Conceptual design. Volume 2

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PHASE III
WATER MANAGEMENT STUDY

VOLUME 2 OF 3
CONCEPTUAL DESIGN

EXXON MINERALS COMPANY
CRANDON PROJECT
CRANDON, WISCONSIN

CH2M HILL

CH2M HILL
engineers
planners
economists
scientists

December 30, 1982

L15028.A0

Exxon Minerals Company
P.O. Box 813
Rhinelander, Wisconsin 54501

Attention: Mr. Curtis Fowler

Dear Mr. Fowler:

Subject: Phase III Water Management Study
Final Report
Exxon Contract: 21081
CH2M HILL No.: L15028.A0
Correspondence No.: L-022

We are pleased to submit this three-volume report summarizing CH2M HILL's findings during the Phase III Water Management Study for the Crandon Project.

It has been our sincere pleasure working with Exxon during this study. We look forward to working with you again on future phases of engineering work.

If we can provide further assistance, please feel free to call me at any time at 414/774-5530.

Sincerely,

Michael R. Harris

Michael R. Harris
Project Manager

jsm/GLT225/4

Enclosures

Milwaukee Regional Office
2929 N. Mayfair Road, P.O. Box 2090, Milwaukee, Wisconsin 53201 414/774-5530

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CRANDON PROJECT

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Section XVIII
CONCEPTUAL DESIGN BASIS

INTRODUCTION

Selection of the preferred water treatment system for the Crandon Project is described in Volume 1 of this report (Sections I through XVII).

As described earlier, the water treatment requirements of the Crandon Project will vary throughout the mine development period and the operating life of the mill. Current projections indicate that contaminated mine water will require treatment through all treatment processes to insure compliance with WPDES permit requirements. During mine development and early operation, however, it is possible that WPDES criteria could be satisfied by treating the contaminated mine water only through lime-soda softening and filtration. Hence, system flexibility to separately handle the contaminated mine water through lime-soda softening and filtration is desirable and has been incorporated into the conceptual design.

To evaluate the required sizes of unit processes in the treatment system, computer modelling runs were performed for each of the following time periods:

- o Mine Development Period
- o Early Operation of Mill - Summer Conditions
- o Early Operation of Mill - Winter Conditions
- o Mature Operation of Mill - Summer Conditions
- o Mature Operation of Mill - Winter Conditions

Copies of the computer model printouts for each of these periods are included in Appendices C, D, and E.

SYSTEM SIZING

To effect the treatment flexibility mentioned above, the contaminated mine water (1,335 gpm) and the Reclaim Pond water (427 gpm) will be handled separately through the neutralization, lime-soda softening, and filtration processes. After these processes they will be combined for further treatment, or the contaminated mine water (quality permitting) will be discharged or recycled while the Reclaim Pond water will go on to further treatment. It was decided for reasons of process flexibility, interchangeability, and economies of design and construction that the two streams be treated in twin neutralization, lime-soda softening, and filtration systems with each system sized to handle the 1,335 gpm contaminated mine water flow. This actually gives about 50 percent excess capacity through the filtration process.

CH2M HILL and Exxon jointly agreed that, for this study, the remainder of the water treatment system should be sized with 20 percent excess capacity over and above the maximum capacity predicted by the computer. The last column in Figure 23 illustrates the design capacity selected for the treatment system unit operations. This excess capacity is provided to allow for:

- o downtime for equipment maintenance and repairs
- o potential periods of excess precipitation
- o allowance for precision in estimating flow rates

The major unit processes in the final effluent/recycle water treatment system were sized to treat all contaminated water pumped from the mine plus a sufficient volume of water from the Reclaim Pond to control scale formation in the mill piping circuit during Mature/Summer operation of the Mine/Mill complex. As shown in the computer printout in Appendix E, a sufficient volume of Reclaim Pond water is treated to "eliminate" scaling in all mill water streams except the effluent from the Reclaim Pond. The total volume of water "treated" in the water treatment system in this run is 400 m^3/hr (1,762 gpm).

A model run under Mature/Winter conditions (also in Appendix E) shows that, at this blowdown rate, no scaling conditions are predicted in the mill circuit (i.e., during the winter, there is less thiosulfate oxidation in the ponds and, therefore, less sulfate generated in the system).

With the flow rate to the treatment system fixed at the volume selected for Mature/Summer conditions, two additional model runs (Appendix D) were made to assess water quality in the mill water circuit during Early mill operations at both Summer and Winter conditions. These runs illustrate that, during Early operation of the mill, calcium sulfate will build up to supersaturation concentrations in the mill circuit. Model predictions of equilibrium water quality, however, may not actually be achieved because a) early operation will only last for a few months and b) the system will be started up with the Reclaim Pond full of the clean water.

Model runs indicate that, during Early mill operation, it may be necessary to add scale inhibitors at the Reclaim Pond pump station to inhibit scale formation in the pipeline to the mill. It is probable that scale inhibitor addition will also be necessary in summer months during Mature operations, and especially during the spring months when thiosalt oxidation rates increase.

The scale inhibitor addition system at the Reclaim Pond is included in the design of the surface facilities and is not considered further in this report.

Figure 23 illustrates computer predictions of flow rates at intermediate points within the preferred water treatment system during each of the selected time periods. Predicted reagent consumption rates and sludge production rates during each time period are also shown.

PROVISIONS FOR RAINFALL/STORMS

The water treatment system is sized to treat long-term average rates of precipitation on the pond system and/or other surface areas with contaminated runoff (see Section IV-SITE WATER SOURCES).[29] The Reclaim Pond has been sized with sufficient freeboard to store rainfall due to short-term storm events and/or years with excess precipitation.

The excess capacity built into the conceptual design of the water treatment system could be used to treat excess water from precipitation but, because of the surge capacity in the Reclaim Pond, it may not be necessary to "use" the excess capacity for that purpose.

PROVISIONS FOR OIL REMOVAL

The proposed water treatment system does not include any provisions for oil removal.

If oil is inadvertently spilled in the mine, it is assumed that it would be captured in facilities located in the mine. If such spills were allowed to enter the mine pumps, it is likely that the combination of turbulence in the pumps and high pressure in the piping system would create an oil-water emulsion which would be difficult to separate. Likewise, the quiescent conditions in the Tailings/Reclaim ponds should provide ideal conditions to capture minor quantities of oil. A simple skimming system near the pond outlets should be sufficient.

