained, positive pressure breathing apparatus and full firefighting protective clothing. Solid xanthates are stable when kept cool and dry. However, exposure to heat and moisture can cause decomposition to flammable and explosive vapor of carbon disulfide. Since xanthates decompose in solution, even at room temperature, fire and explosion hazards can develop with aging.

REACTIVITY DATA

STABILITY:	Unstable
CONDITIONS TO AVOID:	Heating of solid xanthates or heating or aging of xanthates solutions.
POLYMERIZATION:	Will Not Occur
CONDITIONS TO AVOID:	None known
INCOMPATIBLE MATERIALS:	No specific incompatibility.
HAZARDOUS DECOMPOSITION PRODUCTS:	Thermal decomposition or combustion may produce carbon monoxide, carbon dioxide, carbon disulfide and/or sulfur dioxide.

PHYSICAL PROPERTIES

APPEARANCE AND ODOR:	Yellow pellets or powder; odor of carbon disulfide
BOILING POINT:	Not Applicable
MELTING POINT:	360-493 F; 182-256 C
VAPOR PRESSURE:	Not Available
SPECIFIC GRAVITY:	Not Applicable
VAPOR DENSITY:	Not Available
% VOLATILE (BY VOL):	Negligible
OCTANOL/H_2O PARTITION COEF.:	Not Available
pH:	Not Applicable
SATURATION IN AIR (BY VOL):	Not Available
EVAPORATION RATE:	Not Available
SOLUBILITY IN WATER:	Appreciable

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wear NIOSH approved air purifying cartridge or canister respirator. In addition to the protective clothing/equipment in Exposure Control Methods, wear coveralls. Vacuum spills instead of sweeping.

WASTE DISPOSAL

Disposal must be made in accordance with applicable governmental regulations.

SPECIAL PRECAUTIONS

HANDLING AND STORAGE/OTHER: Heating of solid xanthates or heating or aging of xanthate solutions causes some decomposition to poisonous and flammable carbon disulfide. Maintain good housekeeping to control dust accumulations. Special precautions against fire and explosion must be observed in (1) pumping xanthate solutions, (2) draining mobile tanks, (3) cleaning mobile tanks, and (4) performing maintenance work on storage tanks and pipelines leading to and from tanks. Storage tanks should have certain design features for maximum safety, and the vapor space should be free of sources of ignition. Use nonsparking tools and do not smoke when opening drums of xanthate. Do not use xanthate products until you have read the "Safety Discussion" in the AERO Xanthate Handbook from this Company.

Marvin A. Friedman Marvin A. Friedman, Ph.D., Director of Toxicology and Product Safety

HERCULES

MATERIAL SAFETY DATA SHEET

(Approved by U.S. Department of Labor as "Essentially Similar" to Form OSHA-20)

MSDS WS 002E
DATE 2/16/82

PAGE 1 of 2

I. PRODUCT IDENTIFICATION

CHEMICAL NAME AND SYNONYMS	Sodium carboxymethyl cellulose, technical	REGULAR TELEPHONE NO. 302—575-5000 EMERGENCY TELEPHONE NO. 302—995-3000*	
CHEMICAL FAMILY	Cellulose ether	CAS NO. 9004-32-4; Cellulose, carboxymethyl ether, sodium salt	
FORMULA	—	MOLECULAR WEIGHT	—
TRADE NAME AND SYNONYMS	HERCULES® CMC-TECHNICAL GRADE, minimum purity 88%-dry basis, various particle sizes, substitutions, and viscosities**.		

II. HAZARDOUS INGREDIENTS

MATERIAL	%	TLV-TWA VALUES ADOPTED BY ACGIH
Note: As Hercules interprets the U. S. Occupational Safety and Health Act of 1970, this product should not be considered a hazardous material.		

III. PHYSICAL DATA

BOILING POINT, 760 mm Hg	NA	FREEZING POINT	NA
VAPOR PRESSURE @	NA	BULK DENSITY (AS SHIPPED)	600 kg/m^3 - Granular (38 lb/ft^3) Typical
VAPOR DENSITY (AIR=1)	NA	MOISTURE CONTENT % BY WEIGHT	8% maximum (as packed)
SOLUBILITY IN WATER, % BY WEIGHT @ 25°C	Complete	EVAPORATION RATE (BUTYL ACETATE=1)	NA
APPEARANCE AND ODOR: White to tan granular powder or pellet; odorless.		pH	—

IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (TEST METHOD) NA	AUTOIGNITION TEMPERATURE Ca 370°C (698°F) Dust	
FLAMMABLE LIMITS IN AIR PERCENT BY VOLUME	LOWER NA	UPPER NA

EXTINGUISHING MEDIA: Foam, dry chemical, CO_2, water spray or fog.

SPECIAL FIRE-FIGHTING PROCEDURES: None

UNUSUAL FIRE AND EXPLOSION HAZARDS: Flammable dust when finely divided and suspended in air.

NOTES: NA = NOT APPLICABLE

**Most types of technical grades of CMC are designated with a "T", e.g., CMC-7MT. CMC-1A and CMC-6-DG-L are also technical grades although a "T", does not appear in their designations.

*Use this emergency number only after normal business hours and only for emergencies involving safety and health.

MSDS WS 002E DATE 2/16/82 PAGE 2 of 2

V. HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE: Not established[1]

EFFECTS OF OVEREXPOSURE: None known

EMERGENCY AND FIRST AID PROCEDURES: None required

NOTE 1. This material is not expected to cause physiologic impairment at low concentration. Until a specific TLV is adopted by the American Conference of Governmental Industrial Hygienists (ACGIH), Hercules Incorporated suggests that this material be treated as a nuisance dust or particulate in accordance with the recommendations of ACGIH.

VI. REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID: None
UNSTABLE		
STABLE	X	

INCOMPATIBILITY (MATERIALS TO AVOID): None

HAZARDOUS DECOMPOSITION PRODUCTS: None

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID: None
	WILL NOT OCCUR	X	

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Mechanical clean-up for use or disposal.

WASTE DISPOSAL METHOD: Incineration or landfill. Dispose of in accordance with local, state, and Federal regulations.

VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (SPECIFY TYPE): Nuisance dust respirator approved by NIOSH/MSHA in excessive air concentrations.

VENTILATION	LOCAL EXHAUST	—	SPECIAL	—
	MECHANICAL (GENERAL)	—	OTHER	Adequate to control nuisance particulate
PROTECTIVE GLOVES: —			EYE PROTECTION:	Safety glasses

OTHER PROTECTIVE EQUIPMENT: —

IX. SPECIAL PRECAUTIONS

PRECAUTIONARY LABELING:

CAUTION! FLAMMABLE DUST WHEN FINELY DIVIDED AND SUSPENDED IN AIR.
SURFACES SUBJECT TO SPILLS OR DUSTING WITH THIS PRODUCT CAN BECOME SLIPPERY WHEN WET.
Keep away from heat, sparks, and open flame.
Use with adequate ventilation.
Keep floors clean.

OTHER HANDLING AND STORAGE CONDITIONS: Surfaces subject to spills or dusting with this product can become slippery when wet. To protect product quality, store in sealed containers in a dry place away from heat and sunlight.

Appendix E

Water Treatment Sludge Characterization

INTRODUCTION

Waste characterization studies are required by NR 182 to insure that waste characteristics are considered in the design of the disposal facilities.

During mature operations of the Crandon Project, four individual sludges will be combined for disposal with pyrite tailings in the mine waste disposal facility. The combined sludge stream will be about 40 gpm whereas the flow of pyrite tailings will be about 410 gpm of pulp. Therefore, the total sludge from the mature water treatment plant operations will comprise only about 10% by volume of the total flow to the mine waste disposal facilities (MWDF).

The performance of waste characterization studies on the water treatment sludges for the Crandon water treatment plant is complicated by the fact that the actual mine and process waters do not now exist and thus actual sludges cannot be produced. Limited quantities of some synthesized sludges were produced in laboratory testing on synthesized water samples. These synthetic waters differ from the expected waters in some ways. The most significant difference is the absence of suspended mineral particles in all but one of the synthetic mine waters tested. These suspended solids will report to the water treatment sludge and will dilute the sludge to a substantial degree.

At the present time, the most representative estimate of the characterization of the water treatment sludge is from the CH2M Hill water model which is also used to predict effluent water quality. A thorough description of the water model is given in "Phase III Waste Management Study," (CH_2M Hill, 1982).

Three water treatment test programs have generated sludges which have since been used in characterization studies. Two test programs were carried out in 1984 and one was carried out in 1985 This report summarizes the results of characterization studies on sludges generated in testing at Exxon Research and Engineering (ER&E) and Minerals Processing Research of Exxon Minerals Company (MPR). A summary of the two water treatment reports covering the 1984 testing at ER&E and MPR was presented as Appendix A of the Water Treatment Facility Preliminary Engineering Report. The third test program was conducted in 1985 at MPR to generate an appropriate contaminated mine water sludge for EP Toxicity testing. A summary of this testing is presented as Attachment I to this Appendix.

The waste characterization studies performed in 1984 and 1985 had the following objectives and results:

- Estimation of the chemical composition of the sludges.
    - The combined sludge is primarily a mixture of inactive slimes from the mine sumps, calcium carbonate, calcium hydroxide and lesser quantities of precipitated heavy metals.

- Estimation of the chemical reactivity and leaching characteristics of the sludges.
  - Because of the high buffering capacity provided by the excess carbonate and hydroxide, the combined sludge resists dissolution in acid and is chemically stable.
- Estimation of the physical properties which would effect handling and disposal of the sludges.
  - Physically the sludges are typically carbonate and hydroxide precipitates. Due to the gelatinous nature of the hydroxide sludges, they tend to entrap moisture and exhibit a thixotropic nature.
- Determination of the sludge response to EP Toxicity testing.
  - The contaminated mine water sludge and recycle water sludge were determined to be non-hazardous by EP Toxicity testing as all EPA hazardous metals were below the RCRA alert levels in the EP extract.

DISCUSSION

Procedure

The 1984 water treatment testing program at ER&E was in part designed to generate a sufficient quantity of sludge for waste characterization from one liter per minute/15 hour continuous pilot plant runs. This test program was described in the November 1984 report titled "Exxon Minerals Company Crandon Project Water Treatment Testing Program".

The sludges from the ER&E program were obtained by draining the sludges from the pilot plant clarifier at the end of the continuous run. This sludge should be representative of that material which was precipitated. An insignificant portion of the sludge material was lost in the clarifier overflow and recovered in the sand filter.

The 1984 test program at MPR was primarily designed to investigate lowering effluent soluble metal concentrations after treatment with lime-sulfide additions. Sludge generation was not an objective in these tests; and due to the smaller scale (five to six hour runs at 0.1 liter minute), smaller quantities of sludge were produced. This work is described in the September 1984 report titled "Water Treatment Testing - Crandon Project".

In the 1984 MPR program the tall cylinder which was used as a clarifier was drained at the conclusion of the continuous precipitation run and the sludge recovered. However, from the analyses of the clarifier overflow presented in the MPR report, a significant portion of the precipitated material was overflowing the clarifier and this material was not recovered. Thus, the one gram of sludge recovered in the 1984 MPR lab test and used for chemical analyses may not be representative of the total material that was precipitated in the reactor.

The primary objective of the 1985 MPR testing was to produce an appropriate contaminated mine water sludge for EP Toxicity testing. This sludge was prepared in a single large batch test from 50 gallons of synthetic contaminated mine water. In contrast to the synthetic mine waste used in the other test programs, this water did contain the suspended mineral particles expected to be present in the actual contaminated mine waste. Thus the sludge produced from this test was more representative of the projected actual sludge than the contaminated mine water sludges produced in the other test programs and was more appropriate for EP Toxicity testing.

Sludges used for chemical analysis from the three test programs were first filtered and oven dried. Chemical analyses on the sludges were done by dissolving the oven dried sludges in aqua regia and submitting them for inductively coupled plasma (ICP) analysis. The ICP used had no channels for arsenic, selenium, and mercury and thus these metals were analyzed by graphite furnace atomic adsorption (AA) and cold vapor AA. The chemical results are summarized in Table 2. The major constituents of the sludges are iron, zinc, and calcium. A material balance calculation, influent minus effluent concentration, for each constituent indicates that the relative concentration in the sludges is consistent with what was chemically analyzed.

The filter cake sludges were wet with waste water effluent solution. Thus, upon oven drying, the constituents initially in solution became part of the residue. This resulted in the presence of normally soluble elements in the synthetic sludge residues.

Agitated leaching tests were conducted on two of the ER&E sludges (contaminated mine water and recycle water). The procedure employed was that developed by ASTM committee D-18 and published as Method A, Water Extraction Procedure under "Proposed Methods for Leaching of Waste Material". One part of wet sludge filter cake was mixed with four parts deionized water (DI) and agitated on rolls for 48 hours. Clarified supernatant from centrifuging was filtered through 0.45 micrometer filter. The results shown in Tables 3 and 4 indicate that all constituents of the leachate except for selenium are less than primary and secondary drinking water standards.

Chemical Composition

In the absence of the sludges generated from the treatment of actual waters from the Crandon Project, the best estimate of the chemical composition of the anticipated sludges results from the application of the CH_2M Hill water model which is included as Attachment II and which calculates the composition of the water(s) and sludge(s) produced by the water treatment process(es). The estimated chemical composition of the four sludges and their relative weight proportions under mature mine operations are presented in Table 1.

Although the water model reports results in mg/l (volume basis), they have been converted to a dry weight basis (microgram/gram) in Table 1 for comparison to the values in Table 2 which are chemical analyses of some of the synthetic sludges produced from testing during 1984 and 1985.

The synthetic recycle water sludge produced at ER&E was analyzed and the results are given in Table 2. This sludge is predominantly calcium carbonate as a result of the lime, soda ash precipitation of high concentrations of calcium in the influent. It composes nearly 50% of the total sludge and the chemical analysis agrees fairly well with the projections from the water model shown in Table 1. Although the differences between the compositions shown in Table 1 and Table 2 for recycle water sludge are slight, most of the differences which exist can be attributed to:

1) The values in Table 1 represent dry solids; whereas those in Table 2 reflect a filtered sludge cake. Some normally soluble constituents were trapped in the sludge during oven drying and appear in Table 2.

2) Some 900 ppm of suspended inert solids contained in the approximately 190 gpm of contaminated mine water which becomes part of the actual recycle water are reflected in Table 1 but not accounted for in Table 2.

As shown in Table 2, the recycle sludge filter cake had a much higher percent solids (62%) than the other sludges. This is probably because soda ash precipitates a crystalline calcium carbonate; whereas lime neutralization precipitates a hydrated gelatinous metal hydroxide precipitate.

The synthetic contaminated mine water sludges were analyzed chemically and the results are also given in Table 2. Four samples of this sludge were analyzed. However, the three from the 1984 testing are not representative of the sludge which will actually be generated for the following reasons:

1) Two of the sludges were produced from lime precipitation alone without sulfide addition.

2) The actual sludge will be diluted by a factor of over 10 from an estimated 900 mg/l of inert suspended solids from the mine sumps.

The chemical composition projected by the water model (Table 1) is more representative of the actual contaminated mine water sludge. This analysis, which is significantly different than the three 1984 sludges in Table 2, shows the sludge is still mostly calcium, iron and zinc but all constituents have been substantially diluted by relatively inactive solids. The metal content of the MPR 1985 sludge agrees most closely with the water model projections.

X-ray diffraction analyses were performed by MPR on the two ER&E sludges (recycle and contaminated mine water). The results are shown in Attachment III. Calcium carbonate was the only crystalline phase detected. Metal hydroxides were at too low a concentration for detection and probably were not crystalline in any case.

An apparent difference between the sludges produced by MPR and ER&E is that the ER&E sludge from neutralization of contaminated mine water contains a much higher amount of calcium than MPR's. This probably results from a larger amount of unreacted lime indicating a difference in the grade of lime used.

Synthetic evaporator brine sludge has not been generated in any testing so far. The only chemical composition available for this sludge which composes about 5% of the total sludge is given in Table 1 as a water model projection. This sludge is primarily suspended solids from the evaporator brine circuit and is composed mostly of calcium and other impurities.

The synthetic intercepted ground water sludge was not produced in sufficient quantity for chemical analyses. It composes less than 1% by weight of the total sludge. The chemical analyses projected in Table 1 by the water model is the only chemical composition available.

Buffer Capacity

The buffer capacity of each sludge was determined and is reported in Table 2. Samples of oven-dried sludge were reacted with warm one normal HCl and the excess acidity neutralized with standardized caustic to a pH of 4.5. The buffer capacity is reported as percent calcium carbonate equivalent and represents the acid neutralizing capabilities of calcium and magnesium carbonates and hydroxides, as well as those metal hydroxides that precipitate below pH 4.5 such as iron and aluminum. The high values reported in Table 2 (27.5 - 95.1%) are partially responsible for the ability of the sludges to remain insoluble.

Leaching Characteristics

The leaching characteristics of the synthetic samples of contaminated mine and recycle water sludges were estimated in two ways. To estimate the chemical reactivity of the water treatment sludges, the buffer capacities (previously described) of the synthetic samples of contaminated mine water sludge and recycle water sludge were determined and agitated leaching tests were conducted utilizing deionized water. The results of the buffer capacity determinations are given in Table 2 and range from 25 to 95 percent $CaCO_3$. The chemical analyses of the leachates from the deionized water extraction tests are presented in Tables 3 and 4 and are compared with the sludge filtrate analyses.

Heavy metal analyses on the DI leachate typically were not significantly different than the sludge filtrate indicating the reestablishment of chemical equilibrium between the sludge and constituents in solution (pH of sludge leachate and DI leachate is similar). Very soluble constituents such as sodium and sulfate were less in the DI leachate as a result of dilution by DI water.

Physical Characteristics

The physical characteristics of the sludges were estimated by reference to the literature, observation of full scale mining operations, and measurements of the laboratory produced sludges.

The recycle sludge is primarily crystalline calcium carbonate; whereas the lime sludge from treatment of mine water is a hydrated gelatinous precipitate. The sludges will individually be 5-15% dry solids by weight with the combined sludge being about 10%. Due to the gelatinous nature of the hydroxide sludges, they tend to entrap moisture and exhibit a thixotropic nature. This means that although they are gelatinous, they become fluid when being agitated or pumped. Recognition of this fact has been a prime consideration in the design of the pumping and handling of the sludge.

EP Toxicity Testing

Samples of the synthetic recycle water sludge produced by ER&E and the synthetic contaminated mine water sludge produced by MPR in 1985 were subjected to EP Toxicity testing by Environmental Testing and Certification (ETC). These two sludges are projected to represent 96% of the sludge to be sent to the tailings pond.

The EP Toxicity testing consists of a 24-hour acetic acid leach followed by analysis of the leachate, called the EP extract, for specified EPA hazardous metals. The results of the analyses on the EP extract are shown in Table 5. All EPA hazardous metals were below the RCRA alert levels in the EP extract.

CONCLUSION

The sludges are chemically stable and nontoxic; however, they should be stored in a manner in which they will be protected from exposure to acidic pH for an extended period of time. The sludges will be stored in the mine waste disposal facility (MWDF) which has been designed to prevent infiltration of air and rainfall precipitation, prevent generation of acid, and prevent significant seepage. During operation of the mine, the MWDF will be kept alkaline through lime additions at the tailings thickener, reclaim ponds, in the process, as well as by the buffering capacity of the tailings and sludge.

After closure, the design of the cap will preclude the generation of acid by excluding air and seepage from above. This will be accomplished by a cover that contains of up to five feet of random till which has been carefully designed to prevent erosion and allow revegetation. Thus, the MWDF is the best place to store the sludges.