UNIT PROCESS m³/hr (GPM)[1]	MINE DEVELOPMENT[3]	EARLY OPERATION		MATURE OPERATION		DESIGN FLOWRATE	
		SUMMER	WINTER	SUMMER	WINTER	TYPICAL	MAXIMUM
LIME-SODA SOFTENER m³/hr (GPM)	309.2 (1362)	400.2 (1762)	400.3 (1762)	400.2 (1762)	400.2 (1762)	400.2 (1762)	546 (2405)
NEUTRALIZATION	307.3 (1354)	391.1 (1722)	390.8 (1721)	391.1 (1722)	391.3 (1723)	396 (1746)	543 (2390)
FILTRATION	307.3 (1354)	391.1 (1722)	390.8 (1721)	391.1 (1722)	391.3 (1723)	396 (1746)	543 (2390)
REVERSE OSMOSIS	307.3 (1354)	391.1 (1722)	390.8 (1721)	391.1 (1722)	391.3 (1723)	396 (1746)	477 (2100)
VAPOR COMPRESSION EVAP	61.7 (272)	78.1 (344)	78.1 (344)	78.1 (344)	78.3 (345)	79.5 (350)	95.4 (420)
BRINE CONCENTRATION SYSTEM	0.9 (3.9)	3.4 (15.2)	3.5 (15.5)	3.3 (14.4)	3.1 (13.7)	3.6 (16)	4.2 (18)
REAGENT CONSUMPTION kg/hr (lbs/d)[2]							
$Ca(OH)_2$	70.6 (3729)	52.9 (2795)	45.8 (2420)	47.7 (2517)	49.2 (2600)	47.7 (2517)	84.9 (4483)
Na_2CO_3	134 (7073)	340 (17946)	358 (18890)	325 (17177)	340 (17967)	325 (17174)	442 (23330)
H_2SO_4	37.8 (1995)	46.5 (2453)	46.4 (2449)	47.6 (2516)	47.6 (2515)	48.0 (2535)	63.7 (3361)
POLYMER	1.9 (98)	2.4 (128)	2.4 (128)	2.4 (128)	2.4 (128)	2.4 (128)	3.3 (175)
SHMP	3.1 (163)	3.9 (207)	3.9 (207)	3.9 (207)	3.9 (207)	4.0 (210)	4.8 (252)
SLUDGE PRODUCTION kg/hr (lb/d)							
LIME-SODA SOFTENER	116 (6153)	562 (29652)	576 (30393)	562 (29652)	548 (28911)	562 (29652)	691 (36472)
BRINE SOFTENER	160 (8462)	157 (8310)	151 (7979)	158 (8371)	158 (8362)	158 (8371)	192 (10154)
DRIED EVAPORATOR BRINE	87 (4580)	586 (30945)	610 (32182)	553 (29189)	521 (27509)	553 (29189)	731 (38620)

FIGURE 23

NOTES:

1. CAPACITIES ARE BASED ON MODEL PROJECTIONS. TYPICAL DEFINED AS MATURE SUMMER. DESIGN CAPACITIES INCLUDE REAGENT ADDITION AND ADDITIONAL CAPACITY TO PROCESS FILTER BACKWASHING FLOWS.
2. CONSUMPTION RATES ARE BASED ON MODEL PROJECTIONS PLUS REQUIREMENTS FOR EFFLUENT NEUTRALIZATION AND THE BRINE DRYING SYSTEM WHICH ARE NOT MODELED
3. THIS MODEL RUN WAS COMPLETED BEFORE EXXON'S FINAL PROJECTIONS OF MINE SEEPAGE FLOW RATES DURING MINE DEVELOPMENT. EXXON'S LATEST PROJECTIONS INDICATE THAT THE FLOW RATE OF CONTAMINATED MINE SEEPAGE MAY BE LOWER: SEE SECTION XII

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SUMMARY OF TREATMENT SYSTEM CAPACITY REQUIREMENTS, REAGENT COMSUMPTION AND SLUDGE PRODUCTION RATES

SCALE	STATE	COUNTY
NONE	WISCONSIN	FOREST

	DATE		DATE
DRAWN BY DLA		CHECKED BY	
APPROVED BY JSM		APPROVED BY	
APPROVED BY MRH		EXXON	

CH2M HILL

DRAWING NO 051-7-L-021   SHEET ___ OF ___   REVISION NO

SUMMARY

Figures 24 and 25 illustrate average water balances for the Crandon Project during Early and Mature operations (Summer operating conditions). These figures are identical to Figures 15 and 16 except that the water balances around the water treatment system have been revised to reflect reagent water addition rates and sludge/brine flow rates. The design conditions used for these runs are included in the computer printouts in Appendices D and E.

GLT63/1

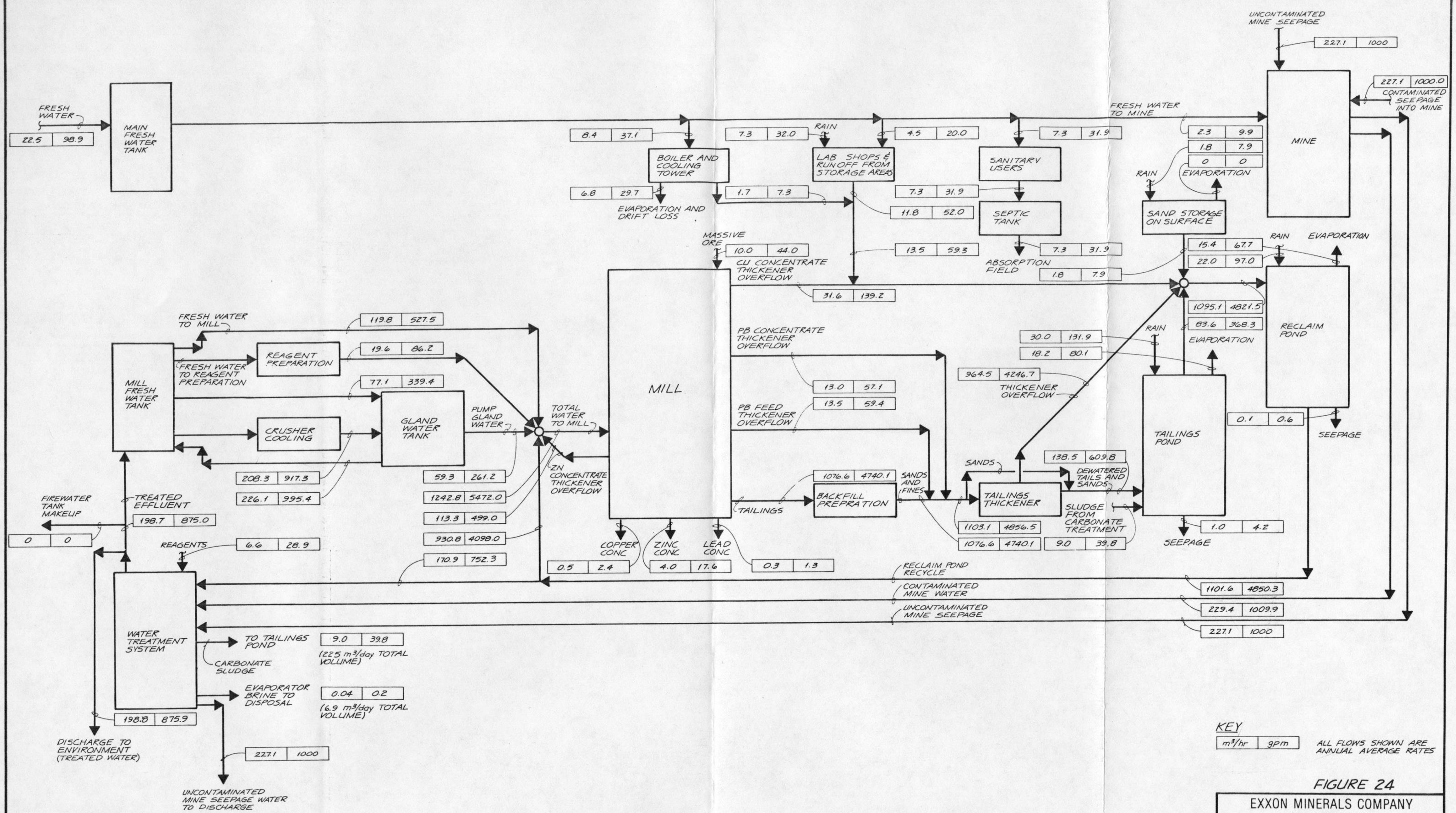


FIGURE 24

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE OVERALL WATER BALANCE FOR CRANDON PROJECT – EARLY SUMMER OPERATION

SCALE NONE | STATE WISCONSIN | COUNTY FOREST

DRAWN BY DLA
APPROVED BY MRH

DRAWING NO. 051-7-L-019

CH2M HILL

EXXON PROPRIETARY

GBB 5/1981

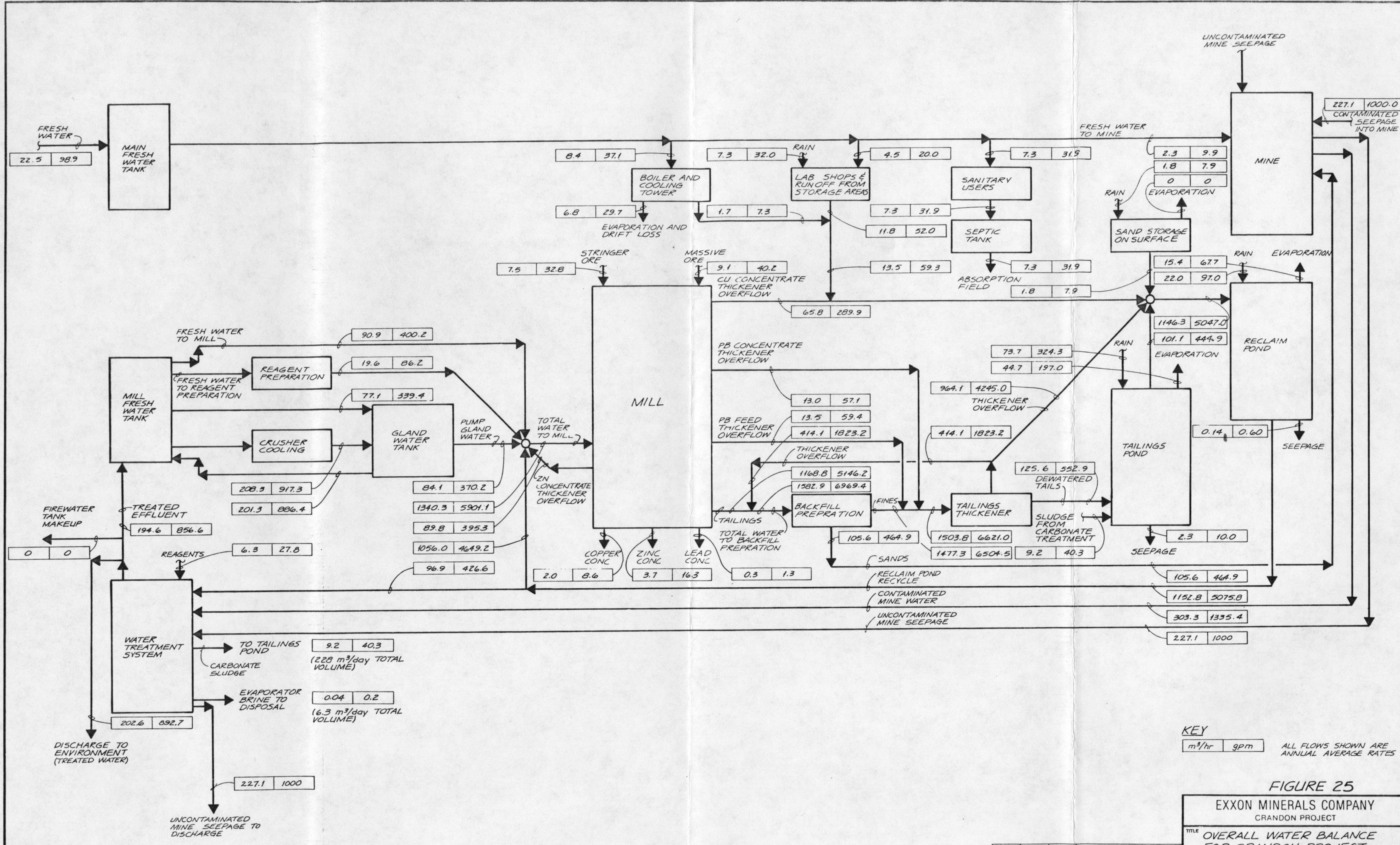


FIGURE 25

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE OVERALL WATER BALANCE FOR CRANDON PROJECT - MATURE SUMMER OPERATION

SCALE NONE | STATE WISCONSIN | COUNTY FOREST

DRAWN BY DLA | APPROVED BY MRH | APPROVED BY EXXON

DRAWING NO. 051-7-L-020

CH2M HILL

Section XIX
CONCEPTUAL DESIGN OF PREFERRED WATER TREATMENT SYSTEM

SIZING AND/OR DESIGN CRITERIA

This section contains a discussion of the criteria used to size the major pieces of equipment and/or intermediate tankage in the preferred water treatment system.