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TABLE 1
WATER MODEL PROJECTIONS OF THE APPROXIMATE COMPOSITION of WATER TREATMENT SLUDGES
(microgram/gram)

Chemical Constituent	Recycle Water	Contaminated Mine Water	Evaporator Brine	Intercepted Ground Water	Total Sludge
Ag	0.0	6.7	220	0.0	14
Al	0.0	0.0	0.0	0.0	0.0
Ba	0.0	0.0	0.0	0.0	0.0
Ca	286000	340	394000	0.0	157000
Cd	4.3	42	250	620	40
Cr	730	120	630	0.0	440
Cu	94	80	250	3200	130
Fe	320	4800	2600	98000	3500
Hg	0.0	0.1	0.0	0.0	0.1
K	0.0	0.0	0.0	0.0	0.0
Mg	6.6	24	0.0	0.0	14
Mn	69	232	370	241	160
Na	0.0	0.0	0.0	0.0	0.0
Pb	95	190	250	320	150
Zn	3800	12000	710	6700	7400
As	2.0	1.3	340	7800	97
B	ND[2]	ND	ND	ND	ND
Se	56	18	580	120	65
Approx. % of Total Dry Wt.	48	46	5	1	100

1) The compositions are on dry weight basis and are numerically best fit.
2) ND - not determined.

Note: Based on summer water chemistry.

TABLE 2

CHEMICAL ANALYSES OF WATER TREATMENT SLUDGES
(microgram/gm)

	Contaminated Mine Water				Recycle	Analytical
Constituent	Lime MPR 1984	Lime + Na_2S MPR 1984	Lime ER&E	Lime & Na_2S MPR 1985	Na_2CO_3 ER&E	Technique Employed(1)
Ag	58	200	66	14	2	AA
Al	15,200	11,100	5,400	35,270	1,300	ICP
Ba	148	98	83	24	5	ICP
Ca	31,300	36,100	192,000	55,400	304,000	ICP
Cd	900	1,000	270	55(6)	24	ICP
Cr	4,700	3,700	850	240	650	ICP
Cu	2,000	1,750	650	920	121	ICP
Fe	89,000	69,000	25,800	86,300	7,900	ICP
Hg	ND	0.2	0.2	0.6	0.2	AA
K	500	500	200	ND	200	ICP
Mg	10,200	13,100	28,500	36,000	7,300	ICP
Mn	5,700	6,100	1,900	1,200	174	ICP
Na	1,090	990	400	200	1,670	ICP
Pb	4,800	3,760	1,210	540(6)	124	ICP
Zn	253,000	269,000	74,000	16,000	4,600	ICP
As	490	390	130	360	16	AA
B	172	130	(55)	ND	20	ICP
S	4,700	16,900	10,000	ND	5,700	ICP
Se	1,100	950	330	30	64	AA
Insol(3)	162,000	149,000	56,000	400,000	6,000	
%Solids(4)	15.3	12.9	13.7	16.6(7)	62	
Buffer(5) Capacity (%)	63.8	69.1	86.2	27.5	95.1	

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(1) AA = Atomic Adsorption, ICP = Inductively Coupled Plasma.
(2) Data in () indicates value is between detection limit and three times detection limit for ICP analysis. ND = not determined.
(3) Acid insoluble component, essentially SiO_2.
(4) Percent oven dry solid in wet filter cake sludge.
(5) Buffer capacity reported as percent $CaCO_3$.
(6) Analyzed by AA.
(7) Percent oven dry solids in settled sludge.

TABLE 3

DI WATER EXTRACTION RESULTS

CONTAMINATED MINE WATER SLUDGE

Constituent	Concentration Units	Sludge Filtrate	DI Water Leachate	Analytical Method(1,2)
Ag	ug/L	7.0	1	AA
Al	ug/L	(65)	141	ICP
Ba	ug/L	70	50	ICP
Ca	mg/L	109	6.2	ICP
Cd	ug/L	1.1	0.2	AA
Cr	ug/L	(8)	(12)	ICP
Cu	ug/L	5	5	ICP
Fe	ug/L	38	(11)	ICP
Hg	ug/L	ND	1	AA
K	mg/L	0.5	(0.8)	ICP
Mg	mg/L	26.5	4.1	ICP
Mn	ug/L	15	3	ICP
Na	mg/L	87.7	64.8	ICP
Pb	ug/L	50	50	ICP
Zn	ug/L	25	(6)	ICP
As	ug/L	10	10	AA
B	ug/L	(61)	(40)	ICP
Cl	mg/L	2	2	IC
SO_4	mg/L	548	147	IC
S(3)	mg/L	230	60.0	ICP
Si	mg/L	0.5	0.8	ICP
Se	ug/L	86	150	AA
Alkalinity	mg/L of $CaCO_3$	11.8	26.8	
pH		9.6	9.3	

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(1) Data in () indicates value is between detection limit and three times detection limit for ICP analysis. ND = not determined.

(2) AA = Atomic Adsorption, ICP = Inductively Coupled Plasma, IC = Ion Chromatagraph.

(3) Sulfur speciation greatly effects ICP signal intensity; polythionates generate several times higher signal per pole of sulfur than sulfate. Thus presence of polythionates results in erroneously high sulfate concentrations based on sulfur ICP values.

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TABLE 4

DI WATER EXTRACTION RESULTS

RECYCLE WATER SLUDGE

Constituent	Concentration Units	Sludge Filtrate	DI Water Leachate	Analytical Method(1,2)
Ag	ug/L	1	1.7	AA
Al	ug/L	130	50	ICP
Ba	ug/L	94	40	ICP
Ca	mg/L	7.0	37.2	ICP
Cd	ug/L	1.9	0.6	AA
Cr	ug/L	78	5	ICP
Cu	ug/L	18	5	ICP
Fe	ug/L	5	5	ICP
Hg	ug/L	ND	1	AA
K	mg/L	4.8	0.5	ICP
Mg	mg/L	4.6	12.4	ICP
Mn	ug/L	3	3	ICP
Na	mg/L	631	17.0	ICP
Pb	ug/L	50	50	ICP
Zn	ug/L	45	14	ICP
As	ug/L	10	10	AA
B	ug/L	83	(20)	ICP
Cl	mg/L	2	2	IC
SO_4	mg/L	1,400	168	IC
S(3)	mg/L	571	70.7	ICP
Si	mg/L	1.9	0-.3	ICP
Se	ug/L	510	79	AA
Alkalinity	mg/L of $CaCO_3$	70.5	11.8	
pH		9.8	9.0	

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(1) Data in () indicates value is between detection limit and three times detection limit for ICP analyses. ND = not determined.

(2) AA = Atomic Adsorption, ICP = Inductively Coupled Plasma, IC = Ion Chromatagraph.

(3) Sulfur speciation greatly effects ICP signal intensity, polythionates generate several times higher signal per pole of sulfur than sulfate. Thus presence of polythionates result in erroneously high sulfate concentrations based on sulfur ICP values.

TABLE 5

EP TOXICITY TESTING RESULTS

ANALYSIS OF EP EXTRACT

Element	Concentration in EP Extract (mg/L) Recycle Water Sludge (ER&E 1984)	Concentration in EP Extract (mg/L) Contaminated Mine Water Sludge (MPR 1984)	RCRA Alert Level (mg/L)
Arsenic	< 1	< 1	5
Barium	< 5	< 5	100
Cadmium	< 0.2	< 0.2	1
Chromium	< 1	< 1	5
Lead	< 1	< 1	5
Mercury	< 0.003	< 0.003	0.2
Selenium	< 0.3	< 0.3	1
Silver	< 0.2	< 0.2	5

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ATTACHMENT I TO APPENDIX E

Preparation of Synthetic Contaminated Mine Water Sludge

MPRD 1985

INTRODUCTION

Subsequent to the 1984 water treatment studies presented in Appendix A, an additional contaminated mine water sludge sample was prepared to provide an appropriate sample for EP toxicity testing.(1) The synthetic contaminated mine waters that were tested in 1984 did not contain the suspended mineral particles that will be present in the actual mine water. These suspended solids will report to the water treatment sludge and will dilute the sludge to a substantial degree.

This attachement describes the preparation of a synthetic sludge sample produced from contaminated mine water containing the type and quantity of suspended solids expected in the actual mine water.

SUMMARY

A simulated contaminated mine water sample was prepared containing 900 ppm of suspended solids. The mine water was adjusted to pH 10.6 with lime to precipitate the metals. Ferric sulfate was added as a coagulant, and sodium sulfide was added to aid in metal precipitation. The sludge produced was analyzed and subjected to EP toxicity testing. The EP toxicity test on the sludge showed that all EPA hazardous metals in the EP extract were below the RCRA alert levels.

SLUDGE PREPARATION

The simulated contaminated mine water used to produce the sludge was prepared by spiking 50 gallons of Crandon well water with the appropriate chemical compounds to reach the target values for the various constituents.

The simulated mine water was analyzed to determine both soluble and soluble plus suspended metal content. The soluble metal content was determined by filtering a well mixed water sample at 0.45 microns, acidifing the sample, and conducting the analysis. The soluble plus suspended metal content was determined by acidifying a sample of the well mixed simulated mine water, filtering at 0.45 microns, and conducting the analysis. The results of these analyses along with the target metal concentrations are presented in Table 1. The target concentrations represent the projected composition of the contaminated mine water at the time this testing was conducted. The projected composition of the contaminated mine water has changed slightly since this testing was conducted due to changes in the quality and quantity of backfill drainage and the projected volume of mine inflow. However, these changes have little effect on the projected composition of the sludge to be produced.

TABLE 1

Chemical Composition of Simulated Mine Water

Element	Compound Added	Concentration Units	Crandon Well H_2O	Simulated Mine H_2O(2)			Analytical Technique
				Target	Filtered	Acidified	
Silver (Ag)	$AgNO_3$	ug/L	<0.5	10	<0.5	(5.3)(3)	ICP
Mercury (Hg)	$HgCl_2$	ug/L	<0.1	0.3	<0.1	<0.1	AA
Aluminum (Al)	$Al_2(SO_4)_3$	ug/L	<5	940	<5	774	ICP
Arsenic (As)	$NaAsO_2$	ug/L	<10	25	17	23	AA
Barium (Ba)	$BaCl_2 \cdot 2H_2O$	ug/L	13	18	8	32	ICP
Calcium (Ca)	$CaSO_4 \cdot H_2O$	mg/L	24	170	162	166	ICP
Cadmium (Cd)	$CdCl_2$	ug/L	<1	56	39	50	AA
Chromium (Cr)	$CrCl_3 \cdot 6H_2O$	ug/L	<5	270	<5	212	ICP
Copper (Cu)	$CuSO_4 \cdot 5H_2O$	ug/L	<5	120	148	98	ICP
Iron (Fe)	(1)	ug/L	(6)	4,980	(10)	3,850	ICP
Magnesium (Mg)	$MgSO_4$	ug/L	12	16	16	17	ICP
Manganese (Mn)	$MnSO_4 \cdot H_2O$	ug/L	(3)	350	326	344	ICP
Sodium (Na)	Na_2SO_4	mg/L	2	76	73	73	ICP
Lead (Pb)	$PbCl_2$	ug/L	11	280	<10	189	ICP
Selenium (Se)	H_2SeO_3	ug/L	<10	110	70	88	AA
Zinc (Zn)	$ZnSO_4 \cdot 7H_2O$	ug/L	19	16,000	4,000	14,200	ICP

(1) Iron added as $FeSO_4 \cdot 7H_2O$ and $Fe_2(SO_4)_3 \cdot 7H_2O$
Targets of 4,700 ug/L Fe^{+2} and 280 ug/L Fe^{+3}

(2) Filtered = Sample taken from agitated drum, filtered at 0.45 microns and then acidified.
Acidified = Sample taken from agitated drum, acidified and agitated, then filtered at 0.45 microns.

(3) Data in () indicates value is between detection limit and three times detection limit.

Fine suspended solids were added to the simulated mine water to produce a concentration of 900 mg/L suspended solids. A sample of Crandon waste rock pulverized to minus 44 microns was used a the source of these solids. The anlaysis of the Crandon waste rock used is shown in Table 2.

TABLE 2

Chemical Composition of Crandon Waste Rock

Constituent	Concentration ug/g	Analytical Technique
Ag	6	ICP
Al	71,700	ICP
As	470	AA
Ba	1,000	ICP
Ca	6,400	ICP
Cd	12	AA
Cr	17	ICP
Cu	1,000	ICP
Fe	100,800	ICP
Mg	37,400	ICP
Mn	1,200	ICP
Na	8,700	ICP
Pb	370	AA
Se	13	AA
Zn	4,000	ICP
SiO_2	51%	AA

The simulated mine water was agitated and aerated for 48 hours. The pH was adjusted to 10.6 with lime, and 20 mg/L ferric sulfate was added. Subsequently 10 mg/L sodium sulfide was added. The sludge was allowed to settle overnight. The sludge settled to 16.6 percent solids.

The analyses of the filtered supernatant and dried sludge are shown in Table 3. All of the metal concentrations in the treated synthetic mine water were below the effluent limitation for discharge to Swamp Creek.

A sample of the sludge slurry was sent to Environmental Testing and Certification (ETC) for EP toxicity testing. The sludge passed the EP toxicity testing and was determined to be non-hazardous. These test results are summarized in Appendix E.

TABLE 3

Chemical Composition of Precipitation Products

Constituent	Mine Water (After Treatment) ug/L	Water Treatment Sludge ug/g	Analytical Technique
Silver (Ag)	<1	14	AA
Mercury (Hg)	<0.1	0.6	AA
Aluminum (Al)	<5	35,300	ICP
Arsenic (As)	<10	360	AA
Barium (Ba)	14	24	ICP
Calcium (Ca)	157,000	55,400	ICP
Cadmium (Cd)	<0.1	55	AA
Chromium (Cr)	<5	240	ICP
Copper (Cu)	<2	920	ICP
Iron (Fe)	(8)(1)	86,300	ICP
Magnesium (Mg)	7,000	35,500	ICP
Manganese (Mn)	(3)	1,200	ICP
Sodium (Na)	70,000	200	ICP
Lead (Pb)	<10	540	AA
Selenium (Se)	77	30	AA
Zinc (Zn)	19	15,700	ICP
Insol.		400,000	
Buffer Capacity (%)(2)		27.5	
Percent Solids		16.6	

(1) Data in () indicates value is between detection limit and three times detection limit.

(2) Buffer Capacity reported as percent $CaCO_3$.

Reference

1. EMC memo, J. H. Wirag to R. N. Kust, "Sludge Characterization Experiments-Crandon Water Treatment," August 28, 1985.

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ATTACHMENT II
Water Model Output
Mature Summer Conditions

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                                                                        2-Jan-86
              EXXON MINERALS CO. - PHASE IV WATER MANAGEMENT STUDY

                              CONFIGURATION 261

              CONVENTIONAL ZINC TAILS DESLIMING - BACKFILL TO MINE

                              MILL SPECIFICATIONS
                        ------------------------------------
                        MILL DESIGN CAPACITY:   6700.00 MTPD
                        MILL OPERATING LEVEL:   6700.00 MTPD
                        GLAND WATER USAGE:       904.80 MTPD
                        " EARLY  SUMMER W/PH CNTL" OPERATION

                           TONNAGE OF ORE PROCESSED
                           --------------------------
                           MASSIVE:      6700.00 MTPD
                           STRINGER:        0.00 MTPD

                                  MILL INPUT
                                  ----------
STREAM      REQUIRED       PRODUCED       UTILIZED      DISCHARGED  (GPM)
-----------------------------------------------------------------------
  Q4          506.00         781.29         506.00         275.29
  Q3         2849.48        2849.97        2849.53           0.44
  Q2          372.40         372.35         372.35           0.00
  Q1         2208.09        2208.09        2208.09
  QD                                                         0.00
FRESH H20                                     0.00
TOTALS       3727.88        4003.61        3727.88         275.73

RECYCLE WATER AS % OF MILL REQUIREMENTS:        100.0%
FRESH WATER MAKEUP AS % OF MILL REQUIREMENTS:     0.0%
DISCHARGE WATER AS % OF MILL REQUIREMENTS:       31.0%
TOTAL DISCHARGE FROM SYSTEM:       6309.00 MTPD      1157.40 GPM

                              POND INFORMATION
                              ----------------
                                      SEEPAGE     EVAP.   RETENTION
        LOCATION              ACRES    (GPM)     FACTOR  WT  % SOLIDS
--------------------------------------------------------------------
 TAILINGS POND                  0.0       0.00    0.000       0.000
 SAND STORAGE                   0.0       0.00    0.000      ******
 SLUDGE STORAGE                 0.0       0.00    0.000      ******
 TAILNGS IMPD                 110.0       5.50    0.800      79.000
 RECLAIM POND                  39.0       0.40    0.920      ******
 SURGE POND                     0.0       0.00    0.000       0.000
 MINE                         *****  *********   ******      85.000

 TOTAL POND SEEPAGE        =        32.16 MTPD          5.90 GPM
 TOTAL POND EVAPORATION    =       814.43 MTPD        149.41 GPM
 TOTAL RAINFALL TO PONDS   =      1290.27 MTPD        236.70 GPM
 NET RAINFALL TO PONDS     =       475.84 MTPD         87.29 GPM
 TOTAL POND EFFLUENT       =     45527.60 MTPD       8352.16 GPM