The system is designed to treat all contaminated water pumped from the mine plus some water from the Reclaim Pond. The sizing basis was discussed in the previous section. Treatment of contaminated mine water and Reclaim Pond water is separated through the filtration process. This separation would permit direct discharge of treated mine water if the quality of the water meets effluent limitations.

The preferred water treatment system will consist of the following unit processes.

Unit Process	Primary Functions
Surge and Equalization	Permit steady state flow rate to treatment processes. Provide tankage for pH adjustment.
Carbonate Precipitation (Lime-soda Softening)	Remove suspended material in raw influent water. Precipitate metal hydroxides. Precipitate calcium as $CaCO_3$, thereby permitting higher water recovery in the reverse osmosis system.
pH Adjustment	Decrease pH in effluent from the carbonate precipitation system.
Mixed Media Filtration	Remove suspended solids from water. (A necessary process to protect reverse osmosis membranes against fouling.)
Reverse Osmosis	Concentrate inorganic dissolved constituents in a smaller brine stream.

Vapor Compression Evaporation	Further concentrate dissolved constituents into a highly concentrated brine stream.
pH Adjustment	Raise effluent pH for discharge/recycle.
Brine Concentration System	Dry inorganic solids residue for ultimate disposal or marketing.

Figures 26, 27, 28, and 29 illustrate a preliminary Process and Instrumentation Diagram (P&ID) for the treatment system. Typical and design maximum flow rates are shown for each of the major streams in the system. The flow rates illustrated for each stream are correct, but since a number of the streams are intermittent (e.g., backwash from filters), the flow rates shown entering and leaving unit operations do not always numerically balance. Figure 30 presents an explanation of the symbols used on the P&ID's.

Figure 31 presents a hydraulic profile for the main water streams through the system.

The water treatment system has been conceptually designed with a series of modular treatment operations. Any individual treatment module can be taken out of service without adverse impact on the remainder of the treatment system. To the maximum extent possible, the design of the treatment system permits independent operation from the mill. With the exception of Milk-of-Lime (MOL), which is available in a pressurized pipeline from the mill MOL circuit, all reagents are stored in day tanks at the treatment building and pumped into the treatment process with local pumps.

The following paragraphs describe sizing criteria for individual items of equipment in the treatment system:

Water Treatment Feed Tanks

The water treatment feed tanks are not included in this design.

Treatment System Feed Pumps

The treatment system feed pumps are not included in this design.