 PRECIPITATION RATE        =        30.77  IN/YR
 EVAPORATION RATE          =        23.36  IN/YR

* --- DENOTES VARIATION FROM BASE CONDITIONS
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USER-DEFINED PERCENT FLOW SPLITS

```
    NODE # 17 - "SPLITTER" NODE #1                  NODE # 18 - "SPLITTER" NODE #2
------------------------------------------      ------------------------------------------
LINK # 20 - SEEPG CONTRL   TO MINE    100.%     LINK # 21 - SEEPG CONTRL   TO MINE    100.%
LINK # 68 - SEEPG CONTRL TO TAILINGS    0.%     LINK # 63 - SEEPG CONTRL TO SURGE PND   0.%

    NODE # 45 - "SPLITTER" NODE #4                  NODE # 46 - "SPLITTER" NODE #7
------------------------------------------      ------------------------------------------
LINK # 50 - TREATED EFFL TO SURGE P.    0.%     LINK # 49 - MINE RETURN    WATER      100.%
LINK # 52 - TREATED EFFL TO TAILINGS  100.%     LINK #133 - MINE RET H20 TO TAILS P.    0.%

    NODE # 51 - "SPLITTER" NODE #5                  NODE # 55 - "SPLITTER" NODE #6
------------------------------------------      ------------------------------------------
LINK # 57 -   TAILINGS   TO P.T. POND   0.%     LINK # 61 - SAND STREAM    TO T53       0.%
LINK # 58 -   TAILINGS      TO T51    100.%     LINK # 62 - SAND STREAM    TO MINE    100.%

    NODE # 59 - "SPLITTER" NODE #8                  NODE # 85 - "SPLITTER" NODE #9
------------------------------------------      ------------------------------------------
LINK # 66 - BOILER & LAB  H20 TO SURG   0.%     LINK #104 - TAIL PND DSG TO RECLAIM P 100.%
LINK # 67 - BOILER & LAB  H20 TO POND 100.%     LINK #105 - TAIL PND DSG  TO RECYCLE    0.%

    NODE # 87 - "SPLITTER" NODE #10                 NODE #108 - "SPLITTER" NODE #11
------------------------------------------      ------------------------------------------
LINK #110 - SANDS DISCHG TO RECLAIM P 100.%     LINK #130 -  SURGE POND     TO T22    100.%
LINK #111 - SS DISCHARGE  TO RECYCLE    0.%     LINK #131 -  SURGE POND     TO T23      0.%
                                                LINK #132 -  SURGE POND     TO T24      0.%

    NODE #110 - "SPLITTER" NODE #12                 NODE #112 - "SPLITTER" NODE #14
------------------------------------------      ------------------------------------------
LINK #134 - SUM OF PONDS    TO T32    100.%     LINK #138 -  RECL POND      TO T42      0.%
LINK #135 - SUM OF PONDS    TO T33      0.%     LINK #139 -  RECL POND      TO T43      0.%
LINK #136 - SUM OF PONDS    TO T34      0.%     LINK #140 -  RECL POND      TO T44    100.%

    NODE #126 - "SPLITTER" NODE #15                 NODE #151 - "SPLITTER" NODE #16
------------------------------------------      ------------------------------------------
LINK #156 - TAILNGS IMPD TO SURGE PND   0.%     LINK #174 - ZN THCK OVFL  TO RECYCLE  100.%
LINK #157 - TAILNGS IMPD TO RECL POND 100.%     LINK #175 - ZN THICKENER OVRFL TO T10   0.%

    NODE #152 - "SPLITTER" NODE #17                 NODE #153 - "SPLITTER" NODE #18
------------------------------------------      ------------------------------------------
LINK #176 - T12 EFFLUENT  TO NODE 51  100.%     LINK #178 - MINE RETURN  H20 TO T62   100.%
LINK #177 - T12 EFFLUENT  TO NODE 45    0.%     LINK #179 - MINE RETURN  H20 TO B.F.    0.%

    NODE #159 - "SPLITTER" NODE 20                  NODE #160 - "SPLITTER" NODE 21
------------------------------------------      ------------------------------------------
LINK #188 - T13 EFFLUENT  TO NODE 51  100.%     LINK #190 - T11 EFFLUENT  TO NODE 45  100.%
LINK #189 - T13 EFFLUENT  TO NODE 45    0.%     LINK #191 - T11 EFFLUENT  TO NODE 51    0.%

    NODE #161 - "SPLITTER" NODE 22
------------------------------------------
LINK #192 - T10 EFFLUENT  TO NODE 45    0.%
LINK #193 - T10 EFFLUENT  TO NODE 51  100.%
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                    EXXON MINERALS CO. - PHASE IV WATER MANAGEMENT STUDY                       2-Jan-86

                                          USER-DEFINED EXPLICIT FLOW SPLITS
                                          ---------------------------------

        NODE # 58 - "SUMMER" NODE                                     NODE #165 - MINE SEEPG DIVERSION
---------------------------------------------------------     ---------------------------------------------------------
LINK # 64 - MINE RTN H20  TO BACKFILL       5655.99 MTPD*      LINK #197 -  MINE SEEPG    TO RECYCLE       1166.58 MTPD*
LINK # 65 - MINE RTN H20  TO SURGE PN          0.00 MTPD*      LINK #198 -  MINE SEEPG      TO T62         4489.41 MTPD*
        NODE #170 - SPLITTER NODE                                     NODE #171 - SPLITTER NODE
---------------------------------------------------------     ---------------------------------------------------------
LINK #201 -   PUMP SEAL          WATER       948.38 MTPD       LINK #203 -  PUMP SEAL   TAILING             163.52 MTPD
LINK #202 -  PUMP SEAL       BACKFILL        545.02 MTPD       LINK #204 -   PUMP SEAL     RECLAIM          784.87 MTPD

* --- DENOTES VARIATION FROM BASE CONDITIONS
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                        USER-DEFINED FLOWS
                        ------------------
LINK #        DESCRIPTION           FLOW-MTPD     FLOW-GPM
-----------------------------------------------------------
  17   SEEPG CONTRL FRESH WATER         0.00          0.00
  18   SEEP. ABOVE   ORE BODY        1907.85*       350.00
  23   TREATED H20  TO RECYCLE          0.00          0.00
 115   SEEPAGE INTO    MINE          4763.08*       873.80
 122    SURGE POND     TO T21       11491.25       2108.10
 124   SUM OF PONDS    TO T31           0.00          0.00
 125   RECL DISCHG     TO T41           0.00          0.00
 141   TAILNGS THCK TO BACKFILL         0.00          0.00
 148   RECLAIM POND    TO MINE          0.00          0.00
 149    RECYCLE IN     TO MINE          0.00          0.00
 151    SURGE POND  TO RECYCLE          0.00          0.00
 152     TAILINGS   TO RECYCLE          0.00          0.00
 159    SURGE POND     TO MINE          0.00          0.00
 161   TAILS PONDS    TO MINE           0.00          0.00
 163   RECYCLE H20    FROM T24          0.00          0.00
 165   RECYCLE H20    FROM T25          0.00          0.00
 167   RECYCLE H20    FROM T34          0.00          0.00
 169   RECYCLE H20    FROM T35          0.00          0.00
 170    RECL POND      TO T45        3242.80*       594.90
 173   RECYCLE H20    FROM T45          0.00          0.00
 180   SEEPG CNTRL    TO MILL           0.00          0.00
 183   SEEPG CNTRL    TO MINE           0.00          0.00
 185   FRESH WATER    TO MINE           0.00          0.00
 194   RECYCLE H20    FROM T71          0.00          0.00
 205   EXCESS WATER   PUMP SEAL      1493.40        273.97


                   STREAMS WITH SCALING PROBLEMS
                   -----------------------------

THE SOLUBILITY PRODUCT OF CASO4 HAS BEEN EXCEEDED IN THE FOLLOWING STREAMS:
          STREAM  40   MILL TAILNGS TO BACKFILL
                    ACTUAL CAXSO4  (MG/L)                      =   0.1144E+07
                    PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9849E+06
          STREAM  51   RECY OUT TO  BACKFILL P.
                    ACTUAL CAXSO4  (MG/L)                      =   0.1038E+07
                    PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9872E+06
          STREAM  53    RECY IN TO  BACKFILL P.
                    ACTUAL CAXSO4  (MG/L)                      =   0.1038E+07
                    PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9871E+06
          STREAM  54   SAND STREAM  FROM BACKFIL
                    ACTUAL CAXSO4  (MG/L)                      =   0.1038E+07
                    PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9871E+06
          STREAM  56     TAILINGS   FROM BACKFIL
                    ACTUAL CAXSO4  (MG/L)                      =   0.1038E+07
                    PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9871E+06

* --- DENOTES VARIATION FROM BASE CONDITIONS
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                                      STREAMS WITH SCALING PROBLEMS
                                      -----------------------------

THE SOLUBILITY PRODUCT OF CASO4 HAS BEEN EXCEEDED IN THE FOLLOWING STREAMS:
       STREAM  58    TAILINGS      TO T51
              ACTUAL CAXSO4  (MG/L)                             =   0.1027E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9914E+06
       STREAM  62   SAND STREAM    TO MINE
              ACTUAL CAXSO4  (MG/L)                             =   0.1038E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9871E+06
       STREAM 112   SEEPAGE FROM RECLAIM POND
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 118   RECLAIM POND   DISCHARGE
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 126    SLUDGE TO        T81
              ACTUAL CAXSO4  (MG/L)                             =   0.3300E+09
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.3818E+07
       STREAM 140    RECL POND      TO T44
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 146     Q3 WATER       TO MILL
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 153   RECLAIM POND  TO RECYCLE
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 170    RECL POND      TO T45
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 171   RECYCLE H20    FROM T44
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 215   T44 EFFLUENT NO TREATMENT
              ACTUAL CAXSO4  (MG/L)                             =   0.1093E+07
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.9893E+06
       STREAM 222   T46 SLUDGE    RO,VCE UNIT
              ACTUAL CAXSO4  (MG/L)                             =   0.3300E+09
              PREDICTED (MARSHALL-SLUSHER) CAXSO4 (MG/L) =   0.3818E+07

* --- DENOTES VARIATION FROM BASE CONDITIONS
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EXXON MINERALS CO. - PHASE IV WATER MANAGEMENT STUDY

TREATMENT SUMMARY

AVAILABLE TREATMENT TECHNOLOGIES

CODE	DESCRIPTION	USED?	SLUDGE PRODUCED (GPM)
A	TAILINGS THICKENER	Y	316.45
B	TAILINGS THICKENER/FILT	N	0.00
C	PH ADJUSTMENT H2SO4	Y	0.00
D	PH ADJUSTMENT CO2	N	0.00
E	PH ADJUSTMENT CA(OH)2	N	0.00
F	LIME PRECIPITATION	Y	16.02
G	CARBONATE TREATMENT	Y	18.18
H	SULFIDE PRECIPITATION	N	0.00
I	SODIUM ALUMINATE PRECIP	N	0.00
J	ALKALINE CHLORINATION	N	0.00
K	FERRO CYANIDE PRECIP.	N	0.00
L	H202 OXIDATION	N	0.00
M	OZONATION	N	0.00
N	BIOL OXIDATION OF THIOS.	N	0.00
O	ION EXCHANGE CATION REM.	N	0.00
P	ION EXCHANGE CA REMOVAL	N	0.00
Q	ION EXCHANGE ANION REM.	N	0.00
R	CARBON ADSORPTION	N	0.00
S	FILTRATION	Y	2.65
T	REVERSE OSMOSIS	N	0.00
U	VAPOR RECOMPRESSION EVAP	N	0.00
V	RO-VRE TREATMENT UNITS	Y	9.69
		TOTAL	362.98

TREATMENT STREAM CONFIGURATIONS

NODE #	DESCRIPTION	CONFIGURATION	QUAL	SLUDGE PER DAY (GPD)	SLUDGE PER LIFE (GAL)
39	TREATMENT STREAM T10	NO TREATMENT			
40	TREATMENT STREAM T11	NO TREATMENT			
41	TREATMENT STREAM T12	NO TREATMENT			
42	TREATMENT STREAM T13	NO TREATMENT			
19	TREATMENT STREAM T61	F,S,C	QD	991.	0.105E+08
52	TREATMENT STREAM T51	A		455688.	0.482E+10
56	TREATMENT STREAM T53	NO TREATMENT			
98	TREATMENT STREAM T21	NO TREATMENT			
99	TREATMENT STREAM T31	NO TREATMENT			
100	TREATMENT STREAM T41	NO TREATMENT			
115	TREATMENT STREAM T22	NO TREATMENT			
116	TREATMENT STREAM T23	NO TREATMENT			
117	TREATMENT STREAM T24	NO TREATMENT			
119	TREATMENT STREAM T32	NO TREATMENT			
120	TREATMENT STREAM T33	NO TREATMENT			

EXXON MINERALS CO. - PHASE IV WATER MANAGEMENT STUDY

TREATMENT STREAM CONFIGURATIONS

NODE #	DESCRIPTION	CONFIGURATION	QUAL	SLUDGE PER DAY (GPD)	SLUDGE PER LIFE (GAL)
121	TREATMENT STREAM T34	NO TREATMENT			
123	TREATMENT STREAM T42	NO TREATMENT			
124	TREATMENT STREAM T43	NO TREATMENT			
125	TREATMENT STREAM T44	NO TREATMENT	Q3		
129	TREATMENT STREAM T71	NO TREATMENT	QD		
140	TREATMENT STREAM T25	NO TREATMENT			
142	TREATMENT STREAM T26	NO TREATMENT			
144	TREATMENT STREAM T35	NO TREATMENT			
146	TREATMENT STREAM T36	NO TREATMENT			
148	TREATMENT STREAM T45	G,S,C	Q4	25827.	0.273E+09
150	TREATMENT STREAM T46	V	Q4	13950.	0.148E+09
154	TREATMENT STREAM T62	F,S,C	QD	24861.	0.263E+09
167	TREATMENT STREAM T81	G	Q3	1380.	0.146E+08

CONSTITUENT ANALYSIS

CONS	UNITS	18 SEEP. ABOVE ORE BODY	21 SEEPG CONTRL TO MINE	22 TREATED H20 TO DISCHARGE	42 PB FD THCKNR TO T13	58 TAILINGS TO T51	115 SEEPAGE INTO MINE	126 SLUDGE TO T81	127 SLUDGE TO NODE 80	172 RECL POND TO T46
HS	MOLE	0.813E-07	0.813E-07	0.316E-07	0.316E-08	0.559E-11	0.200E-05	0.100E-06	0.316E-10	0.316E-07
AGS	MG/L	0.100E-02	0.100E-02	0.170E-02	0.173E-01	0.222E-01	0.100E-01	1.42	0.106E-01	0.181E-01
AGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.580	0.000E+00
ALS	MG/L	0.100E-01	0.100E-01	0.522	1.54	1.90	0.530	122.	4.25	1.50
ALP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BAS	MG/L	0.100E-01	0.100E-01	0.164E-01	0.345E-01	0.162E-01	0.200E-01	1.32	0.516E-01	0.168E-01
BAP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CAS	MG/L	27.5	27.5	134.	450.	525.	44.8	0.242E+04	89.2	30.6
CAP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.55	0.000E+00	0.000E+00	0.941E+04	0.000E+00
CDS	MG/L	0.390E-01	0.390E-01	0.280E-03	0.165E-01	0.134E-01	0.700E-01	1.57	0.104E-01	0.200E-01
CDP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.25	0.000E+00
CRS	MG/L	0.100E-02	0.100E-02	0.353E-01	5.16	1.15	0.100E+00	4.04	0.491E-01	0.515E-01
CRP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.166	0.000E+00	0.000E+00	27.3	0.000E+00
CUS	MG/L	0.202	0.202	0.534E-02	0.611	0.444	0.100E+00	1.58	0.127E-01	0.202E-01
CUP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.641E-01	0.000E+00	0.000E+00	7.77	0.000E+00
FE2S	MG/L	0.710	0.710	0.000E+00	0.775E-01	0.103	1.74	0.000E+00	0.000E+00	0.000E+00
FE2P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE3S	MG/L	0.000E+00	0.000E+00	0.212	0.197	0.183	0.000E+00	16.4	0.200	0.201
FE3P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	226.	0.000E+00
HGS	MG/L	0.100E-03	0.100E-03	0.170E-03	0.578E-03	0.209E-03	0.400E-03	0.190E-01	0.709E-03	0.243E-03
HGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.371E-02	0.000E+00
KS	MG/L	1.29	1.29	2.98	16.2	17.0	1.31	942.	32.4	12.5
MGS	MG/L	16.0	16.0	16.4	2.47	1.41	19.3	395.	20.7	5.00
MGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.213	0.000E+00	0.000E+00	0.978	0.000E+00
MNS	MG/L	0.450E-01	0.450E-01	0.301E-01	0.814E-01	0.389E-01	0.423	2.36	0.300E-01	0.301E-01
MNP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.134E-02	0.000E+00	0.000E+00	10.3	0.000E+00
NAS	MG/L	4.72	4.72	35.4	382.	301.	4.11	0.559E+05	0.189E+04	710.
PBS	MG/L	0.400E-01	0.400E-01	0.201E-01	0.966E-01	0.890E-01	0.340	1.58	0.200E-01	0.202E-01
PBP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.136E-02	0.000E+00	0.000E+00	9.71	0.000E+00
SES	MG/L	0.180E-01	0.180E-01	0.272E-01	0.207	0.357	0.100E-02	9.18	0.216	0.117
SEP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.216E-01	0.000E+00	0.000E+00	3.35	0.000E+00
ZNS	MG/L	0.443	0.443	0.318E-01	1.35	1.95	20.4	4.52	0.378E-01	0.577E-01
ZNP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.287	0.000E+00	0.000E+00	506.	0.000E+00
OHS	MOLE	0.123E-06	0.123E-06	0.316E-06	0.316E-05	0.179E-02	0.500E-08	0.100E-06	0.316E-03	0.316E-06
OHP	MOLE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.380E-04	0.000E+00	0.000E+00	0.490E-01	0.000E+00

CONSTITUENT ANALYSIS

CONS	UNITS	18 SEEP. ABOVE ORE BODY	21 SEEPG CONTRL TO MINE	22 TREATED H2O TO DISCHARGE	42 PB FD THCKNR TO T13	58 TAILINGS TO T51	115 SEEPAGE INTO MINE	126 SLUDGE TO T81	127 SLUDGE TO NODE 80	172 RECL POND TO T46
ASS	MG/L	0.510	0.510	0.247E-01	0.323E-01	0.874E-01	0.100E-01	2.16	0.264E-01	0.300E-01
ASP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.117E-01	0.000E+00	0.000E+00	5.23	0.000E+00
CO3S	MG/L	0.000E+00	0.000E+00	0.356	0.000E+00	0.412E-01	0.000E+00	0.722E-02	35.2	0.281
CO3P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.39	0.000E+00	0.000E+00	0.142E+05	0.000E+00
CLS	MG/L	12.0	12.0	6.45	5.54	4.40	4.00	321.	12.5	4.09
CNS	MG/L	0.100E-02	0.100E-02	0.728E-02	3.00	0.349	0.100E-02	0.751	0.291E-01	0.100E-01
FS	MG/L	0.480	0.480	0.750	4.27	4.57	0.200	166.	6.38	3.39
HC3S	MG/L	134.	134.	57.2	145.	12.7	30.0	185.	5.65	45.1
NO3S	MG/L	1.99	1.99	4.48	0.831	0.817	1.64	152.	7.62	2.11
PO4S	MG/L	0.280	0.280	0.165	0.762	0.747	0.000E+00	776.	20.6	0.660
PO4P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SO4S	MG/L	15.0	15.0	406.	0.185E+04	0.196E+04	200.	0.136E+06	0.458E+04	0.170E+04
SO4P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.22	0.000E+00	0.000E+00	8.48	0.000E+00
SS	MG/L	0.000E+00	0.000E+00	0.425E-02	0.411E-01	0.399E-01	0.000E+00	2.17	0.734E-01	0.289E-01
SP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S2OS	MG/L	0.000E+00	0.000E+00	20.4	94.1	188.	0.000E+00	0.147E+04	61.4	19.5
CO2S	MG/L	2.00	2.00	3.04	0.000E+00	2.41	2.00	0.000E+00	0.267E-03	2.39
NH3S	MG/L	0.000E+00	0.000E+00	0.896	0.742	0.738	0.000E+00	0.000E+00	1.03	0.880
O2S	MG/L	5.00	5.00	4.74	2.55	2.57	5.00	0.000E+00	3.76	3.07
SIOS	MG/L	8.20	8.20	9.37	15.0	14.6	9.00	915.	34.8	12.7
BODS	MG/L	2.00	2.00	2.65	1.80	8.16	2.00	0.000E+00	2.11	1.44
CODS	MG/L	5.00	5.00	21.0	15.4	25.9	29.0	0.000E+00	17.8	9.53
HARD	MG/L	146.	146.	402.	0.114E+04	0.132E+04	233.	0.000E+00	308.	97.0
PH	****	7.09	7.09	7.50	8.50	11.3	5.70	7.00	10.5	7.50
TDS	MG/L	162.	162.	695.	0.273E+04	0.283E+04	368.	0.200E+06	0.674E+04	0.255E+04
TEMP	C	7.00	20.0	20.0	20.0	20.0	7.00	85.0	20.0	20.0
TOCS	MG/L	7.00	7.00	3.38	1.05	6.82	1.00	0.000E+00	1.45	0.971
TSSA	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.56	0.000E+00	0.000E+00	0.253E+05	0.000E+00
TSSN	MG/L	50.0	50.0	1.28	42.1	0.167E+06	50.0	0.000E+00	0.360E+05	0.000E+00
FLOW	MTPD	1907.85	1907.85	6299.40	1454.40	28474.60	4763.08	52.81	200.85	4311.61
FLOW	M3/HR	79.49	79.49	262.48	60.60	1186.44	198.46	2.20	8.37	179.65
FLOW	GPM	350.00	350.00	1155.64	266.81	5223.74	873.80	9.69	36.85	790.98
FLOW	TGD	504.00	504.00	1664.12	384.21	7522.18	1258.27	13.95	53.06	1139.01
FLOW	MGD	0.5040	0.5040	1.6641	0.3842	7.5222	1.2583	0.0140	0.0531	1.1390
SOLIDS	MTPD	0.00	0.00	0.00	0.00	2106.93	0.00	0.00	0.00	0.00

CONSTITUENT ANALYSIS

CONS	UNITS	178 MINE RETURN H2O TO T62	196 TOTAL DISCHG FROM SYSTEM	199 BLEND TO T45	206 EXCESS WATER TO NODE 128	207 T61 SLUDGE LIME PRECIP	208 T61 EFFLUENT LIME PRECIP	209 T61 SLUDGE FILTRATION	210 T61 EFFLUENT FILTRATION	212 T61 EFFLUENT PH ADJ H2SO4
HS	MOLE	0.168E-05	0.317E-07	0.131E-09	0.999E-07	0.316E-10	0.316E-10	0.316E-10	0.316E-10	0.316E-07
AGS	MG/L	0.117E-01	0.170E-02	0.181E-01	0.766E-03	0.100E-02	0.100E-02	0.100E-02	0.100E-02	0.100E-02
AGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ALS	MG/L	0.744	0.521	1.50	0.282E-02	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.100E-01
ALP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BAS	MG/L	0.192E-01	0.164E-01	0.168E-01	0.705E-03	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.100E-01
BAP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CAS	MG/L	119.	134.	419.	1.83	86.5	86.5	86.5	86.5	86.5
CAP	MG/L	0.415	0.000E+00	0.110	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CDS	MG/L	0.610E-01	0.281E-03	0.256E-01	0.830E-03	0.200E-03	0.200E-03	0.200E-03	0.200E-03	0.392E-03
CDP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.388E-01	19.6	0.192E-03	0.000E+00
CRS	MG/L	0.194	0.352E-01	1.07	0.429E-02	0.100E-02	0.100E-02	0.100E-02	0.100E-02	0.100E-02
CRP	MG/L	0.271E-01	0.000E+00	0.717E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CUS	MG/L	0.110	0.533E-02	0.150	0.108E-02	0.500E-02	0.500E-02	0.500E-02	0.500E-02	0.598E-02
CUP	MG/L	0.104E-01	0.000E+00	0.276E-02	0.000E+00	0.000E+00	0.197	99.7	0.976E-03	0.000E+00
FE2S	MG/L	1.49	0.288E-06	0.481	0.189E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE2P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE3S	MG/L	0.278E-01	0.211	0.159	0.330E-03	0.200	0.200	0.200	0.200	0.230
FE3P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.11	0.309E+04	0.303E-01	0.000E+00
HGS	MG/L	0.366E-03	0.170E-03	0.243E-03	0.101E-04	0.100E-03	0.100E-03	0.100E-03	0.100E-03	0.100E-03
HGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KS	MG/L	3.71	2.98	12.5	1.04	1.29	1.29	1.29	1.29	1.29
MGS	MG/L	16.5	16.3	5.00	0.163	16.0	16.0	16.0	16.0	16.0
MGP	MG/L	0.347E-01	0.000E+00	0.919E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MNS	MG/L	0.364	0.301E-01	0.124	0.128E-02	0.300E-01	0.300E-01	0.300E-01	0.300E-01	0.301E-01
MNP	MG/L	0.219E-03	0.000E+00	0.578E-04	0.000E+00	0.000E+00	0.150E-01	7.59	0.743E-04	0.000E+00
NAS	MG/L	48.6	35.3	227.	29.3	4.72	4.72	4.72	4.72	4.72
PBS	MG/L	0.300	0.201E-01	0.150	0.970E-03	0.200E-01	0.200E-01	0.200E-01	0.200E-01	0.201E-01
PBP	MG/L	0.221E-03	0.000E+00	0.584E-04	0.000E+00	0.000E+00	0.200E-01	10.1	0.991E-04	0.000E+00
SES	MG/L	0.570E-01	0.271E-01	0.195	0.512E-02	0.108E-01	0.108E-01	0.108E-01	0.108E-01	0.108E-01
SEP	MG/L	0.352E-02	0.000E+00	0.932E-03	0.000E+00	0.000E+00	0.720E-02	3.64	0.357E-04	0.000E+00
ZNS	MG/L	17.3	0.318E-01	5.20	0.369E-02	0.250E-01	0.250E-01	0.250E-01	0.250E-01	0.271E-01
ZNP	MG/L	0.467E-01	0.000E+00	0.124E-01	0.000E+00	0.000E+00	0.418	211.	0.207E-02	0.000E+00
OHS	MOLE	0.287E-03	0.316E-06	0.761E-04	0.100E-06	0.316E-03	0.316E-03	0.316E-03	0.316E-03	0.316E-06
OHP	MOLE	0.619E-05	0.000E+00	0.164E-05	0.000E+00	0.000E+00	0.348E-03	0.176	0.172E-05	0.000E+00

CONSTITUENT ANALYSIS

CONS	UNITS	178 MINE RETURN H20 TO T62	196 TOTAL DISCHG FROM SYSTEM	199 BLEND TO T45	206 EXCESS WATER TO NODE 128	207 T61 SLUDGE LIME PRECIP	208 T61 EFFLUENT LIME PRECIP	209 T61 SLUDGE FILTRATION	210 T61 EFFLUENT FILTRATION	212 T61 EFFLUENT PH ADJ H2SO4
ASS	MG/L	0.224E-01	0.246E-01	0.326E-01	0.370E-02	0.300E-01	0.300E-01	0.300E-01	0.300E-01	0.300E-01
ASP	MG/L	0.191E-02	0.000E+00	0.505E-03	0.000E+00	0.000E+00	0.480	244.	0.000E+00	0.000E+00
CO3S	MG/L	0.664E-02	0.355	0.424E-01	0.446E-03	116.	116.	116.	116.	0.788
CO3P	MG/L	0.389	0.000E+00	0.103	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CLS	MG/L	4.05	6.45	4.09	0.172	12.0	12.0	12.0	12.0	12.0
CNS	MG/L	0.100E-01	0.727E-02	0.100E-01	0.825E-03	0.100E-02	0.100E-02	0.100E-02	0.100E-02	0.100E-02
FS	MG/L	0.867	0.751	3.39	1.38	0.480	0.480	0.480	0.480	0.480
HC3S	MG/L	26.8	57.2	13.6	9.19	18.7	18.7	18.7	18.7	127.
NO3S	MG/L	5.56	4.47	2.11	0.258	1.99	1.99	1.99	1.99	1.99
PO4S	MG/L	0.114	0.164	0.660	0.158	0.280	0.280	0.280	0.280	0.280
PO4P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SO4S	MG/L	469.	406.	0.165E+04	59.2	29.4	29.4	29.4	29.4	0.000E+00
SO4P	MG/L	0.524	0.000E+00	0.139	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	144.
SS	MG/L	0.609E-02	0.425E-02	0.289E-01	0.240E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S2OS	MG/L	29.2	20.4	19.5	1.61	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO2S	MG/L	2.07	3.06	0.895	21.8	0.990E-03	0.990E-03	0.000E+00	0.990E-03	6.72
NH3S	MG/L	1.28	0.896	0.880	0.879	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
O2S	MG/L	4.63	4.74	3.07	2.49	5.00	5.00	5.00	5.00	5.00
SIOS	MG/L	9.88	9.36	12.7	1.57	8.20	8.20	8.20	8.20	8.20
BODS	MG/L	2.93	2.64	1.44	1.44	2.00	2.00	2.00	2.00	2.00
CODS	MG/L	28.0	21.0	9.53	9.52	5.00	5.00	5.00	5.00	5.00
HARD	MG/L	400.	401.	0.108E+04	5.25	282.	282.	282.	282.	282.
PH	****	5.77	7.50	9.88	7.00	10.5	10.5	10.5	10.5	7.50
TDS	MG/L	744.	694.	0.236E+04	106.	277.	277.	277.	277.	404.
TEMP	C	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
TOCS	MG/L	1.81	3.37	0.971	0.971	7.00	7.00	7.00	7.00	7.00
TSSA	MG/L	1.56	0.000E+00	0.412	0.000E+00	0.000E+00	13.2	0.668E+04	0.313	0.000E+00
TSSN	MG/L	0.123E+04	1.28	363.	0.798E-01	0.000E+00	50.0	0.248E+05	1.19	1.19
FLOW	MTPD	5655.99	6309.00	4409.38	9.60	-0.00	1907.85	3.75	1904.10	1904.10
FLOW	M3/HR	235.67	262.88	183.72	0.40	-0.00	79.49	0.16	79.34	79.34
FLOW	GPM	1037.61	1157.40	808.91	1.76	-0.00	350.00	0.69	349.31	349.31
FLOW	TGD	1494.15	1666.66	1164.83	2.54	-0.00	504.00	0.99	503.01	503.01
FLOW	MGD	1.4942	1.6667	1.1648	0.0025	-0.0000	0.5040	0.0010	0.5030	0.5030
SOLIDS	MTPD	7.00	0.00	1.44	0.00	0.00	0.00	0.00	0.00	0.00

CONSTITUENT ANALYSIS

		213	214	215	216	217	218	219	221	222
CONS	UNITS	T51 SLUDGE TLNGS THCKNR	T51 EFFLUENT TLNGS THCKNR	T44 EFFLUENT NO TREATMENT	T45 SLUDGE CARBONATE TR	T45 EFFLUENT CARBONATE TR	T45 SLUDGE FILTRATION	T45 EFFLUENT FILTRATION	T45 EFFLUENT PH ADJ H2SO4	T46 SLUDGE RO,VCE UNIT
HS	MOLE	0.559E-11	0.559E-11	0.316E-07	0.316E-10	0.316E-10	0.316E-10	0.316E-10	0.316E-07	0.100E-06
AGS	MG/L	0.222E-01	0.222E-01	0.204E-01	0.181E-01	0.181E-01	0.181E-01	0.181E-01	0.181E-01	1.42
AGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ALS	MG/L	1.90	1.90	1.77	1.50	1.50	1.50	1.50	1.50	122.
ALP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BAS	MG/L	0.162E-01	0.162E-01	0.159E-01	0.168E-01	0.168E-01	0.168E-01	0.168E-01	0.168E-01	1.32
BAP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CAS	MG/L	511.	511.	527.	30.0	30.0	30.0	30.0	30.6	0.242E+04
CAP	MG/L	259.	6.66	0.000E+00	0.182E+05	11.9	0.125E+05	0.594	0.000E+00	0.000E+00
CDS	MG/L	0.134E-01	0.134E-01	0.129E-01	0.200E-01	0.200E-01	0.200E-01	0.200E-01	0.200E-01	1.57
CDP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.257	0.168E-03	0.176	0.840E-05	0.000E+00	0.000E+00
CRS	MG/L	0.500E-01	0.500E-01	1.38	0.500E-01	0.500E-01	0.500E-01	0.500E-01	0.515E-01	4.04
CRP	MG/L	14.2	0.435	0.000E+00	46.7	0.305E-01	32.0	0.152E-02	0.000E+00	0.000E+00
CUS	MG/L	0.200E-01	0.200E-01	0.165	0.200E-01	0.200E-01	0.200E-01	0.200E-01	0.202E-01	1.58
CUP	MG/L	5.46	0.168	0.000E+00	6.07	0.396E-02	4.16	0.198E-03	0.000E+00	0.000E+00
FE2S	MG/L	0.103	0.103	0.119	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE2P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE3S	MG/L	0.183	0.183	0.207	0.200	0.200	0.200	0.200	0.201	16.4
FE3P	MG/L	0.000E+00	0.000E+00	0.000E+00	20.1	0.131E-01	13.8	0.656E-03	0.000E+00	0.000E+00
HGS	MG/L	0.209E-03	0.209E-03	0.199E-03	0.243E-03	0.243E-03	0.243E-03	0.243E-03	0.243E-03	0.190E-01
HGP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KS	MG/L	17.0	17.0	15.7	12.5	12.5	12.5	12.5	12.5	942.
MGS	MG/L	0.000E+00	0.000E+00	0.856	5.00	5.00	5.00	5.00	5.00	395.
MGP	MG/L	18.2	0.558	0.000E+00	0.419	0.274E-03	0.287	0.137E-04	0.000E+00	0.000E+00
MNS	MG/L	0.300E-01	0.300E-01	0.380E-01	0.300E-01	0.300E-01	0.300E-01	0.300E-01	0.301E-01	2.36
MNP	MG/L	0.114	0.351E-02	0.000E+00	4.30	0.281E-02	2.95	0.140E-03	0.000E+00	0.000E+00
NAS	MG/L	301.	301.	291.	710.	710.	710.	710.	710.	0.559E+05
PBS	MG/L	0.800E-01	0.800E-01	0.963E-01	0.200E-01	0.200E-01	0.200E-01	0.200E-01	0.202E-01	1.58
PBP	MG/L	0.115	0.354E-02	0.000E+00	5.94	0.387E-02	4.07	0.194E-03	0.000E+00	0.000E+00
SES	MG/L	0.214	0.214	0.245	0.117	0.117	0.117	0.117	0.117	9.18
SEP	MG/L	1.84	0.565E-01	0.000E+00	3.60	0.235E-02	2.47	0.117E-03	0.000E+00	0.000E+00
ZNS	MG/L	0.500E-01	0.500E-01	0.849	0.500E-01	0.500E-01	0.500E-01	0.500E-01	0.577E-01	4.52
ZNP	MG/L	24.4	0.750	0.000E+00	236.	0.154	161.	0.769E-02	0.000E+00	0.000E+00
OHS	MOLE	0.179E-02	0.179E-02	0.316E-06	0.316E-03	0.316E-03	0.316E-03	0.316E-03	0.316E-06	0.100E-06
OHP	MOLE	0.323E-02	0.993E-04	0.000E+00	0.117E-01	0.571E-05	0.599E-02	0.285E-06	0.000E+00	0.000E+00

CONSTITUENT ANALYSIS

CONS	UNITS	213 T51 SLUDGE TLNGS THCKNR	214 T51 EFFLUENT TLNGS THCKNR	215 T44 EFFLUENT NO TREATMENT	216 T45 SLUDGE CARBONATE TR	217 T45 EFFLUENT CARBONATE TR	218 T45 SLUDGE FILTRATION	219 T45 EFFLUENT FILTRATION	221 T45 EFFLUENT PH ADJ H2SO4	222 T46 SLUDGE RO,VCE UNIT
ASS	MG/L	0.100E-01	0.100E-01	0.363E-01	0.300E-01	0.300E-01	0.300E-01	0.300E-01	0.300E-01	2.16
ASP	MG/L	0.997	0.306E-01	0.000E+00	0.142	0.929E-04	0.103	0.000E+00	0.000E+00	0.000E+00
CO3S	MG/L	0.409E-01	0.409E-01	0.553E-01	40.6	40.6	40.6	40.6	0.281	0.722E-02
CO3P	MG/L	196.	6.24	0.000E+00	0.275E+05	17.8	0.187E+05	0.891	0.000E+00	0.000E+00
CLS	MG/L	4.40	4.40	4.11	4.09	4.09	4.09	4.09	4.09	321.
CNS	MG/L	0.349	0.349	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.751
FS	MG/L	4.57	4.57	4.30	3.39	3.39	3.39	3.39	3.39	166.
HC3S	MG/L	0.116E-02	0.116E-02	8.89	6.52	6.52	6.52	6.52	45.1	185.
NO3S	MG/L	0.817	0.817	0.875	2.11	2.11	2.11	2.11	2.11	152.
PO4S	MG/L	0.747	0.747	0.856	0.660	0.660	0.660	0.660	0.660	776.
PO4P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SO4S	MG/L	0.194E+04	0.194E+04	0.207E+04	0.165E+04	0.165E+04	0.165E+04	0.165E+04	0.170E+04	0.136E+06
SO4P	MG/L	274.	8.41	0.000E+00	6.32	0.412E-02	4.33	0.206E-03	0.000E+00	0.000E+00
SS	MG/L	0.399E-01	0.399E-01	0.371E-01	0.289E-01	0.289E-01	0.289E-01	0.289E-01	0.289E-01	2.17
SP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S2OS	MG/L	188.	188.	16.1	19.5	19.5	19.5	19.5	19.5	0.147E+04
CO2S	MG/L	0.106E-07	0.106E-07	0.471	0.346E-03	0.346E-03	0.000E+00	0.346E-03	2.39	0.000E+00
NH3S	MG/L	0.738	0.738	0.734	0.880	0.880	0.880	0.880	0.880	0.000E+00
O2S	MG/L	2.57	2.57	2.52	3.07	3.07	3.07	3.07	3.07	0.000E+00
SIOS	MG/L	14.6	14.6	13.8	12.7	12.7	12.7	12.7	12.7	915.
BODS	MG/L	8.16	8.16	0.909	1.44	1.44	1.44	1.44	1.44	0.000E+00
CODS	MG/L	25.9	25.9	2.89	9.53	9.53	9.53	9.53	9.53	0.000E+00
HARD	MG/L	0.128E+04	0.128E+04	0.132E+04	95.6	95.6	95.6	95.6	97.0	0.000E+00
PH	****	11.3	11.3	7.50	10.5	10.5	10.5	10.5	7.50	7.00
TDS	MG/L	0.279E+04	0.279E+04	0.294E+04	0.248E+04	0.248E+04	0.248E+04	0.248E+04	0.255E+04	0.200E+06
TEMP	C	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	85.0
TOCS	MG/L	6.82	6.82	0.671	0.971	0.971	0.971	0.971	0.971	0.000E+00
TSSA	MG/L	849.	25.0	0.000E+00	0.462E+05	30.0	0.315E+05	1.50	0.000E+00	0.000E+00
TSSN	MG/L	0.122E+07	25.0	50.0	0.171E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FLOW	MTPD	1724.97	26749.63	18777.97	93.86	4315.52	3.90	4311.61	4311.61	52.81
FLOW	M3/HR	71.87	1114.57	782.42	3.91	179.81	0.16	179.65	179.65	2.20
FLOW	GPM	316.45	4907.29	3444.87	17.22	791.69	0.72	790.98	790.98	9.69
FLOW	TGD	455.69	7066.50	4960.61	24.80	1140.04	1.03	1139.01	1139.01	13.95
FLOW	MGD	0.4557	7.0665	4.9606	0.0248	1.1400	0.0010	1.1390	1.1390	0.0140
SOLIDS	MTPD	2108.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CONSTITUENT ANALYSIS

CONS	UNITS	223 T46 EFFLUENT RO,VCE UNIT	224 T62 SLUDGE LIME PRECIP	225 T62 EFFLUENT LIME PRECIP	226 T62 SLUDGE FILTRATION	227 T62 EFFLUENT FILTRATION	229 T62 EFFLUENT PH ADJ H2SO4	230 T71 EFFLUENT NO TREATMENT	231 T81 SLUDGE CARBONATE TR	232 T81 EFFLUENT CARBONATE TR
HS	MOLE	0.100E-06	0.316E-10	0.316E-10	0.316E-10	0.316E-10	0.316E-07	0.317E-07	0.316E-10	0.316E-10
AGS	MG/L	0.734E-03	0.200E-02	0.200E-02	0.200E-02	0.200E-02	0.200E-02	0.170E-02	0.300E-01	0.300E-01
AGP	MG/L	0.000E+00	0.428	0.138E-02	0.891	0.498E-05	0.000E+00	0.000E+00	14.0	0.666E-02
ALS	MG/L	0.000E+00	0.744	0.744	0.744	0.744	0.744	0.521	122.	122.
ALP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BAS	MG/L	0.680E-03	0.192E-01	0.192E-01	0.192E-01	0.192E-01	0.192E-01	0.164E-01	1.32	1.32
BAP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CAS	MG/L	0.991	154.	154.	154.	154.	154.	134.	30.0	30.0
CAP	MG/L	0.000E+00	21.3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.250E+05	11.9
CDS	MG/L	0.810E-03	0.200E-03	0.200E-03	0.200E-03	0.200E-03	0.231E-03	0.281E-03	0.200E-01	0.200E-01
CDP	MG/L	0.000E+00	2.69	0.867E-02	5.60	0.312E-04	0.000E+00	0.000E+00	15.6	0.742E-02
CRS	MG/L	0.209E-02	0.500E-01	0.500E-01	0.500E-01	0.500E-01	0.501E-01	0.352E-01	0.500E-01	0.500E-01
CRP	MG/L	0.000E+00	7.56	0.244E-01	15.7	0.879E-04	0.000E+00	0.000E+00	40.1	0.191E-01
CUS	MG/L	0.818E-03	0.500E-02	0.500E-02	0.500E-02	0.500E-02	0.506E-02	0.533E-02	0.200E-01	0.200E-01
CUP	MG/L	0.000E+00	5.11	0.165E-01	10.6	0.594E-04	0.000E+00	0.000E+00	15.7	0.749E-02
FE2S	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.288E-06	0.000E+00	0.000E+00
FE2P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FE3S	MG/L	0.000E+00	0.200	0.200	0.200	0.200	0.204	0.211	0.200	0.200
FE3P	MG/L	0.000E+00	306.	0.987	637.	0.356E-02	0.000E+00	0.000E+00	163.	0.775E-01
HGS	MG/L	0.984E-05	0.200E-03	0.200E-03	0.200E-03	0.200E-03	0.200E-03	0.170E-03	0.190E-01	0.190E-01
HGP	MG/L	0.000E+00	0.734E-02	0.237E-04	0.153E-01	0.853E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
KS	MG/L	1.02	3.71	3.71	3.71	3.71	3.71	2.98	942.	942.
MGS	MG/L	0.162	16.5	16.5	16.5	16.5	16.5	16.3	395.	395.
MGP	MG/L	0.000E+00	1.54	0.496E-02	3.20	0.179E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MNS	MG/L	0.122E-02	0.300E-01	0.300E-01	0.300E-01	0.300E-01	0.302E-01	0.301E-01	0.300E-01	0.300E-01
MNP	MG/L	0.000E+00	14.8	0.477E-01	30.8	0.172E-03	0.000E+00	0.000E+00	23.5	0.112E-01
NAS	MG/L	28.9	48.6	48.6	48.6	48.6	48.6	35.3	0.586E+05	0.586E+05
PBS	MG/L	0.818E-03	0.200E-01	0.200E-01	0.200E-01	0.200E-01	0.201E-01	0.201E-01	0.200E-01	0.200E-01
PBP	MG/L	0.000E+00	12.4	0.400E-01	25.8	0.144E-03	0.000E+00	0.000E+00	15.7	0.749E-02
SES	MG/L	0.474E-02	0.342E-01	0.342E-01	0.342E-01	0.342E-01	0.342E-01	0.271E-01	5.51	5.51
SEP	MG/L	0.000E+00	1.16	0.376E-02	2.42	0.135E-04	0.000E+00	0.000E+00	36.9	0.176E-01
ZNS	MG/L	0.234E-02	0.250E-01	0.250E-01	0.250E-01	0.250E-01	0.339E-01	0.318E-01	0.500E-01	0.500E-01
ZNP	MG/L	0.000E+00	767.	2.47	0.160E+04	0.891E-02	0.000E+00	0.000E+00	45.0	0.214E-01
OHS	MOLE	0.100E-06	0.316E-03	0.316E-03	0.316E-03	0.316E-03	0.316E-06	0.316E-06	0.316E-03	0.316E-03
OHP	MOLE	0.000E+00	0.829E-01	0.133E-03	0.859E-01	0.480E-06	0.000E+00	0.000E+00	0.441E-01	0.565E-05

EXXON MINERALS CO. - PHASE IV WATER MANAGEMENT STUDY

2-Jan-86

CONSTITUENT ANALYSIS

CONS	UNITS	223 T46 EFFLUENT RO,VCE UNIT	224 T62 SLUDGE LIME PRECIP	225 T62 EFFLUENT LIME PRECIP	226 T62 SLUDGE FILTRATION	227 T62 EFFLUENT FILTRATION	229 T62 EFFLUENT PH ADJ H2SO4	230 T71 EFFLUENT NO TREATMENT	231 T81 SLUDGE CARBONATE TR	232 T81 EFFLUENT CARBONATE TR
ASS	MG/L	0.364E-02	0.224E-01	0.224E-01	0.224E-01	0.224E-01	0.224E-01	0.246E-01	0.300E-01	0.300E-01
ASP	MG/L	0.000E+00	0.844E-01	0.272E-03	0.176	0.000E+00	0.000E+00	0.000E+00	21.4	0.102E-01
CO3S	MG/L	0.358E-03	24.9	24.9	24.9	24.9	0.169	0.355	60.3	60.3
CO3P	MG/L	0.000E+00	34.5	0.555E-01	35.8	0.200E-03	0.000E+00	0.000E+00	0.373E+05	17.8
CLS	MG/L	0.166	4.05	4.05	4.05	4.05	4.05	6.45	321.	321.
CNS	MG/L	0.810E-03	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.100E-01	0.727E-02	0.751	0.751
FS	MG/L	1.37	0.867	0.867	0.867	0.867	0.867	0.751	166.	166.
HC3S	MG/L	9.19	4.00	4.00	4.00	4.00	27.2	57.2	9.70	9.70
NO3S	MG/L	0.257	5.56	5.56	5.56	5.56	5.56	4.47	152.	152.
PO4S	MG/L	0.156	0.114	0.114	0.114	0.114	0.114	0.164	776.	776.
PO4P	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SO4S	MG/L	55.9	483.	483.	483.	483.	520.	406.	0.136E+06	0.136E+06
SO4P	MG/L	0.000E+00	8.76	0.748E-01	48.2	0.269E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SS	MG/L	0.234E-02	0.609E-02	0.609E-02	0.609E-02	0.609E-02	0.609E-02	0.425E-02	2.17	2.17
SP	MG/L	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S2OS	MG/L	1.58	29.2	29.2	29.2	29.2	29.2	20.4	0.147E+04	0.147E+04
CO2S	MG/L	21.8	0.212E-03	0.212E-03	0.000E+00	0.212E-03	1.44	3.06	0.514E-03	0.514E-03
NH3S	MG/L	0.880	1.28	1.28	1.28	1.28	1.28	0.896	0.000E+00	0.000E+00
O2S	MG/L	2.49	4.63	4.63	4.63	4.63	4.63	4.74	0.000E+00	0.000E+00
SIOS	MG/L	1.55	9.88	9.88	9.88	9.88	9.88	9.36	915.	915.
BODS	MG/L	1.44	2.93	2.93	2.93	2.93	2.93	2.64	0.000E+00	0.000E+00
CODS	MG/L	9.53	28.0	28.0	28.0	28.0	28.0	21.0	0.000E+00	0.000E+00
HARD	MG/L	3.14	453.	453.	453.	453.	453.	401.	0.170E+04	0.170E+04
PH	****	7.00	10.5	10.5	10.5	10.5	7.50	7.50	10.5	10.5
TDS	MG/L	102.	753.	753.	753.	753.	821.	694.	0.199E+06	0.199E+06
TEMP	C	20.0	20.0	20.0	20.0	20.0	20.0	20.0	85.0	85.0
TOCS	MG/L	0.971	1.81	1.81	1.81	1.81	1.81	3.37	0.000E+00	0.000E+00
TSSA	MG/L	0.000E+00	0.259E+04	6.00	0.387E+04	0.180	0.000E+00	0.000E+00	0.634E+05	30.0
TSSN	MG/L	0.000E+00	0.612E+05	44.0	0.276E+05	1.32	1.32	1.28	0.000E+00	0.000E+00
FLOW	MTPD	4258.81	87.31	4402.10	6.80	4395.30	4395.30	6309.00	5.22	47.58
FLOW	M3/HR	177.45	3.64	183.42	0.28	183.14	183.14	262.88	0.22	1.98
FLOW	GPM	781.29	16.02	807.58	1.25	806.33	806.33	1157.40	0.96	8.73
FLOW	TGD	1125.06	23.06	1162.91	1.80	1161.11	1161.11	1666.66	1.38	12.57
FLOW	MGD	1.1251	0.0231	1.1629	0.0018	1.1611	1.1611	1.6667	0.0014	0.0126
SOLIDS	MTPD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CONSTITUENT ANALYSIS

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             COMBINED INF   RO SLUDGE
 CONS UNITS     AT MILL     STREAM T46
+--------------------------------------------------------------------------------------------------------
 HS    MOLE    0.217E-07    0.142E-05
 AGS   MG/L    0.173E-01    0.870E-01
 AGP   MG/L    0.000E+00    0.000E+00
 ALS   MG/L     1.51         7.48
 ALP   MG/L    0.000E+00    0.000E+00
 BAS   MG/L    0.145E-01    0.806E-01
 BAP   MG/L    0.000E+00    0.000E+00
 CAS   MG/L     445.         148.
 CAP   MG/L    0.000E+00    0.000E+00
 CDS   MG/L    0.135E-01    0.960E-01
 CDP   MG/L    0.000E+00    0.000E+00
 CRS   MG/L     1.16        0.247
 CRP   MG/L    0.000E+00    0.000E+00
 CUS   MG/L    0.151        0.970E-01
 CUP   MG/L    0.000E+00    0.000E+00
 FE2S  MG/L    0.975E-01    0.000E+00
 FE2P  MG/L    0.000E+00    0.000E+00
 FE3S  MG/L    0.177         1.00
 FE3P  MG/L    0.000E+00    0.000E+00
 HGS   MG/L    0.178E-03    0.117E-02
 HGP   MG/L    0.000E+00    0.000E+00
 KS    MG/L     13.5         57.7
 MGS   MG/L     2.00         24.2
 MGP   MG/L    0.000E+00    0.000E+00
 MNS   MG/L    0.414E-01    0.145
 MNP   MG/L    0.000E+00    0.000E+00
 NAS   MG/L     249.        0.342E+04
 PBS   MG/L    0.966E-01    0.969E-01
 PBP   MG/L    0.000E+00    0.000E+00
 SES   MG/L    0.207        0.562
 SEP   MG/L    0.000E+00    0.000E+00
 ZNS   MG/L     1.38        0.277
 ZNP   MG/L    0.000E+00    0.000E+00
 OHS   MOLE    0.627E-04    0.706E-08
 OHP   MOLE    0.000E+00    0.000E+00
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                         CONSTITUENT ANALYSIS
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             COMBINED INF  RO SLUDGE
CONS UNITS     AT MILL     STREAM T46
+------------------------------------------------------------------------------------------------------------
ASS   MG/L    0.323E-01    0.132
ASP   MG/L    0.000E+00    0.000E+00
CO3S  MG/L    0.466E-01    0.442E-03
CO3P  MG/L    0.000E+00    0.000E+00
CLS   MG/L     3.44         19.6
CNS   MG/L    0.863E-02    0.460E-01
FS    MG/L     4.27         10.2
HC3S  MG/L     9.34         11.3
NO3S  MG/L    0.831         9.30
PO4S  MG/L    0.762         47.5
PO4P  MG/L    0.000E+00    0.000E+00
SO4S  MG/L    0.176E+04    0.836E+04
SO4P  MG/L    0.000E+00    0.000E+00
SS    MG/L    0.411E-01    0.133
SP    MG/L    0.000E+00    0.000E+00
S2OS  MG/L     20.1         89.9
CO2S  MG/L     3.67         26.9
NH3S  MG/L    0.742        0.880
O2S   MG/L     2.55         3.07
SIOS  MG/L     12.2         56.0
BODS  MG/L     1.80         1.44
CODS  MG/L     15.4         9.53
HARD  MG/L    0.112E+04    0.000E+00
PH    ****     7.66         5.85
TDS   MG/L    0.249E+04    0.122E+05
TEMP  C        20.0         20.0
TOCS  MG/L     1.05        0.971
TSSA  MG/L    0.000E+00    0.000E+00
TSSN  MG/L     42.1        0.000E+00
FLOW  MTPD     20496.97       862.32
FLOW  M3/HR      854.04        35.93
FLOW  GPM       3760.22       158.20
FLOW  TGD       5414.72       227.80
FLOW  MGD         5.4147        0.2278
 SOLIDS MTPD        0.00          0.00


 THE FOLLOWING STREAMS HAVE ZERO FLOW:
    9  10  11  12  16  17  23  24  31  41  46  50  57  61  63  65  66  68  70  71
   72  78  79  80  81  82  83  84  85  89  90  91  92  99 100 102 105 109 110 111
  123 124 125 130 131 132 133 134 135 136 138 139 141 148 149 151 152 154 155 156
  159 160 161 162 163 164 165 166 167 168 169 173 175 177 179 180 183 185 189 191
  192 193 194 195 211 220 228 233 237 239 240 241 242 243 244 245 246 247 248 249
  250 251 252 253
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**  R.O. UNIT - TREATMENT BLOCK T46 **
THE MAXIMUM ALLOWABLE R.O. RECOVERY RATE IS     80.0     PERCENT
BASED ON A LIMITING FACTOR OF CALCIUM FLUORIDE SOLUBILITY


THE FACTORS LIMITING R.O. RECOVERY ARE LISTED BELOW WITH THEIR
CORRESPONDING RECOVERY RATES:
CALCIUM FLUORIDE -      80.0     PERCENT
BARIUM SULFATE   -      80.0     PERCENT
CALCIUM SULFATE  -      80.0     PERCENT
SILICA           -      80.0     PERCENT


VOLUME OF SLUDGE PRODUCED IN THIS R.O. UNIT =       158.20 GPM


INFLUENT IRON CONCENTRATION IN STREAM 172 IS GREATER THAN .05 MG/L
IRON REMOVAL PRETREATMENT WILL BE REQUIRED TO MINIMIZE IRON FOULING
```