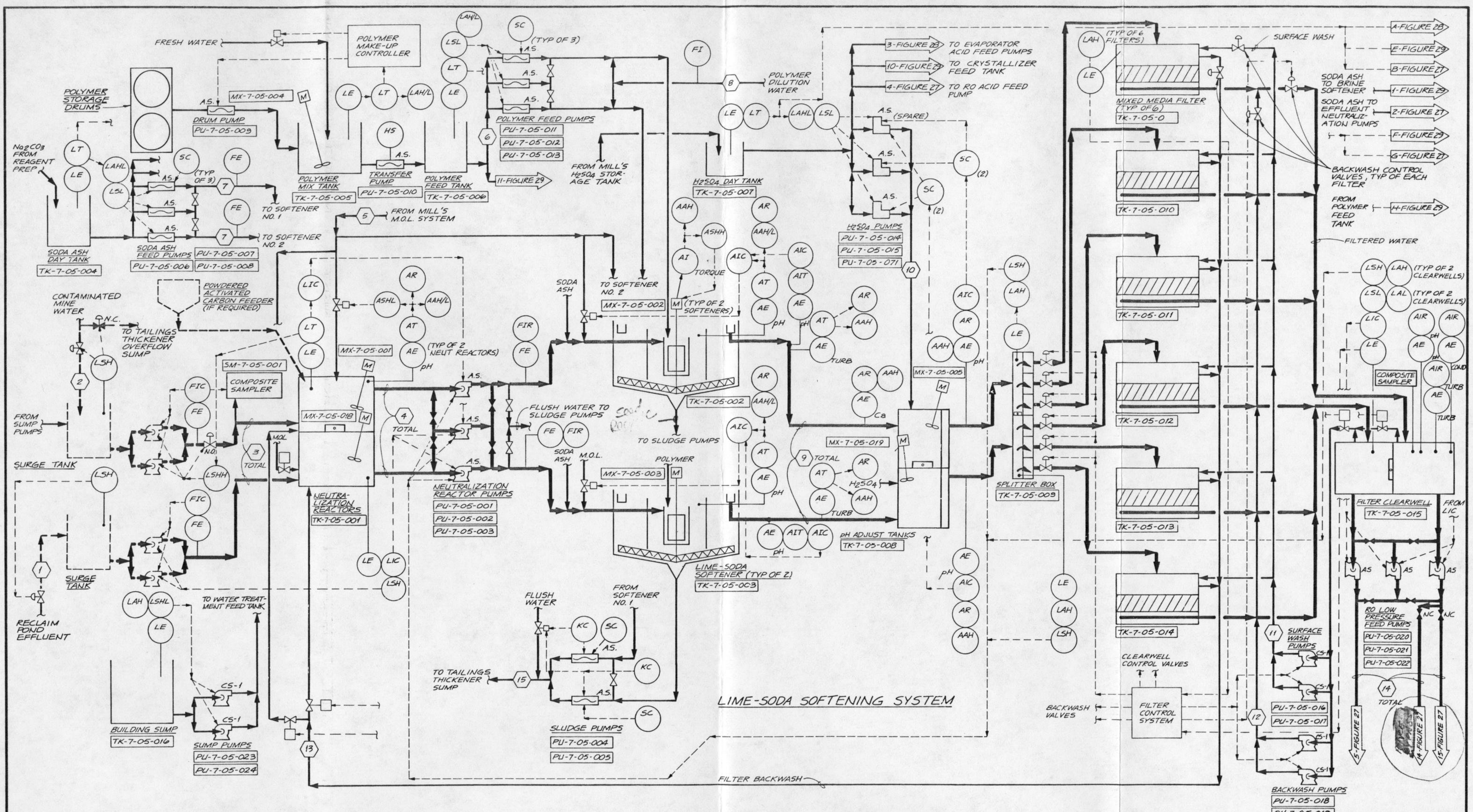


FIGURE 26

STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TYPICAL FLOW m³/hr (US GPM)	97 (427)	303 (1,335)	400 (1,762)	400 (1,762)	0.5 (2.2)	0.5 (2.1)	1.3 (5.8)	1.9 (8.4)	396 (1,746)	0.02 (0.07)	23 (100)	579 (2,550)	593 (2,610)	396 (1,746)	23 (100)
MAX FLOW m³/hr (US GPM)	171 (752.2)	303 (1,335)	480 (2,115)	546 (2,405)	1.0 (4.2)	0.7 (2.9)	1.8 (7.8)	2.6 (11.6)	543 (2,390)	0.02 (0.10)	23 (100)	579 (2,550)	593 (2,610)	477 (2,100)	23 (100)
TYPICAL SOLIDS FLOW Kg/hr (lbs/DAY)	—	292 (15,400)	292 (15,400)	292 (15,400)	25.8 (1363)	2.4 (127)	146.2 (7,721)	—	—	30.1 (1,589)	—	—	—	—	562 (29,652)
MAX SOLIDS FLOW Kg/hr (lbs/DAY)	—	292 (15,400)	292 (15,400)	292 (15,400)	49.2 (2,596)	3.3 (173)	196 (10,371)	—	—	42.1 (2,223)	—	—	—	—	691 (36,472)
CONTINOUS FLOW	X	X	X	X	X	X	X	X	X	X				X	
INTERMITTENT FLOW											X	X	X		X

ADDITIONAL STREAM CRITERIA

- 1,2,3 TYPICAL FLOWS AS PREDICTED IN WATER USE MODEL OUTPUT RUN 127 MAX FLOW = 1.2 x TYP
- 4 MAX BASED ON 45 MINUTES TO PUMP OUT 1 FILTER BACKWASH VOLUME
- 5 5% LIME SOLUTION FROM M.O.L. FACILITY
- 6 POLYMER MIXED AT 0.5% AND DOSED AT ~ 6 mg/l
- 7 10% SOLUTION FROM REAGENT PREP FACILITY
- 8 POLYMER DILUTED TO 0.1%
- 10 93% H_2SO_4 FROM MILLS STORAGE TANK
- 15 SLUDGE UNDERFLOW CONCENTRATION OF 6%
- 9 SLUDGE PUMPS OPERATING 1/2 TIME BASED ON DAILY AVERAGE SLUDGE PRODUCTION OF 40 gpm (TYP) & 49 gpm (PEAK)

NOTES: (TYPICAL FOR FIGURES 26-29)

1. ONLY MAJOR CONTROL ELEMENTS & CONTROL VALVES ARE SHOWN
2. INSTRUMENTATION SYMBOLS SHOWN ARE STD INSTRUMENT SOCIETY OF AMERICA 55.1 DESIGNATIONS
3. EXXON EQUIP NO'S DESIGNATED BY XX-7-05-XXX

REVISED	DATE	BY	DESCRIPTION

CH2M HILL

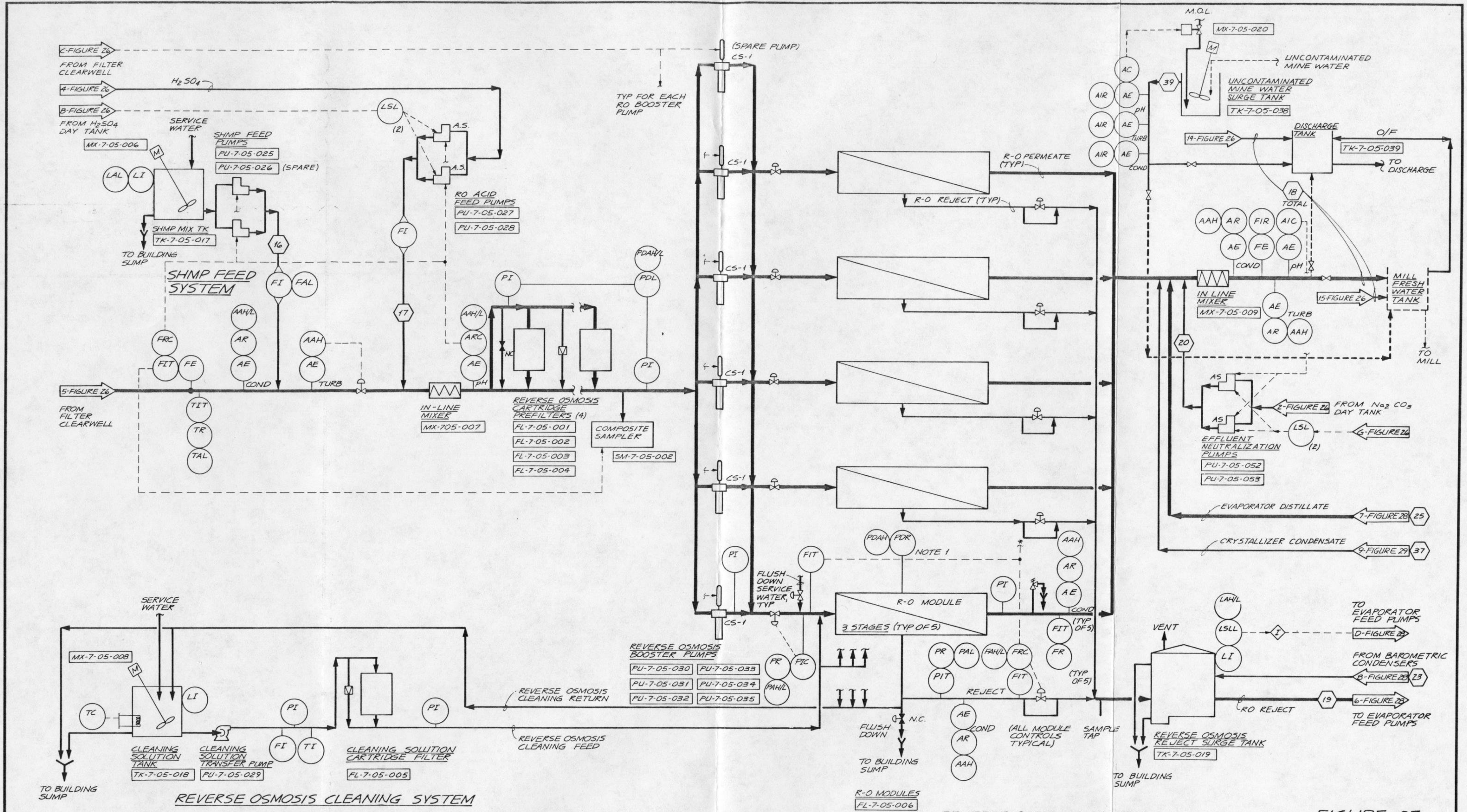
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: PRELIMINARY PROCESS & INSTRUMENTATION DIAGRAM LIME-SODA SOFTENING

SCALE: NONE | STATE: WISCONSIN | COUNTY: FOREST

DRAWN BY: DAK | DATE | CHECKED BY | DATE
APPROVED BY: JSM | DATE | APPROVED BY | DATE
APPROVED BY: MRH | DATE | EXXON | DATE

DRAWING NO. 051-7-L-022 | SHEET OF | REVISION NO.



STREAM NUMBER	39	16	17	18	19	20
TYPICAL FLOW m^3/hr (US. GPM)	227 (1000)	0.003 (0.015)	0.01 (0.04)	397 (1749)	79 (350)	0.004 (0.02)
MAX FLOW m^3/hr (US. GPM)	227 (1000)	0.004 (0.019)	0.01 (0.05)	478 (2104)	95 (420)	0.004 (0.02)
SOLIDS: TYPICAL FLOW Kg/hr (lbs/DAY)	—	4 (210)	17.5 (925)	—	—	0.4 (21)
MAX FLOW Kg/hr (lbs/DAY)	—	4.8 (252)	21.1 (1112)	—	—	0.5 (25)
CONTINUOUS FLOW	X	X	X	X	X	X
INTERMITTENT FLOW						

ADDITIONAL STREAM CRITERIA

16 SHMP DOSED AT 10 mg/ℓ
17 H_2SO_4 DOSED AT 41 mg/ℓ
20 Na_2CO_3 DOSED AT 1 mg/ℓ

NOTES

1. PRESSURE DIFFERENTIAL RECORDING ACROSS 1ST, 2ND, 3RD, STAGES OF REVERSE OSMOSIS
2. RO SYSTEM OPERATED AT 80% RECOVERY

FIGURE 27

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY PROCESS & INSTRUMENTATION DIAGRAM REVERSE OSMOSIS SYSTEM

SCALE NONE | STATE WISCONSIN | COUNTY FOREST

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APPROVED BY JSM
APPROVED BY MRH
DRAWING NO. 051-7-L-023

CH2M HILL

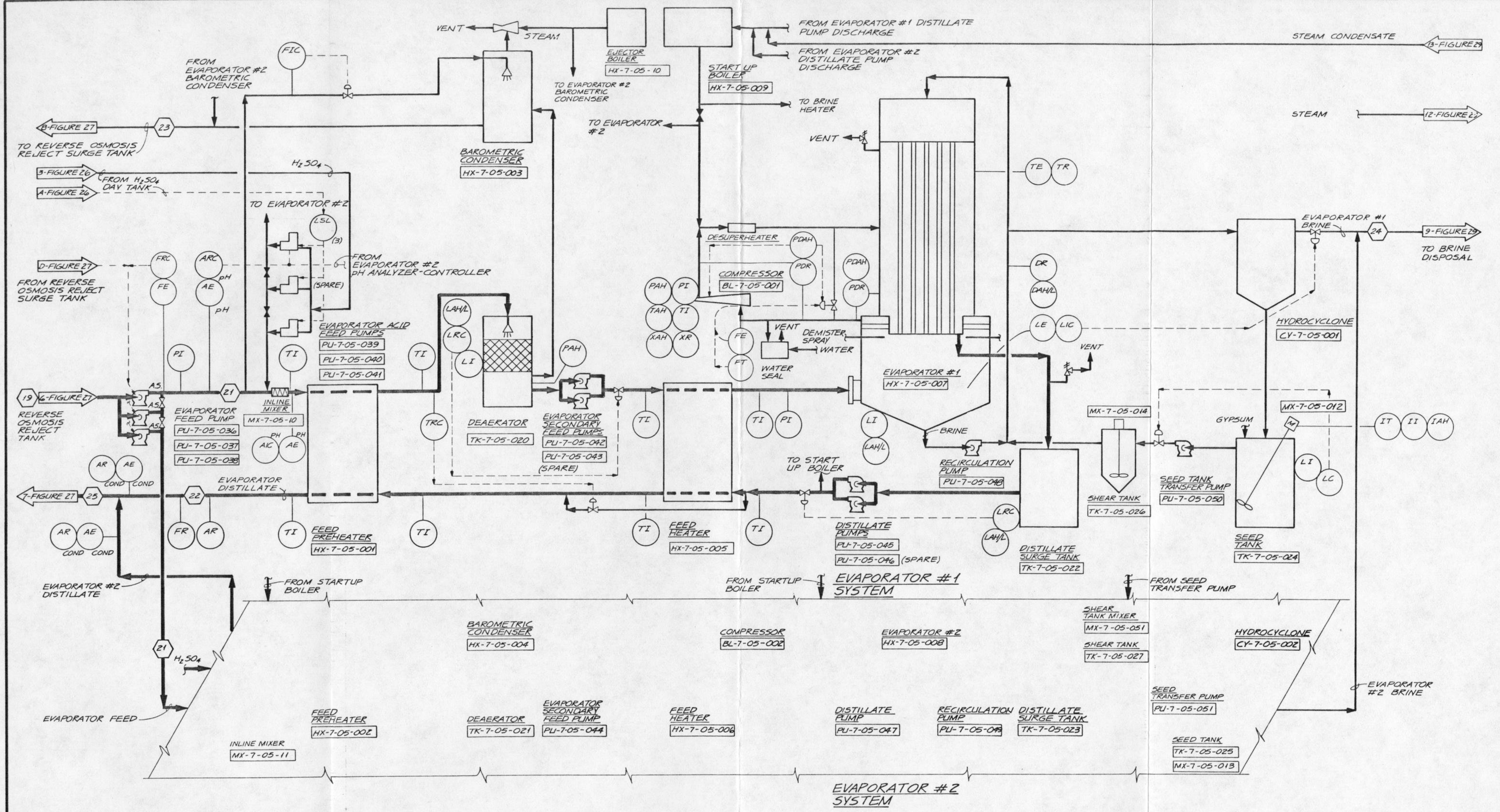


FIGURE 28

STREAM NUMBER	21	22	23	24	25	
TYPICAL FLOW m³/hr (U.S.GPM)	39.8 (175)	37.9 (167)	<0.2 (<1)	3.6 (16)	75.8 (334)	
MAX FLOW m³/hr (U.S.GPM)	47.7 (210)	45.6 (201)	<0.2 (<1)	4.2 (18)	91.2 (402)	
SOLIDS: TYPICAL FLOW Kg/hr (lbs/DAY)	—	—	—	657 (34694)	—	
MAX FLOW Kg/hr (lbs/DAY)	—	—	—	853 (45036)	—	
CONTINUOUS FLOW	X	X	X	X	X	
INTERMITTENT FLOW						