ATTACHMENT III- X-RAY RESULTS

#2 XO

Test # 16-49.1

```
APD-3600 2ND DERIVATIVE PEAK ALGORITHM      8/28/84   11:46:59
RAW DATA FILE             : 8000.RD
SAMPLE ID                 : 8000
RAW DATA FILE DATE        :   8/28/84
GENERATOR SETTINGS        : 45 KV     40 MA
STEP SIZE, CNT TIME       : 0.010 DEG      0.20 SEC
RANGE OF DATA             :   10.000 - 100.000 DEG
RANGE IN D                :   8.8382 -   1.0056 A
MAX PEAK CTS, CPS         :   2510. CTS 12550. CPS
SECF APPLIED              :   NONE

2-THETA   WIDTH        COUNTS          D          I            LINE TYPE
 (DEG)   (APPROX)   PEAK   BKGND     (ANG)     (NORM)    a1  a2  BT  AM  O

 18.317   0.42        13.    35.     4.8437     0.52     X   X
 23.042   0.11       202.    34.     3.8599     8.03     X   X
 26.620   0.15        37.    35.     3.3486     1.48     X   X
 29.367   0.12      2510.    41.     3.0414   100.00     X   X
 30.918   0.14        35.    41.     2.8923     1.39     X   X
 31.357   0.09        53.    41.     2.8528     2.12     X   X
 35.957   0.09       317.    53.     2.4977    12.62     X   X
 39.394   0.08       529.    42.     2.2873    21.08     X   X
 43.143   0.09       424.    37.     2.0951    16.91     X
 43.286   0.06       276.    37.     2.0937    10.98         X
 44.090   0.21        44.    36.     2.0540     1.74     X   X
 47.088   0.09       207.    35.     1.9300     8.26     X   X
 47.421   0.10       581.    35.     1.9172    23.14     X   X
 48.434   0.10       566.    35.     1.8795    22.57     X   X
 50.141   0.07        61.    35.     1.8194     2.42     X   X
 51.969   0.30        10.    34.     1.7596     0.38     X   X
 56.564   0.09        90.    44.     1.6258     3.60     X
 56.761   0.06        61.    44.     1.6246     2.42         X
 57.401   0.11       286.    45.     1.6040    11.38     X
 57.564   0.06       180.    46.     1.6038     7.15         X
 57.946   0.13        36.    46.     1.5915     1.43     X   X
 60.666   0.11       207.    48.     1.5253     8.26     X
 60.894   0.11       142.    46.     1.5239     5.64         X
 61.261   0.08        90.    45.     1.5119     3.60     X
 61.464   0.11        64.    44.     1.5111     2.55         X
 63.018   0.12        76.    38.     1.4751     3.02     X   X
 64.656   0.13       174.    37.     1.4405     6.94     X
 64.885   0.08       112.    36.     1.4395     4.48         X
 65.440   0.12        96.    35.     1.4262     3.83     X   X
 69.141   0.10        40.    34.     1.3575     1.58     X
 70.126   0.08        69.    34.     1.3409     2.74     X
 72.823   0.12       100.    35.     1.2977     3.98     X
 73.045   0.10        61.    35.     1.2975     2.42         X
 73.644   0.08        31.    32.     1.2853     1.25     X
 75.364   0.32        10.    29.     1.2612     0.41     X   X
 76.294   0.11        67.    27.     1.2471     2.68     X
 77.014   0.10        77.    27.     1.2372     3.09     X
 80.972   0.11        29.    27.     1.1864     1.16     X
 81.423   0.12        83.    27.     1.1810     3.30     X
 83.785   0.13       144.    26.     1.1536     5.74     X
 84.041   0.10        86.    26.     1.1536     3.45         X
 84.804   0.14        62.    26.     1.1423     2.49     X
 85.080   0.12        42.    26.     1.1421     1.68         X
 85.962   0.10        14.    25.     1.1299     0.55     X
 86.358   0.37        18.    25.     1.1285     0.74         X
 91.665   0.10        27.     4.     1.0739     1.08     X
   46  PEAKS IDENTIFIED        46 CRYSTALLINE       0 AMORPHOUS
   46  PEAKS LISTED .
```

(#2311)

16 - 49-2

```
APD-3600 2ND DERIVATIVE PEAK ALGORITHM          8/27/84  15:54:59
RAW DATA FILE              :  6000.RD
SAMPLE ID                  :  6000
RAW DATA FILE DATE         :  8/27/84
GENERATOR SETTINGS         :  45 KV     40 MA
STEP SIZE, CNT TIME        :  0.010 DEG    0.20 SEC
RANGE OF DATA              :   10.000 - 100.000 DEG
RANGE IN D                 :   8.8382 -   1.0056 A
MAX PEAK CTS, CPS          :   2927. CTS 14634. CPS
SECF APPLIED               :   NONE

2-THETA   WIDTH          COUNTS            D          I              LINE TYPE
 (DEG)  (APPROX)     PEAK    BKGND      (ANG)      (NORM)    a1  a2  BT  AM  O

 13.884    0.11        14.     19.      6.3783       0.49     X   X
 15.953    0.30         8.     18.      5.5556       0.29     X   X
 23.175    0.13       243.     18.      3.8381       8.31     X   X
 25.052    0.12        10.     18.      3.5546       0.35     X   X
 26.697    0.24         9.     17.      3.0154       0.31             X
 28.281    0.22        12.     14.      3.1557       0.39     X   X
 29.507    0.15      2927.     14.      3.0273     100.00     X   X
 31.529    0.14        61.     15.      2.8376       2.08     X   X
 36.101    0.12       471.     18.      2.4881      16.09     X   X
 39.546    0.21       724.     18.      2.2789      24.72     X   X
 40.527    0.33        10.     16.      2.2260       0.35     X   X
 43.294    0.22       650.     18.      2.0899      22.22     X   X
 44.178    0.22        41.     18.      2.0501       1.40     X   X
 47.214    0.15       246.     18.      1.9251       8.42     X   X
 47.609    0.25       625.     18.      1.9101      21.35     X   X
 48.588    0.13       708.     18.      1.8738      24.18     X   X
 52.014    0.27        10.     15.      1.7582       0.33     X   X
 56.670    0.12       132.     17.      1.6243       4.52     X   X
 57.503    0.12       380.     18.      1.6027      12.99     X   X
 58.253    0.14        32.     18.      1.5839       1.11     X   X
 60.757    0.12       222.     18.      1.5232       7.59     X
 60.985    0.08       185.     18.      1.5218       6.32         X
 61.459    0.12       106.     18.      1.5087       3.62     X   X
 63.148    0.13        92.     18.      1.4724       3.15     X   X
 64.757    0.11       240.     17.      1.4384       8.21     X
 64.985    0.10       156.     17.      1.4375       5.34         X
 65.640    0.26       121.     16.      1.4224       4.18     X   X
 69.275    0.12        55.     16.      1.3552       1.87     X
 70.300    0.26        67.     16.      1.3391       2.30     X   X
 72.949    0.11       119.     15.      1.2958       4.06     X
 73.734    0.17        35.     15.      1.2842       1.19     X   X
 76.388    0.13        69.     14.      1.2458       2.35     X
 76.657    0.10        38.     14.      1.2451       1.31         X
 77.171    0.18        74.     14.      1.2351       2.53     X
 77.424    0.14        59.     14.      1.2347       2.03         X
 81.042    0.14        32.     15.      1.1856       1.11     X
 81.583    0.13       104.     15.      1.1791       3.55     X
 82.720    0.28        11.     15.      1.1667       0.37     X   X
 83.859    0.14       190.     15.      1.1528       6.51     X
 84.158    0.09       112.     15.      1.1523       3.84         X
 84.905    0.12        86.     16.      1.1412       2.96     X
 85.194    0.14        52.     16.      1.1409       1.77         X
 86.476    0.17        21.     15.      1.1254       0.72     X   X
 90.026    0.29         5.     15.      1.0900       0.17     X   X
 92.180    0.30         6.     16.      1.0701       0.21     X   X
 93.084    0.19        32.     15.      1.0621       1.11     X   X
 94.802    0.12       151.     12.      1.0464       5.17     X
 95.092    0.12       216.     12.      1.0449       7.38     X   X
 95.416    0.12        92.     12.      1.0439       3.15         X
 96.159    0.17        59.     11.      1.0352       2.03     X
 97.711    0.13        28.
```

(#312)

16-49-3

```
APD-3600 2ND DERIVATIVE PEAK ALGORITHM      8/28/84    9:34:10
RAW DATA FILE              : 7000.RD
SAMPLE ID                  : 7000
RAW DATA FILE DATE         :  8/28/84
GENERATOR SETTINGS         : 45 KV     40 MA
STEP SIZE, CNT TIME        : 0.010 DEG     0.20 SEC
RANGE OF DATA              :  10.000 - 100.000 DEG
RANGE IN D                 :  8.8382 -   1.0056 A
MAX PEAK CTS, CPS          :  3181. CTS 15905. CPS
SECF APPLIED               :  NONE

2-THETA   WIDTH        COUNTS           D          I            LINE TYF
 (DEG)  (APPROX)    PEAK   BKGND      (ANG)     (NORM)   a1  a2  BT  AM C

 10.069   0.07       10.     36.     8.7854     0.32     X   X
 23.072   0.13      237.     18.     3.8550     7.46     X   X
 29.426   0.15     3181.     18.     3.0355   100.00     X   X
 31.450   0.20       56.     18.     2.8446     1.77     X   X
 34.400   0.16        8.     18.     2.6071     0.26     X   X
 35.998   0.09      488.     18.     2.4949    15.35     X   X
 38.427   0.24       35.     17.     2.3427     1.09     X   X
 39.414   0.06      660.     16.     2.2862    20.76     X   X
 43.183   0.08      671.     20.     2.0950    21.09     X   X
 44.615   0.13       59.     20.     2.0310     1.86     X   X
 47.102   0.11      219.     18.     1.9294     6.89     X   X
 47.515   0.21      615.     18.     1.9136    19.34     X   X
 48.525   0.26      807.     17.     1.8761    25.36     X   X
 55.124   0.25        9.     15.     1.6661     0.28     X   X
 56.567   0.10      135.     15.     1.6257     4.23     X
 56.748   0.07      100.     15.     1.6249     3.14         X
 57.397   0.11      350.     15.     1.6041    10.99     X
 57.590   0.08      243.     15.     1.6031     7.65         X
 58.134   0.17       37.     15.     1.5868     1.17     X   X
 60.675   0.11      259.     16.     1.5251     8.15     X
 60.874   0.10      174.     16.     1.5243     5.48         X
 61.392   0.20      108.     16.     1.5102     3.40     X   X
 63.040   0.14       83.     16.     1.4746     2.60     X   X
 64.664   0.13      272.     16.     1.4403     8.56     X
 64.888   0.09      164.     16.     1.4394     5.15         X
 65.630   0.11       96.     16.     1.4214     3.02     X
 69.169   0.16       46.     14.     1.3582     1.45     X   X
 70.209   0.21       66.     14.     1.3406     2.06     X   X
 71.159   0.28       10.     14.     1.3250     0.32     X   X
 72.877   0.17      123.     14.     1.2980     3.87     X   X
 73.657   0.15       32.     14.     1.2851     1.02     X
 73.900   0.10       26.     14.     1.2846     0.82         X
 76.293   0.13       71.     16.     1.2471     2.22     X
 76.545   0.12       44.     16.     1.2467     1.37         X
 77.146   0.19       74.     16.     1.2364     2.33     X   X
 80.950   0.15       30.     14.     1.1877     0.95     X   X
 81.488   0.15       90.     14.     1.1802     2.84     X
 81.765   0.13       61.     15.     1.1798     1.91         X
 83.754   0.15      196.     14.     1.1539     6.16     X
 84.043   0.12      119.     14.     1.1536     3.74         X
 84.792   0.12       94.     11.     1.1424     2.96     X
 85.077   0.13       56.     10.     1.1422     1.77         X
 86.484   0.14       30.      5.     1.1244     0.95     X
 87.112   0.14       14.      3.     1.1179     0.43     X
  44   PEAKS IDENTIFIED      44 CRYSTALLINE       0 AMORPHOUS
  44   PEAKS LISTED
```

```
 24-  27    Ca C 03                                                    INORG-MIN
           3.029 (100)      1.873 ( 34)      3.852 ( 28)     LATTICE:  0
22 LINES IN PATTERN         PATTERN ACCESSED     9  TIMES          SPN:  14364
             3.852   28        1.926    4        1.525    3        1.154    3
             3.029  100        1.907   17        1.506    2        1.142    3
             2.834    2        1.873   34        1.441    5        1.047    2
             2.495    7        1.626    2        1.417    3        1.044    2
             2.283   18        1.603   15        1.336    3
             2.095   26        1.582    2        1.178    3
```

```
  5- 586    Ca C 03                                                    INORG-MIN        *
           3.035 (100)      2.285 ( 18)      2.095 ( 18)     LATTICE:  0
39 LINES IN PATTERN         PATTERN ACCESSED    10  TIMES          SPN:  10332
             3.861   12        1.603    8        1.297    2        1.045    4
             3.035  100        1.587    2        1.284    1        1.035    2
             2.845    3        1.525    5        1.247    1        1.023    1 S
             2.495   14        1.518    4        1.235    2        1.012    2
             2.285   18        1.510    3        1.179    3        0.989    1 S
             2.095   18        1.473    2        1.154    3        0.985    1
             1.927    5        1.440    5        1.142    1        0.978    1
             1.913   17        1.422    3        1.124    1 S      0.977    3
             1.875   17        1.356    1        1.061    1        0.965    2
             1.626    4        1.339    2        1.047    3
```

914-67-KJF

EXXON ENGINEERING

Technology Department

APPENDIX F

EXXON MINERALS COMPANY
CRANDON PROJECT
REVERSE OSMOSIS WATER TREATMENT TESTING PROGRAM

EE.1DC.85
February, 1985

By: R. G. Balmer
K. J. Fetchko

Environmental Control and
Safety Division

EXXON MINERALS COMPANY
CRANDON PROJECT
REVERSE OSMOSIS WATER TREATMENT TESTING PROGRAM

TABLE OF CONTENTS

APPENDIX: EXPERIMENTAL PROCEDURES

LIST OF TABLES AND FIGURES

I. INTRODUCTION/SUMMARY

Exxon Minerals Company, a division of Exxon Corporation, is proposing to develop a zinc-copper-lead mine in Forest County, Wisconsin. This is known as the Crandon Project. Prior to construction, a permit will have to be obtained from the State of Wisconsin's Department of Natural Resources (DNR) to allow discharge of treated water from the mine/mill complex. Exxon Minerals requested that the Environmental Control and Safety Division (ECSD) of Exxon Research and Engineering Co. (ER&E) conduct the laboratory water treatment testing necessary to support permitting efforts. The Analytical and Information Division of ER&E performed the required chemical analyses.

Contaminated mine, reclaim, and recycle waters are all generated within the proposed Crandon Complex. Contaminated mine water is that water which will seep into the active workings of the mine, and is collected and pumped to the surface. Reclaim water is the reclaim pond effluent, which is reused in processing the ore. Recycle water is a mixture of contaminated mine water and reclaim water which will be treated to reduce the dissolved solids concentration. This treated (recycle) water is returned to ore processing. The proposed treatment for excess contaminated mine water is lime/sulfide precipitation, filtration, and pH adjustment. The proposed treatment for the recycle water is lime/soda ash softening, filtration, reverse osmosis, and evaporation of the R.O. brine.

The main objective of this program was to demonstrate the applicability of reverse osmosis (R.O.) treatment for removing dissolved solids from pretreated recycle water, and to project water quality at full-scale operation. Pretreated contaminated mine water and reclaim water were also treated using R.O., as requested by Exxon Minerals. However, R.O. treatment of these waters will not be routinely required for the full scale facility.

To achieve the previously mentioned objectives, a bench scale R.O. unit was used to test the three waters. Treatment of a water stream by R.O. produces a concentrate stream (reject), high in dissolved solids; and a product stream (permeate), low in dissolved solids. The routine measure of R.O. membrane performance is the percent removal of a constituent ion from the permeate stream, commonly referred to as rejection rate. Synthesized waters were used since real Crandon project waters are not available at the present time. Pretreatment of these waters was lime/soda ash precipitation and filtration for the recycle and reclaim waters, and lime precipitation and filtration for the contaminated mine water. Pretreatment was required to prevent membrane pluggage. The results from these tests were compared to two DuPont De Nemours & Co. [the R.O. test membrane's manufacturer(1)] computer projections. The first projection

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(1)The reverse osmosis membrane used in the test program was selected for convenience only, and its use should not be construed as a recommendation of a particular product or manufacturer.

being at the operating conditions of the bench scale R.O. unit, (limited to 10% hydraulic recovery by single membrane pilot configuration) and the second at full scale operating conditions, i.e. 75% hydraulic recovery.

Qualitative and quantitative analysis of the R.O. feed, permeate and reject were done using Inductively Coupled Plasma Emission Spectroscopy (ICPES), since our major interest is membrane performance usually determined by rejection rates of the common ions, i.e., sodium and chloride. Heavy metals were analyzed; but, no detailed conclusions were drawn because only trace levels were present in the feed.

Laboratory testing confirmed expected reductions in dissolved solids levels for all three streams. R.O. rejection rates in excess of 95% for recycle and 90% for reclaim and contaminated mine water were observed. When compared with the DuPont computer model, the laboratory data showed model projections to be reliable, but conservative. The laboratory data further showed that for those cases evaluated, the experimental permeate concentrations were equal to or better than full-scale projections indicating the degree of conservatism built into the model.

Results of the heavy metal analyses showed that trace to non-detectable concentrations were present in all feed streams; therefore, rejection rates for these ions were not quantified because of uncertainties in the analytical methods at the low levels, as well as the test unit scale of operation. However, with the exception of iron (system contamination) those metals which are present in the permeate and reject streams at levels of certainty show reasonable rejection. Therefore, it is our opinion, and DuPont concurs, that heavy metals in general will be rejected at 90 - 95% or better.

II. FEED WATER SYNTHESIS/PRETREATMENT

The mine, recycle and reclaim waters were synthesized using Crandon well water and adding various chemical compounds to achieve the Target water compositions (Table 1). These waters were synthesized, since real project water is not available at the present time. Table 2 shows the compounds added and average water qualities actually obtained. In the synthetic matrices, several metals, such as iron, copper and aluminum do not remain in the soluble form but precipitate, as indicated by our earlier work (EE.2DC.84). Therefore, these concentrations are lower than predicted. In this type of minerals operation, cyanide is likely to exist only in extremely low concentrations as non-toxic complex ions. Since these complex ions are difficult to reproduce synthetically, cyanide was not added to the test waters. Further information concerning the synthesis and pretreatment of the contaminated mine and reclaim water can be found in a report entitled, "Exxon Minerals Company, Crandon Project: Water Treatment Testing Program" (EE.2DC.84).

The bench pretreatment system consisted of a clarifier and a dual media gravity filter (Figure 1). The clarifier had a surface area of 0.79 ft^2, and a residence time of approximately 1.8 hours. The filter was a dual media (sand and anthracite coal) gravity type with a surface area of 0.087 ft^2. During the day, the unit was operated at a continuous feed rate of 1 L/min, a sludge recycle of 200 ml/min, and with various chemical additions (details discussed with each feed). Chemical feed and sludge blowdown rates were adjusted based on clarifier effluent pH and turbidity, as well as recycle settling characteristics of the sludge. During off-hours (unmanned operation) the system feed and chemical addition was discontinued, and the sludge recycle was raised to approximately 800 ml/min to prevent the sludge blanket from cementing. Startup and normal operating procedures are detailed in the Appendix, Procedure A. The detailed chemical dosages and clarifier performance are summarized below:

Due to its light sludge, pretreatment of the <u>mine water</u> was carried out by operating the clarifier at a reduced sludge recycle of 100 ml/min. In addition, lime was added at 60 mg/L (CaO) to control pH, and polyelectrolyte (Magnifloc 1563C(2)) was also added at a rate of 0.3 mg/L to clarify the effluent. The pH of the clarifier effluent was maintained between 10.2 and 10.4 (typical of cold lime softener operation), and the effluent turbidity remained clear (95% to 100% transmittance using a Bausch & Lomb Spec 20 spectrophotometer) throughout the operation.

Pretreatment of the <u>recycle water</u> was carried out by operating the clarifier at a sludge recycle of 200 ml/min. Chemicals were added as follows: lime at 84 mg/L (CaO) to control pH, soda ash at 1085 mg/L (Na_2CO_3) to reduce hardness, and polyelectrolyte (Magnifloc 1563C) at 0.3 mg/L to clarify effluent. The pH of the clarifier effluent was maintained between 10.2 and 10.4, and effluent turbidity was also clear (97% to 100% transmittance Spec. 20).

---

(2) The polymer used in the test program was selected for convenience only, and its use should not be construed as a recommendation of a particular product or manufacturer.

Pretreatment of the reclaim water was carried out by operating the clarifier at a sludge recycle of 200 ml/min with chemical addition of lime at 195 mg/L (CaO), soda ash at 1400 mg/L (Na_2CO_3), and polyelectrolyte (Magnifloc 1563C) at 0.3 mg/L. It should be noted that during this run the pH of the clarifier effluent averaged 10.7; however, this slightly higher pH is not of concern, since it is within operating limits of a lime softener. Effluent turbidity was clear (97% to 100% transmittance Spec. 20).

III. REVERSE OSMOSIS UNIT AND TEST PROCEDURE

Reverse osmosis (R.O.) is a process for removing dissolved solids from water by means of pressure exerted on a semi-permeable membrane. The rate of water transport is a function of the pressure applied, apparent osmotic pressure, membrane characteristics, and solution temperature. This rate of water transport is called the recovery rate. Treatment of a stream by R.O. produces a concentrate stream (reject), high in total dissolved solids (TDS) content, and a permeate stream (product) with a low concentration of dissolved solids. Permeate quality depends on the fraction of water recovered as permeate (percent recovery), the ionic characteristics of the water, and membrane characteristics.

R.O. membranes are classified by material of construction and type of configuration. Today, membranes are normally constructed of either cellulose acetate or aromatic polyamides, and the types of acceptable configurations can be tubular, spiral wound, or hollow fiber.

The Crandon Project had initially chosen a spiral wound configuration due to economics and ease of operation. In our study we used aromatic polyamide, because of its ability to operate in a wide pH range (4 - 11) and its resistance to chemical attack. However, these decisions on membrane material and configuration should be reevaluated during the final engineering phase of the Crandon Project.

Test Unit Description

The R.O. bench unit is capable of testing a spiral wound membrane at a (maximum) feed rate of 900 ml/min, and maximum operating pressure of 2800 kpa (Figure 2). This unit consists of a positive displacement pump, 15 micron sintered metal filters, pulsation dampener, backpressure regulator, and flowmeters to monitor the feed, concentrate and permeate streams. All wetted parts are either type 304 or 316 stainless steel. The reverse osmosis membrane is a custom laboratory permeater built by E.I. DuPont de Nemours & Co. The membrane is a laboratory version of the spiral wound aromatic polyamide B-15 DuPont "Permasep(3)" permeater; the laboratory version is 2 inches in diameter and 20 inches long, whereas the full size counterpart is 4 inches in diameter and 40 inches long. The membrane rejection properties, i.e., the percentage of dissolved solids removed from the permeate stream, should be the same as the full scale unit. However, for design purposes, the membrane rejection properties are considered to be 95%.

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(3)DuPont's registered trademark for its reverse osmosis products.

Unit Operating Procedure

Mine, recycle and reclaim waters were fed to the R.O. unit for a period of five hours each. Samples of permeate and reject were taken after the first, third and fifth hours. Procedures for preparing the sample bottles and sample preparation prior to analysis can be found in the Appendix, Procedures C and D. Distilled water was rinsed through the unit for 30 minutes before and after each run to check that the unit operating characteristics had not changed. The target recovery rate was 10% at a total feed rate of 800 cc/min. Permeate, reject and feed flowrates and pressures were recorded every hour. Detailed operating instructions can be found in the Appendix, Procedure B.

IV. RESULTS AND DISCUSSION

A. Laboratory Results

The R.O. unit performed as expected, and showed rejection of all ions in each of the three waters. Attention throughout the remainder of this report will be focused on the principal ions, that is, those ions which have significant concentrations in the permeate. These ions are calcium, magnesium, sodium, and potassium for the cations; and sulfate, chloride, and fluoride for the anions. Tables 3 - 5 summarize the cation concentrations in the feed, permeate and reject streams for the three waters. Percent rejection rates were only calculated for the above cations.

Trace cation concentrations are reported, but percent rejections were not calculated. This is due to several factors which would affect the validity of a trace concentration value, but not an ion with a significant concentration. The test unit was a bench scale unit using 1/4" tubing, thereby resulting in a high surface area to volume ratio and increasing contamination potential. The unit is new, and the wetted surfaces have not yet fully passivated; thus, allowing for some solubility of the metals of construction. The unit's run length was several hours as compared to the continuous operations of a full scale unit. The trace ion concentrations were at or near the detectability limit of ICPES. ICPES was used because the primary objective of this program was to verify DuPont's computer projections as a conservative permeate quality prediction tool and not to determine trace ion concentrations.

The contaminated mine water run achieved the expected permeate recovery rate of 9.0 - 10.4%. Detailed operating conditions are summarized in Table 10. All ions showed rejection by the reverse osmosis membrane. Cations with significant feed concentrations showed excellent rejection rates in excess of 90%. Calcium was rejected at 97%, magnesium at 96%, sodium at 90%, and sulfate at 94% (See Tables 3 and 6). These rejection rates corroborate the R.O. membrane manufacturer's expected rejection rates. Potassium did not exhibit good rejection, probably due to its very small ionic size which allowed passage through the R.O. membrane. Iron had a low rejection rate of 17% due to possible iron contamination from the stainless steel tubing used throughout the new R.O. unit. This contamination can be expected to diminish as the unit's stainless steel passivates through continuing use, and rejection rates of 90 - 95% can be expected.