ADDITIONAL STREAM CRITERIA

21 pH CONTROL AS NECCSSARY TO MAINTAIN pH IN 5.0-7.0 RANGE

NOTES:

1. EVAPORATOR SYSTEMS SHALL BE SUPPLIED AS DESIGNED BY VENDOR SYSTEM SHOWN IS TYPICAL
2. EVAPORATOR SYSTEMS #1 AND #2 ARE IDENTICAL
3. EVAPORATOR OPERATED AT 96% RECOVERY

CH2M HILL

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY PROCESS AND INSTRUMENTATION DIAGRAM EVAPORATOR SYSTEM

SCALE NONE | STATE WISCONSIN | COUNTY FOREST

DRAWN BY DLA
APPROVED BY JSM
APPROVED BY MRH
DRAWING NO. 051-7-L-024

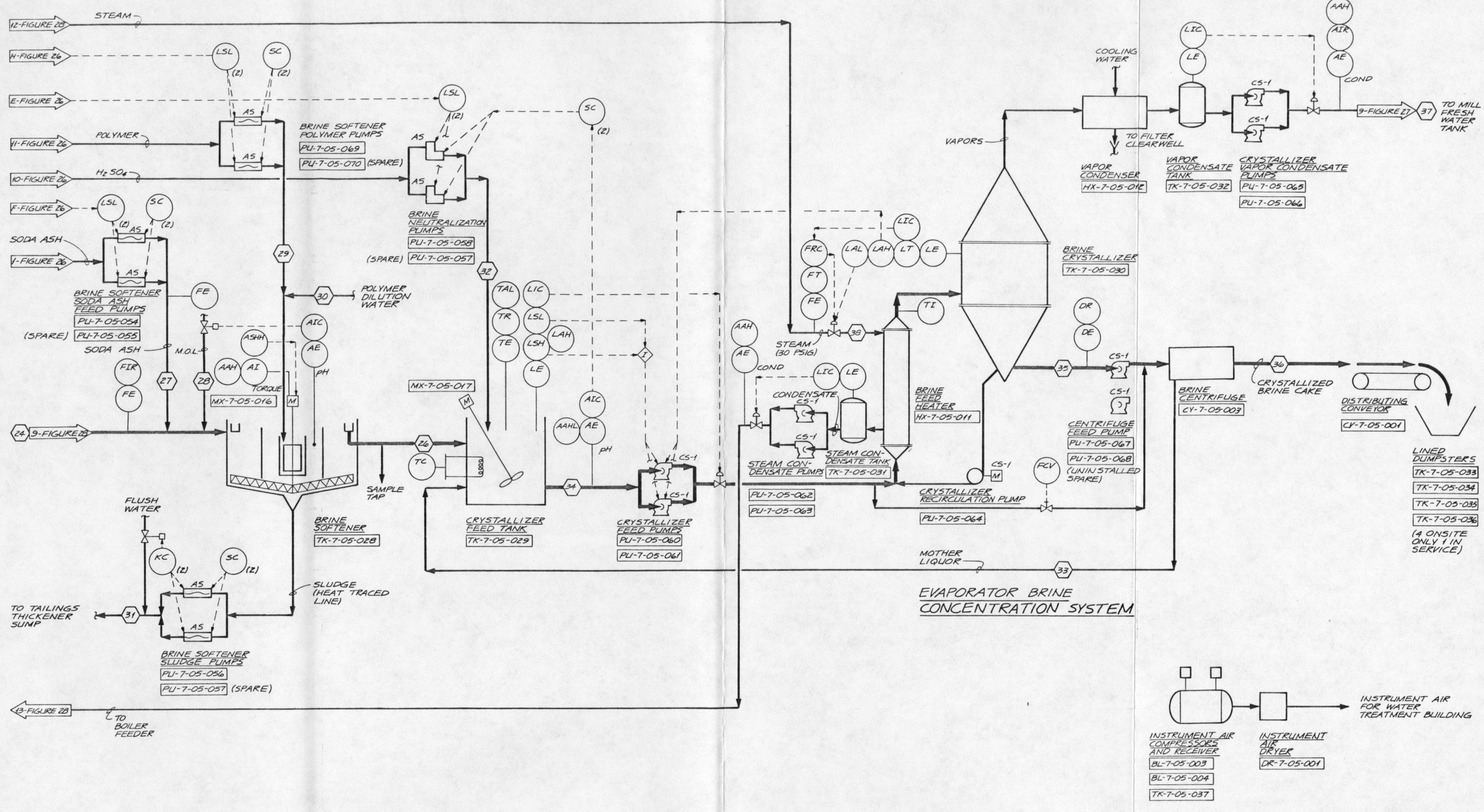


FIGURE 29

STREAM NUMBER	26	27	28	29	30	31	32	33	34	35	36	37	38
TYPICAL FLOW m³/hr (US GPM)	4.0 (17.5)	0.3 (1.3)	0.4 (1.9)	0.001 (0.02)	0.02 (0.08)	1.1 (5.0)	0.22 ℓ/hr (1.4gpd)	1.0 (4.2)	4.9 (21.7)	1.2 (5.5)	0.3 (1.1)	4.0 (17.5)	—
MAX FLOW m³/hr (US GPM)	5.0 (22.0)	0.6 (2.8)	0.7 (3.1)	0.001 (0.03)	0.03 (0.12)	1.1 (5.0)	0.27 ℓ/hr (1.7gpd)	1.2 (5.4)	6.2 (27.4)	1.6 (7.2)	0.4 (1.7)	5.0 (21.8)	—
SOLIDS: TYPICAL FLOW Kg/hr (lbs/d)	553 (29,189)	32.4 (1,712)	21.9 (1,154)	<0.1 (1)	—	158 (8,371)	0.4 (21)	663 (35,030)	1216 (64,220)	1216 (64,220)	553 (29,189)	—	4261 (225,000)
MAX FLOW Kg/hr (lbs/d)	731 (38,620)	48.5 (2,560)	22.5 (1,887)	<0.1 (2)	—	192 (10,155)	0.5 (26)	878 (46,340)	1609 (84,960)	1609 (84,964)	731 (38,620)	—	5303 (280,000)
CONTINUOUS FLOW	X	X	X	X	X		X	X	X	X	X	X	X
INTERMITIENT FLOW						X							