The reclaim water run achieved a permeate recovery rate of 9.3 - 10%. Operating conditions were similar to the mine water run (Table 10). All ions showed rejection (Tables 4 and 6). Calcium and magnesium were rejected at 76% and 60%; while sodium and sulfate were rejected at 96% and 98%, respectively. The rejection rates for sodium and sulfate compared well with rejection rates of the other waters. However, this was not the case with the rejection rates of calcium and magnesium. This is probably due to their relatively lower inlet concentrations in the reclaim water (order of magnitude lower than the contaminated mine and recycle water). These lower rejection rates are not a concern at present since reclaim water is not proposed to be R.O. treated under the current Crandon Design. As with the mine water, potassium showed poor rejection, and iron pickup was noted. Trace cations and anions were rejected as with the mine water.

The recycle water run achieved a permeate recovery of 9.1 - 10%. All ions were rejected (Tables 5 and 6): calcium at 97%, magnesium at 96%, sodium at 97%, and sulfate at 97%. Again, the rejection results corroborate the manufacturer's expected rejection rates (Table 7). Potassium, iron, trace cations and anions all behaved in a manner similar to the mine and reclaim water runs.

Overall, dissolved solids (anions and cations) were rejected by the reverse osmosis membrane as expected. Rejection rates for calcium, magnesium, sodium and sulfate were in excess of 90% for those waters to potentially be treated by R.O. (i.e., contaminated mine and recycle waters). Potassium showed poor rejection due to its small ionic size. Iron's rejection rates appear low due to probable iron contamination from the new R.O. unit's stainless steel tubing.

B. Comparison to Full Scale

An objective of this experimental program was to determine if DuPont's computer generated permasep R.O. projections are accurate, and to project the water qualities at full scale operation. To meet this objective, the synthesized mine, reclaim and recycle waters were tested with the bench scale R.O. unit at 10% recovery as described earlier. DuPont also conducted computer projections for each water under operating conditions identical to the bench scale unit (10% recovery), and at operating conditions corresponding to full scale (75% recovery).

The projections for the 10% recovery rates were performed using the 4-inch B-15 membrane, model 3440 which has an initial flow of 2100 gallon per day. The projections for the 75% recovery rate were performed using the 8 inch B-15 membrane, model 3840 which has an initial flow of 8600 gallon per day. Both membranes, according to DuPont, reject 95% of a 2000 mg/liter NaCl solution at standard conditions (420 psig, 77°F,and 10% recovery).

Sulfuric acid addition was required to reduce feed pH from approximately 10.2 to 7 for all three waters prior to R.O. treatment. The computer projection also adjusted the pH by sulfuric acid addition. Hexametaphosphate was added to the three waters in the experiments and by the computer program to prevent $BaSO_4$ scaling from developing in all cases, CaF_2 scaling in the 75% recovery cases, and $CaSO_4$ scaling for the mine water at 75% recovery.

The concentrations of all principal ions, both cations and anions, were fed into the computer program along with the actual bench scale operating conditions summarized in Table 10. The program produced projected concentrations of the principal cations (Ca, Mg, Na and K), and the principal anions (SO_4, Cl and F) in the permeate. DuPont did not project heavy metals, such as Ag, Cd, Cr, Pb, Se, Zn, and Fe, but they expect rejection rates would be 90 - 95% or better.

The computer program showed divalent ion (calcium, sulfate, etc.) rejection rates of 96% for recycle water at 75% hydraulic recovery. This is due to the large size and high charge density of these ions. Monovalent ions, such as sodium and chloride, were rejected at 89% or better at a 75% recovery rate. Tables 7 - 9 summarize the principal ions, their feed concentrations, the concentrations of the bench unit's permeate stream at 10% recovery, the computer projected concentrations at identical operating conditions as the bench unit, and the projected concentrations under full scale operating conditions and 75% recovery.

For all three waters at 10% recovery, the results of the bench scale R.O. unit and the computer projections compare well. For recycle water, the performance of the bench scale unit exceeded the computer projection at 10% recovery for all ions except potassium and fluoride (Table 9). This demonstrates that the computer program projects conservatively. The potassium concentration for the bench scale unit may be unreliable, since it is near the detection limit.

Results for the contaminated mine and reclaim waters were similar to the recycle water. Again, the computer program at 10% recovery projected permeate qualities in higher concentrations than those obtained from the bench scale R.O. unit.

The computer projected rejection rates of 90% or better at 75% recovery (full scale) for all principal ions of significant concentrations. Based on the direct comparison of the bench scale unit and the computer projection at 10% recovery and identical operating conditions, the computer projection is determined to be reliable but conservative. Hence, it is concluded that R.O. treatment of all three waters can be expected to result in 90% rejection of all ions.

TABLE 1

PROJECTED WATER QUALITY(1)

CONSTITUENT		CONTAMINATED MINE WATER	RECLAIM WATER	RECYCLE WATER
Calcium	(Ca)	166	580	414
Magnesium	(Mg)	16.5	3.0	8.1
Sodium	(Na)	76	317	220
Potassium	(K)	5.6	19.3	13.8
Silver	(Ag)	0.01	0.01	0.01
Arsenic	(As)	0.025	0.023	0.030
Cadmium	(Cd)	0.056	0.012	0.030
Chromium	(Cr)	0.27	1.36	0.92
Copper	(Cu)	0.12	0.17	0.15
Mercury	(Hg)	0.00034	0.00015	0.00022
Lead	(Pb)	0.28	0.11	0.18
Selenium	(Se)	0.11	0.34	0.24
Zinc	(Zn)	15.8	0.8	6.8
Barium	(Ba)	0.018	0.011	0.014
Iron	(Fe+3)	0.28	0.57	0.45

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(1)All values reported as mg/L

TABLE 2

AVERAGE WATER QUALITY OF SYNTHESIZED RAW WATER

ELEMENT OF INTEREST		COMPOUND ADDED	CONTAMINATED MINE WATER	RECLAIM WATER	RECYCLE WATER
Silver	Ag	Ag_2SO_4	(0.002)	0.007	0.006
Aluminum	Al	$Al_2(SO_4)_3 \cdot 18H_2O$	0.062	0.084	0.040
Arsenic	As	$NaAsO_2$	<0.015	<0.015	<0.015
Barium	Ba	$BaSO_4$	0.010	0.208	0.008
Calcium	Ca	$CaSO_4$	184	624	435
Cadmium	Cd	$CdSO_4$	0.035	<0.002	<0.002
Chromium	Cr	$Cr_2(So_4)_3 \cdot nH_2O$	0.004	0.007	0.005
Copper	Cu	$CuSO_4$	0.007	0.007	0.007
Iron, +2	Fe	$FeSO_4 \cdot 7H_2O$			
Iron, +3		$Fe_2(SO_4)_3 \cdot nH_2O$	0.080	0.081	0.073
Potassium	K	None	0.945	0.831	2.219
Magnesium	Mg	$MgSO_4$	16.8	38.1	12.6
Manganese	Mn	$MnSO_4 \cdot H_2O$	0.295	0.113	0.180
Sodium	Na	Na_2SO_4	84.9	236	238
Lead	Pb	$PbSO_4$	0.033	(0.010)	<0.009
Selenium	Se	$Na_2SeO_3 \cdot 5H_2O$	0.034	0.138	0.111
Silica	Si	None	4.29	3.94	3.85
Zinc	Zn	$ZnSO_4 \cdot 7H_2O$	4.20	0.01	0.52

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(1)All analyses reported in mg/L
(2)All analyses performed by inductively coupled plasma emission spectroscopy (ICPES)
(3)Data with < indicate the value is below the detection limit
(4)Data with ( ) indicate value is between the detection limit and 3 times the detection limit
(5)Compounds were added in order of increasing solubility, not in order shown

TABLE 3

CONTAMINATED MINE WATER CATIONS: AVERAGE REVERSE OSMOSIS PERFORMANCE

MAJOR CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT	PERCENT REMOVAL
Calcium	(Ca)	179	5.8	207	97
Magnesium	(Mg)	11	0.42	13	96
Sodium	(Na)	84	9.2	96.8	89
Potassium	(K)	(1.10)	1.47	2.05	-

TRACE CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT
Barium	(Ba)	0.010	0.0013	0.019
Iron	(Fe)	0.060	0.050	0.083
Silver	(Ag)	0.084	(0.0027)	(0.0033)
Arsenic	(As)	<0.015	<0.015	<0.015
Cadmium	(Cd)	0.0046(4)	<0.002	0.0038(4)
Chromium	(Cr)	0.008	(0.005)	(0.006)
Copper	(Cu)	(0.002)	(0.002)	0.008
Mercury	(Hg)	<0.003	<0.003	<0.003
Lead	(Pb)	0.095	<0.009	<0.009
Selenium	(Se)	(0.020)	(0.020)	0.050
Zinc	(Zn)	0.052	0.005	0.059

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(1) All analyses reported in mg/L
(2) All analyses performed by inductively coupled plasma emission spectroscopy (ICPES) except those footnoted
(3) Data in ( ) indicate value is between detection limit and 3 times detection limit
(4) Analyses performed by graphite furnace atomic absorption
(5) Data with < indicate the value is below the detection limit

TABLE 4

RECLAIM WATER CATIONS: AVERAGE REVERSE OSMOSIS PERFORMANCE

MAJOR CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT	PERCENT REMOVAL
Calcium	(Ca)	1.56	0.38	6.1	76
Magnesium	(Mg)	0.10	0.04	2.0	60
Sodium	(Na)	877	32	1005	96
Potassium	(K)	(1.11)	(1.07)	1.47	-

TRACE CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT
Barium	(Ba)	0.0040	(0.0005)	0.0046
Iron	(Fe)	0.049	0.031	0.042
Silver	(Ag)	(0.0017)	(0.0038)	<0.0014
Arsenic	(As)	<0.015	(0.018)	<0.015
Cadmium	(Cd)	.0007 (4)	<0.002	<0.002
Chromium	(Cr)	0.015	(0.004)	0.009
Copper	(Cu)	0.004	(0.002)	0.004
Mercury	(Hg)	<0.003	<0.003	<0.003
Lead	(Pb)	<0.009	<0.009	<0.009
Selenium	(Se)	0.20	(0.030)	0.24
Zinc	(Zn)	0.0057	<0.0007	0.0064

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(1) All analyses reported in mg/L

(2) All analyses performed by inductively coupled plasma emission spectroscopy (ICPES) except those footnoted

(3) Data in ( ) indicate value is between detection limit and 3 times detection limit

(4) Analyses performed by graphite furnace atomic absorption

(5) Data with < indicate the value is below the detection limit

TABLE 5

RECYCLE WATER CATIONS:
AVERAGE REVERSE OSMOSIS PERFORMANCE

MAJOR CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT	PERCENT REMOVAL
Calcium	(Ca)	30	0.95	32	97
Magnesium	(Mg)	2.2	0.1	2.7	96
Sodium	(Na)	654	20	693	97
Potassium	(K)	(1.09)	(1.20)	1.39	-

TRACE CATION CONTAMINANTS

CATION		FEED	PERMEATE	REJECT
Barium	(Ba)	0.0037	0.0007	0.0062
Iron	(Fe)	0.068	0.082	0.047
Silver	(Ag)	0.0062	<0.0014	(0.0041)
Arsenic	(As)	<0.015	<0.015	(0.017)
Cadmium	(Cd)	0.00034(4)	<0.002	<0.002
Chromium	(Cr)	0.010	(0.006)	0.008
Copper	(Cu)	(0.002)	(0.003)	(0.002)
Mercury	(Hg)	<0.003	<0.003	<0.003
Lead	(Pb)	(0.010)	<0.009	<0.009
Selenium	(Se)	0.16	<0.010	0.11
Zinc	(Zn)	0.019	0.002	0.0033

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(1) All analyses reported in mg/L
(2) All analyses performed by inductively coupled plasma emission spectroscopy (ICPES) except those footnoted
(3) Data in (   ) indicate value is between detection limit and 3 times detection limit
(4) Analyses performed by graphite furnace atomic absorption
(5) Data with < indicate the value is below the detection limit

TABLE 6

CONTAMINATED MINE, RECLAIM AND RECYCLE ANIONS: AVERAGE REVERSE OSMOSIS PERFORMANCE

WATER	ANION	PROJECTED FEED(1)	PERMEATE
Contaminated			
• Mine Water			
	SO_4	544	32
	F	1.2	0.60
	Cl	6.3	0.55
	S_2O_4	25.4	-
• Reclaim Water			
	SO_4	1800	21
	F	4.43	0.57
	Cl	13.4	0.21
	S_2O_4	9.7	-
• Recycle Water			
	SO_4	1300	38
	F	3.1	0.43
	Cl	1.6	1.07
	S_2O_4	16	-

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(1) Values projected/calculated at pH 10.3
(2) All analyses reported in mg/L

TABLE 7

COMPARISON OF PERMEATE CONCENTRATIONS
BENCH UNIT VS. COMPUTER PROJECTIONS
CONTAMINATED MINE WATER

ION[1]		FEED WATER	BENCH UNIT[2] 10% RECOVERY	COMPUTER PROJECTION 10% RECOVERY	COMP. PROJECTIC 75% RECOVERY
Calcium	(Ca)	179	5.8	25.1	6.5
Magnesium	(Mg)	11	0.42	1.5	0.4
Sodium	(Na)	84	9.2	12.2	3.7
Potassium	(K)	1.1	1.47	0.4	0.1
Sulfate	(SO_4)	617.8	32	88.1	22.8
Chloride	(Cl)	6.3	0.55	2.3	0.7
Fluoride	(F)	1.2	0.60	0.0[3]	0.1

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(1) All values reported in mg/L

(2) Permeate stream concentrations obtained from the Reverse Osmosis bench scale unit

(3) Values were below the computer program's significant figure limit

TABLE 8

COMPARISON OF PERMEATE CONCENTRATIONS BENCH UNIT VS. COMPUTER PROJECTIONS RECLAIM WATER

ION(1)		FEED WATER	BENCH UNIT(2) 10% RECOVERY	COMPUTER PROJECTION 10% RECOVERY	COMP. PROJECTIO 75% RECOVERY
Calcium	(Ca)	1.6	0.38	0.3	0.2
Magnesium	(Mg)	.1	0.04	0.0(3)	0.0(3)
Sodium	(Na)	882.5	32	198.0	76.5
Potassium	(K)	1.1	1.07	0.6	.1
Sulfate	(SO_4)	1800	21.	404.0	73.4
Chloride	(Cl)	13.4	0.21	7.3	1.8
Fluoride	(Fl)	4.4	0.57	0.2	.5

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(1) All values reported in mg/L
(2) Permeate stream concentrations obtained from the Reverse Osmosis bench scale unit
(3) Values were below the computer program's significant figure limit

TABLE 9

COMPARISON OF PERMEATE CONCENTRATIONS
BENCH UNIT VS. COMPUTER PROJECTIONS
RECYCLE WATER

ION[1]		FEED WATER	BENCH UNIT[2] 10% RECOVERY	COMPUTER PROJECTION 10% RECOVERY	COMP. PROJECTIO 75% RECOVERY
Calcium	(Ca)	30	0.95	5.1	1.1
Magnesium	(Mg)	2.2	0.1	.4	.1
Sodium	(Na)	654.	20	111.4	25.7
Potassium	(K)	1.1	1.2	0.5	.1
Sulfate	(SO_4)	1404.9	38	238.5	53.9
Chloride	(Cl)	11.6	1.07	5.3	1.2
Fluoride	(F)	3.1	0.43	0.1	.1

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(1) All values reported in mg/L
(2) Permeate stream concentrations obtained from the Reverse Osmosis bench scale unit

TABLE 10

TYPICAL OPERATING CONDITIONS FOR REVERSE OSMOSIS UNIT(1)

WATER	FEED FLOW RATE cc/min	REJECT FLOW RATE cc/min	FEED PRESSURE kpa	REJECT PRESS kpa
Contaminated Mine	800	740	2800	580
Reclaim	810	730	2800	530
Recycle	790	718	2800	630

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(1)All runs operated @70°F

Figure 1

BENCH SCALE CONTINUOUS CLARIFIER AND GRAVITY FILTER

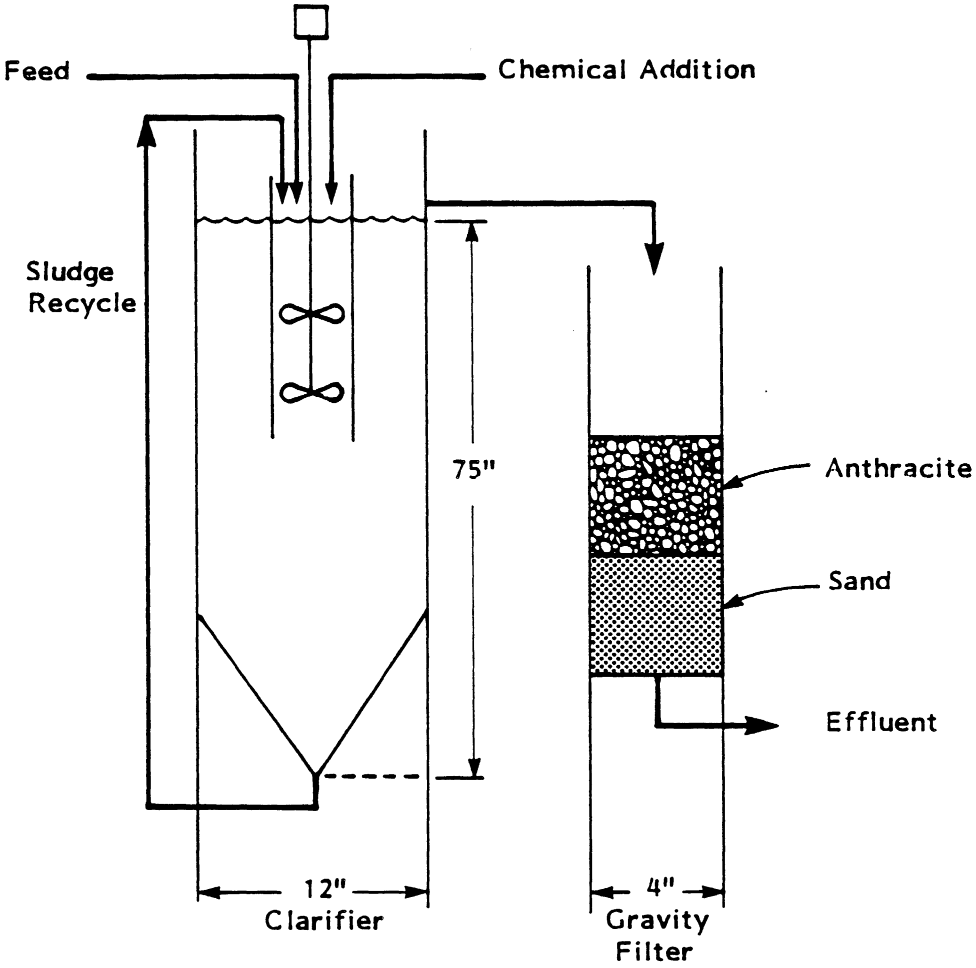
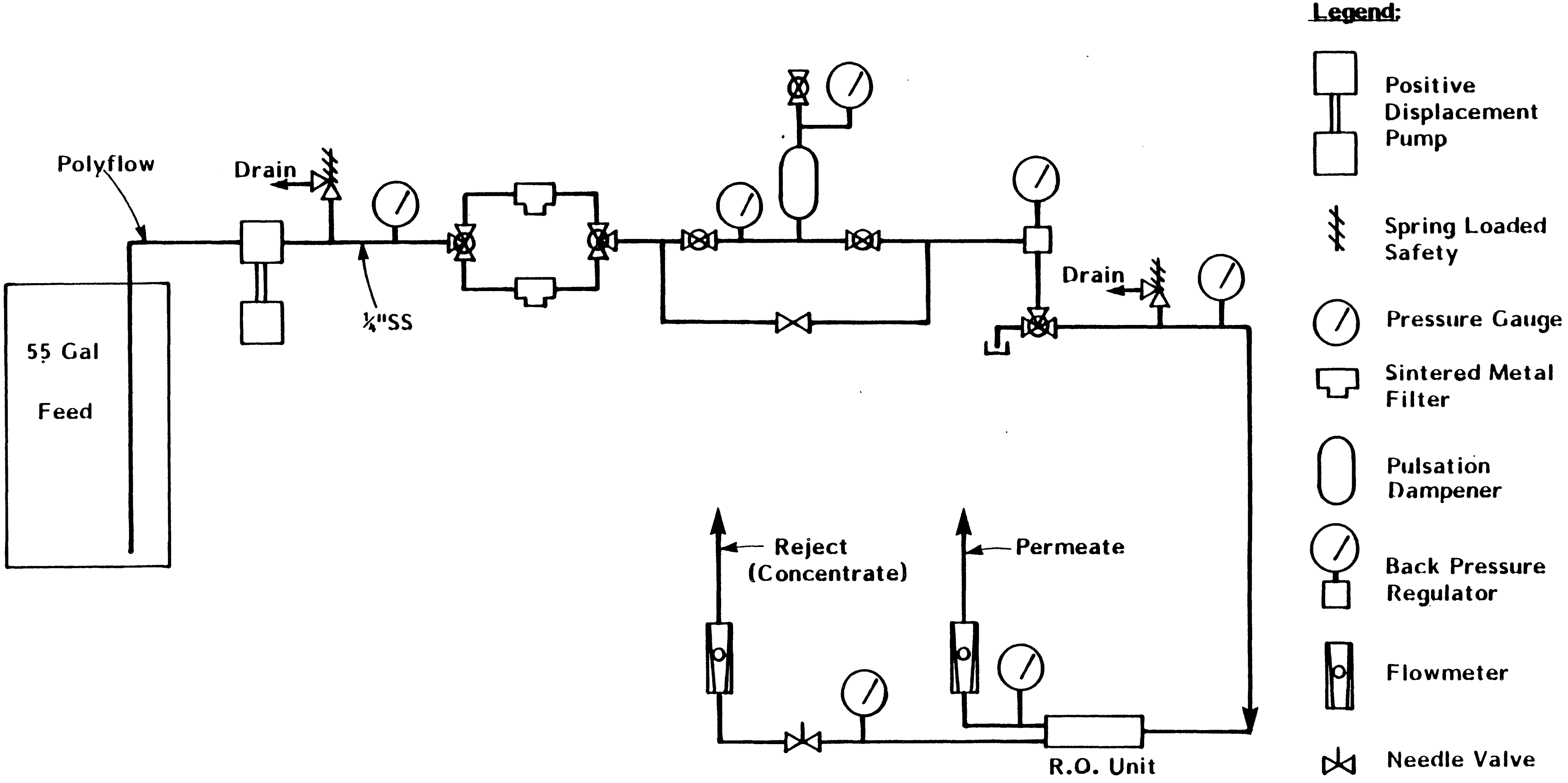


Figure 2

REVERSE OSMOSIS UNIT FLOWPLAN



APPENDIX

PROCEDURE A

PROCEDURES FOR CONTINUOUS CLARIFIER RUN

Start-Up

1. Fill clarifier with feed using feed pump at maximum flow rate
2. Turn feed pump off
3. Add chemicals (e.g., lime, soda ash, polymer) while recirculating clarifier contents with recycle pumps
4. Turn on feed pump at 1 liter per minute when pH = 10.1, allowing clarifier overflow to drain into gravity filter
5. Adjust chemical slurry pumps to desired dosage rates
6. Record time and pump settings

Operating

1. Check and record pH of clarifier effluent and recirculating sludge every fifteen minutes until pH = 10.3 is achieved and maintained
2. Every hour, check and record pH of clarifier effluent and recirculating sludge
3. Every hour, check solids content of sludge by sampling 100 ml of sludge in graduated cylinder and recording volume of settled sludge after 10 minutes
4. Every hour, check turbidity of filter effluent using Spec 20
5. If necessary, adjust flowrate of chemicals to maintain pH = 10.3
6. Record any changes to flowrates
7. Record time of chemical slurry replacement in order to allow check on actual chemical requirement
8. Every 2 hours, check feed flowrate with graduated cyclinder and clock

Sampling

1. Every 2 hours, collect 2 samples of feed and 2 samples of filter effluent
2. Every 4 hours, collect 2 samples of clarifier overflow ahead of filter

APPENDIX

PROCEDURE B

OPERATING INSTRUCTIONS FOR THE REVERSE OSMOSIS UNIT

(see Figure 2)

- Open all valves on the flow path from the feed drum to the permeate and reject drums
- Load the backpressure regulator's dome with cylinder nitrogen to the desired feed operating pressure (maximum 3000 kpa)
- Open the needle valve on the reject stream fully
- Turn the pump on, and set the feed flowrate by adjusting the micrometer knob on the pump (100% @2800 kpa yields 0.9 liter/min)
- Slowly close the reject stream needle valve until the desired flowrates in the reject and permeate streams are obtained
- Record flowrates and pressures on each stream every hour

APPENDIX

PROCEDURE C

SAMPLE BOTTLE PREPARATION

Acid Rinsing

1. Fill bottle with distilled water; discard water
2. Fill bottle halfway with 50% Nitric Acid
3. Swirl acid solution to contact all interior surfaces twice during 5 minute period
4. Dump acid solution to waste acid container
5. Fill bottle with distilled water; discard water
6. Fill bottle halfway with 50% Hydrochloric Acid
7. Swirl acid solution to contact all interior surfaces twice during 5 minute period
8. Dump acid solution to waste acid container
9. Fill bottle with distilled water; discard water
10. Rinse bottles with distilled water for 15 minutes

Note: Follow above procedures for bottle caps also

APPENDIX

PROCEDURE D

SAMPLE PREPARATION

Acid Rinsing of Millipore Filtering Apparatus (After every use)

1. Rinse flask, filter top, and filter bottom with distilled water
2. Rinse with 50% Nitric Acid
3. Rinse with 50% Hydrochloric Acid
4. Rinse well with distilled water

"Filtered and Acidified" Sample Preparation

1. Connect flask, filter top and filter bottom using 0.45μ filter paper to vacuum source
2. Decant sample into filtering apparatus and allow to filter into flask
3. Disconnect apparatus, pour sample into sample bottle
4. Add 2 ml of ultra pure Nitric Acid into sample bottle

"Acidified" Sample Preparation

1. Decant sample into sample bottle
2. Add 2 ml of ultra pure Nitric Acid into sample bottle
3. Connect flask, filter top and filter bottom using 0.45μ filter paper to vacuum source
4. Pour sample bottle contents into filtering apparatus and allow to filter into flask
5. Disconnect apparatus, pour sample into sample bottle

SUPPLEMENT TO APPENDIX F

Because of constraints in the recoveries feasible with the bench scale RO testing apparatus, it was not possible to attain the high recoveries (80%) projected for the full-scale RO system at Crandon. It is appropriate, however, to compare vendor model predictions of performances at higher recovery rates with the predictions of the Crandon Project Water Use Model. The following table illustrates this comparison for the test run with recycle water.

		10% Recovery		75% Recovery	
Ion(1)	Feed Water	Bench Unit[2]	Vendor Model	Vendor Model	Crandon Model[4]
Calcium (Ca)	30	0.95	5.1	1.1	1.2
Magnesium (Mg)	2.2	0.1	0.4	0.1	0.09
Sodium (Na)	654	20	111.4	25.7	65
Potassium (K)	(1.1)	(1.2)	0.5	0.1	0.11
Sulfate (SO_4)	1405	38	238.5	53.9	56.2
Chloride (Cl)	11.6	1.07	5.3	1.2	1.2
Fluoride (F)	3.1	0.43	0.1	0.1	0.16

1) All values are in ppm (mg/L)

2) Permeate concentrations obtained from the reverse osmosis bench scale unit which employed a spiral-wound polyamide element.

3) Data in ( ) indicate value is between 1 and 3 times detection limit.

4) The Crandon Model simulates the performance of either polyamide or cellulose acetate spiral-wound membranes. Membrane selection will be evaluated further in final engineering.

As concluded in the body of Appendix F, the bench scale unit provided an effluent quality at 10-percent recovery which was generally better than predicted by the vendor model, indicating that the vendor model is conservative. As shown above, the prediction of effluent quality by the Crandon model at 75-percent recovery is similar to or slightly more conservative than the vendor model. It is concluded that the Crandon model provides a realistic, but conservative, estimate of effluent quality.

Appendix G
REVERSE OSMOSIS AND EVAPORATOR INSTALLATIONS

Table G-1 (Page 1 of 2)

REVERSE OSMOSIS INSTALLATIONS: WASTEWATER TREATMENT

	Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Wastewater TDS (mg/l)	Percent Recovery	Pretreatment[a]	Membrane Type and Manufacturer[b]	System Vendor	Comments
1.	R. D. Nixon Station Colorado Springs, Colorado	1980	Combined wastes from coal-fired powerplant	700	5,000	50	Algicide, Cl_2, $FeCl_3$, coag, clarification, mixed media filtration	Spiral-wound CA UOP Fluid Systems	UOP Fluid Systems	Operates as designed. Permeate reused in powerplant. Award-winning plant.
2.	Bridgeport Brass Bridgeport, Connecticut	1974	Combined wastes from copper-brass mill	600	350 total (45 mg/l heavy metals)	95	Equalization, caustic treatment, filtration	Spiral-wound CA UOP Fluid Systems	UOP Fluid Systems	Early mechanical and process problems solved after 2 years. Decommissioned ca. 1983.
3.	San Juan Station Public Service Co. of New Mexico Farmington, New Mexico	1977	Combined wastes from coal-fired powerplant	400	4,000	80	Cl_2, dual-media filtration	Spiral-wound CA UOP Fluid Systems	El Paso Environmental Systems	Included recycle of concentrate through $CaSO_4$ precipitator/clarifier. Serious membrane fouling due to algae, oil, $CaSO_4$ scaling. Operation discontinued late 1978.
4.	San Juan Station Public Service Company of New Mexico Farmington, New Mexico	1980	Combined wastes from coal-fired powerplant	2,000	4,300	80	Lime-soda softening, dual-media filtration, dechlorination	Spiral-wound PA UOP Fluid Systems	Resources Conservation Company	Operational. Throughput limited by severe flux decline (probably due to algae and Cl_2 attack). PA membranes being replaced with CA manufactured by Hydranautics.
5.	Water Factory 21 Orange County Water District Fountain Valley, California	1977	Tertiary treated municipal effluent (for groundwater recharge)	3,500	1,400	85	Activated sludge, Cl_2, lime softening, filtration, activated carbon	Spiral-wound CA UOP Fluid Systems	UOP Fluid Systems	Operational. Early fouling problems with carbon fines reduced by downflow carbon units. Some first-stage organic fouling. Award-winning plant.

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[a] pH adjustment, scale inhibitor addition, and cartridge filters included in all cases.

[b] CA = cellulose acetate. PA = polyamide.

Note: These are wastewater applications only. A great many other RO installations exist in brackish water and seawater service that have constraints and configurations similar to the RO system proposed at Crandon.

Table G-1 (Page 2 of 2)

	Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Wastewater TDS (mg/l)	Percent Recovery	Pretreatment[a]	Membrane Type and Manufacturer[b]	System Vendor	Comments
6.	BUREC Demonstration Yuma, Arizona (pilot plants)	1975	Irrigation return flow	600	3,100	75-85	Cl_2, lime-soda softening, dual-media filtration	Spiral-wound CA and hollow fine PA Various manufacturers	Various	Long-term testing showed this pretreatment system and spiral-wound CA membranes optimum.
7.	BUREC RO Facility Yuma, Arizona (full-scale plant)	1989 (?)	Irrigation return flow	52,000	3,100	75	Cl_2 lime-soda softening, dual-media filtration	Spiral-wound CA UOP Fluid Systems and Hydranautics	UOP Fluid Systems; Hydranautics	Under construction.
8.	Denver Water Reuse Facility Denver Water Board Colorado	1983	Tertiary treated municipal effluent (for general reuse)	70	1,000	90	Activated sludge, Cl_2, lime softening, recarbonation, filtration, activated carbon, ozone, carbon	Spiral-wound PA UOP Fluid Systems	UOP Fluid Systems	Demonstration plant.
9.	Rocky Flats Arsenal Denver, Colorado	1977	Combined wastes from munitions manufacturing	250	3,900	95	Cl_2, lime-soda softening, filtration	Spiral-wound and hollow fine	UOP and Dow	Status unknown (believed out of service).
10.	Wyodak Power Plant Gillette, Wyoming	1979	Tertiary treated municipal effluent (for boiler feedwater)	200	3,800	70	Cl_2, lime-soda softening, filtration	Spiral-wound CA	Unknown	Operation. Algae fouling minimized by high lime doses.
11.	G&M Finishing Ephrata, Pennsylvania	1979	Textile dyeing wastewater	272	5,000 to 10,000	75-90	Lime softening and filtration	Spiral-wound PA UOP Fluid Systems	UOP Fluid Systems	Currently operational despite manufacturing process revisions resulting in wastewater composition changes.

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EVAPORATOR INSTALLATIONS: WASTEWATER TREATMENT

Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Pretreatment	Evaporator Type	Manufacturer	Comments
1. St. Jo Minerals Monaco, Pennsylvania	1981	SO_2 scrubber wastes (citrate process)	7	Filtration	Forced circulation	Goslin-Envirotech	Operational.
2. Potash Corporation of America Sussex, New Brunswick	1982	Mine effluent ($CaCl_2$, NaCl wastes)	1,500	Equalization, clarification, pH adjustment	Vapor compression	HPD	One body, dual compressors. Operational.
3. Union Carbide Bishop, California	1974	Tungsten mine wastes (solvent extraction raffinate)	70	Equalization, clarification, pH adjustment	Forced circulation evaporator and crystallizer	HPD	Early heat exchanger material problems. Operational.
4. Union Carbide (UCAR) TBL South Africa	1978	Tungsten mine wastes (solvent extraction raffinate)	160	Equalization, clarification, pH adjustment	Forced circulation evaporator and crystallizer	HPD	Operational.
5. Sulphide Corporation Boolaro, Australia	1979	Mining wastes (lead/zinc mine)	150	Equalization, clarification	Forced circulation	HPD	Operational. Na_2SO_4 recovery.
6. Thiokal Chemical Moss Point, Mississippi	1980	Caustic scrubber wastes	70	Equalization	Draft tube crystallizer	HPD	Operational.
7. Chevron Perth Amboy, New Jersey	1980	SO_2 scrubber wastes (Wellman-Lord process)	70	Equalization, clarification	Forced circulation	HPD	Operational. Na_2SO_4 and $Na_2S_2O_3$ byproduct recovery.
8. San Juan Power Plant Public Service Company of New Mexico Farmington, New Mexico	1981	SO_2 scrubber wastes (Wellman-Lord process)	50	Equalization, clarification	Forced circulation	HPD	Operational. NA_2SO_4 and $Na_2S_2O_3$ byproduct recovery.
9. Texas Instruments Dallas, Texas	1979	Etching wastes from semiconductor manufacturing	60	Equalization, clarification	Forced circulation	HPD	Operational. $(NH_3)_2SO_4$ and Na_2SO_4 byproduct recovery.

Note: These are industrial wastewater applications only. Literally hundreds of other evaporator installations exist in services the chemistries of which correlate to Crandon's; e.g., black liquor and red liquor evaporators in pulp mills, radwaste evaporators in nuclear plants, and various evaporation/crystallization processes in the inorganic chemicals industries.

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	Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Pretreatment	Evaporator Type	Manufacturer	Comments
10.	Wycon Chemical (Colorado Interstate Gas) Tablerock, Wyoming	1979	SO_2 scrubber wastes (Pritchard process)	40	Equalization, clarification	Falling film	HPD	Operational. $(NH_3)_2S_2O_3$ byproduct recovery.
11.	MHO Antwerp, Belgium	1979	Metals reduction plant wastes (segregated waste acids)	350	Equalization, clarification	Forced circulation (six units)	HPD	Operational.
12.	Eli Lilly Motescarlos, Brazil	1979	Pharmaceutical wastes	20	Equalization	Falling film and forced circulation	HPD	Operational.
13.	Diamond Shamrock Van Buren, Arkansas	1978	$CaCl_2$, NaCl wastes with heavy metal contamination	30	Confidential	Forced circulation	HPD	Operational.
14.	Northwest Alloys Addy, Washington	1981	Magnesium plant wastes	70	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
15.	Ray D. Nixon Station Colorado Springs, Colorado	1980	RO brine from treatment of powerplant wastes (uses reverse osmosis brine)	350	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Two units, each approximately 185 gpm.
16.	Deerhaven Station Gainesville Regional Utilities Gainesville, Florida	1981	Powerplant wastes	170	Equalization, pH adjustment	Vapor compression (and spray dryer)	Resources Conservation Company	Operational. Early problems spray nozzle materials.
17.	San Juan Station Public Service Co. of New Mexico Farmington, New Mexico	1975	Powerplant wastes (cooling tower blowdown)	170	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Some scaling and corrosion problems.
18.	San Juan Station Public Service Co. of New Mexico Farmington, New Mexico	1980	RO brine	250	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Some scaling and corrosion problems.

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	Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Pretreatment	Evaporator Type	Manufacturer	Comments
19.	San Juan Station Public Service Co. of New Mexico Farmington, New Mexico	1983	Combined powerplant wastes	500	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
20.	Pawnee Station Public Service of Colorado	1982	Combined powerplant wastes	170	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
21.	Clark Station Nevada Power Company Las Vegas, Nevada	1982	Combined powerplant wastes	450	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
22.	Four Corners Station Arizona Public Service	1982	Combined powerplant wastes	600	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
23.	Navajo Station Salt River Project Page, Arizona	1975	Powerplant wastes	170	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
24.	Navajo Station Salt River Project Page, Arizona	1981	Powerplant wastes	800	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Two units, each approximately 400 gpm.
25.	Hayden Station Colorado Ute Hayden, Colorado	1976	Powerplant wastes	170	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
26.	Craig Station Colorado Ute Craig, Colorado	1979	Powerplant wastes	600	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Three units, each approximately 225-gpm feed.
27.	Colstrip Station Montana Power and Light Colstrip, Montana	1976	Powerplant wastes	340	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational.
28.	Huntington Station Utah Power and Light	1975	Powerplant wastes	170	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Some corrosion problems.

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	Owner	Startup	Wastewater Source	Wastewater Flow (gpm)	Pretreatment	Evaporator Type	Manufacturer	Comments
29.	Great Plains Coal Gasification Project Beulah, North Dakota	1983	Waste brines from coal gas plant	600	Equalization, pH adjustment	Spray film	Aqua-chem	Substantial pilot work, commercial plant operational.
30.	Otter Tail Power Company Grant County, South Dakota	1980	Electric utility cooling wastewater	600	Equalization, pH adjustment, coarse filtration	Vapor compression	Resources Conservation Company	Operational.
31.	Tugco-Monticello Mt. Pleasant, Texas	1982	Electric utility waste cooling water (uses reverse osmosis brine)	270	Equalization, pH adjustment	Vapor compression (spray dryer)	Resources Conservation Company	Operational.
32.	Tugco-Martin Lake Tatum, Texas	1983	Electric utility combined wastewater	600	Equalization pH adjustment	Vapor compression	Resources Conservation Company	Operational.
33.	SASOL II South Africa	1983	Coal gasification wastewater, including ash pile runoff, ash sluicing wastewater, stripped gas liquor	1,800	Equalization, pH adjustment	Vapor compression	Resources Conservation Company	Operational. Three units, approximately 600 gpm each.
34.	ASARCO Hayden, Arizona	1983	Acidic industrial wastewater	270	Lime neutralization, clarification	Vapor compression	Resources Conservation Company	Operational.