ADDITIONAL STREAM CRITERIA:

26 S.G. = 1.12, TEMP = 85°C
27 10% Na_2CO_3 SOLUTION S.G. = 1.1
28 5% LIME SOLUTION FROM MILL'S M.O.L. FACILITY S.G. = 1.03
29 POLYMER MIXED AT 0.5%, DILUTED 1:5 FOR DOSAGE OF 6 mg/ℓ IN SOFTENER
31 SLUDGE PUMP OPERATING 1/2 TIME ASSUMING AVG SLUDGE FLOWRATE OF 1.8 gpm AND PEAK FLOWRATE OF 2.1gpm; S.G. = 1.25; 20% SUSP SOLIDS
32 93% H_2SO_4 SOLUTION S.G. = 1.03
33 30% DISSOLVED SOLIDS, S.G. = 1.2
35 TEMP = 100°C S.G. = 1.85; 25% SUSPENDED SOLIDS 30% DISSOLVED SOLIDS
36 100% SUSPENDED SOLIDS CAPTURE IN CENTRIFUGE, TEMP = 80°C S.G. = 2.1

NOTES:

1. CRYSTALLIZER SYSTEM SHALL BE SUPPLIED AS DESIGNED BY VENDOR, SYSTEM SHOWN IS TYPICAL

REVISED	DATE	BY	DESCRIPTION

CH2M HILL

EXXON MINERALS COMPANY
CRANDON PROJECT

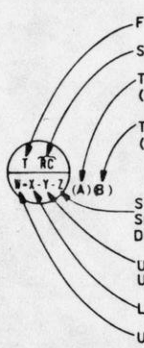
TITLE: PRELIMINARY PROCESS AND INSTRUMENTATION DIAGRAM BRINE CONCENTRATION SYSTEM

SCALE: NONE	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: DLA	DATE	CHECKED BY	DATE
APPROVED BY: JSM	DATE	APPROVED BY	DATE
APPROVED BY: MRH	DATE	EXXON	DATE
DRAWING NO: 051-7-L-025		SHEET ___ OF ___	REVISION NO

G88 5/1981

INSTRUMENTATION & CONTROL LEGEND

INSTRUMENT IDENTIFICATION TAG NUMBERS



INSTRUMENT SOCIETY OF AMERICA TABLE

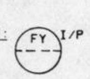
LETTER	FIRST LETTER(S)		SUCCEEDING LETTERS		
	PROCESS OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS(†)		ALARM		
B	BURNER FLAME		USERS CHOICE(†)	USERS CHOICE(†)	USERS CHOICE(†)
C	CONDUCTIVITY			CONTROL	
D	DENSITY (S.G.)	DIFFERENTIAL			
E	VOLTAGE		PRIMARY 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

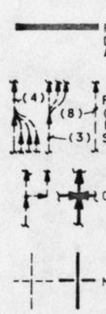
A ANALOG
D DIGITAL
E VOLTAGE
F FREQUENCY
I CURRENT
P PNEUMATIC
PF PULSE FREQUENCY
PD PULSE DURATION

EXAMPLE:



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

LINE LEGEND



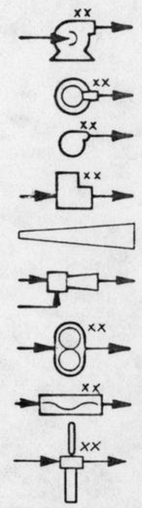
PROCESS (CLOSED CONDUIT, DASHED LINE INDICATES ALTERNATE FLOW STREAM

PARALLELING LINES. (PARENTHETICAL NUMBER INDICATES THE NUMBER OF SIGNALS REPRESENTED)

CONNECTING LINES

NON-CONNECTING LINES

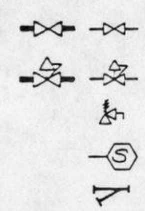
PUMPS & COMPRESSORS



CENTRIFUGAL (DRY PIT) PUMP
CENTRIFUGAL (WET PIT) PUMP
SUBMERSIBLE SUMP PUMP
CHEMICAL FEED PUMP
COMPRESSOR (CENTRIFUGAL) OR BLOWER
INJECTOR
GEAR PUMP OR BLOWER (POSITIVE DISPLACEMENT)
PROGRESSING CAVITY PUMP
TURBINE PUMP

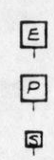
NOTE:
XX = AS ADJUSTABLE SPEED
CS-1 CONSTANT SPEED (SINGLE SPEED)
CS-2 CONSTANT SPEED (TWO SPEED)

GATES & VALVES



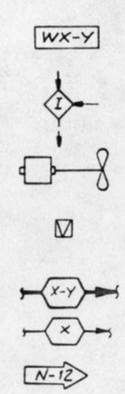
GATE
PRESSURE REGULATOR
PRESSURE RELIEF
SAMPLE POINT
WYE STRAINER

ACTUATORS



ELECTRIC (MOTOR)
PNEUMATIC
SOLENOID

MISCELLANEOUS SYMBOLS



EQUIPMENT TAG (FOR PUMPS ETC.)
INTERLOCK
MIXER
RUPTURE DISK
UNIT PROCESS INTERFACE DESIGNATION
X = SOURCE UNIT PROCESS NUMBER
Y = DISCHARGE STREAM NUMBER
INTRA-UNIT PROCESS INTERFACE DESIGNATION
X = INTERFACE LETTER
SHEET REFERENCE ARROW

NOTE:
EQUIPMENT ITEMS SHOWN BY DASHED LINES ARE NOT INCLUDED IN THIS CONTRACT.

FIGURE 30

REVISED	DATE	BY	DESCRIPTION

CH2M HILL

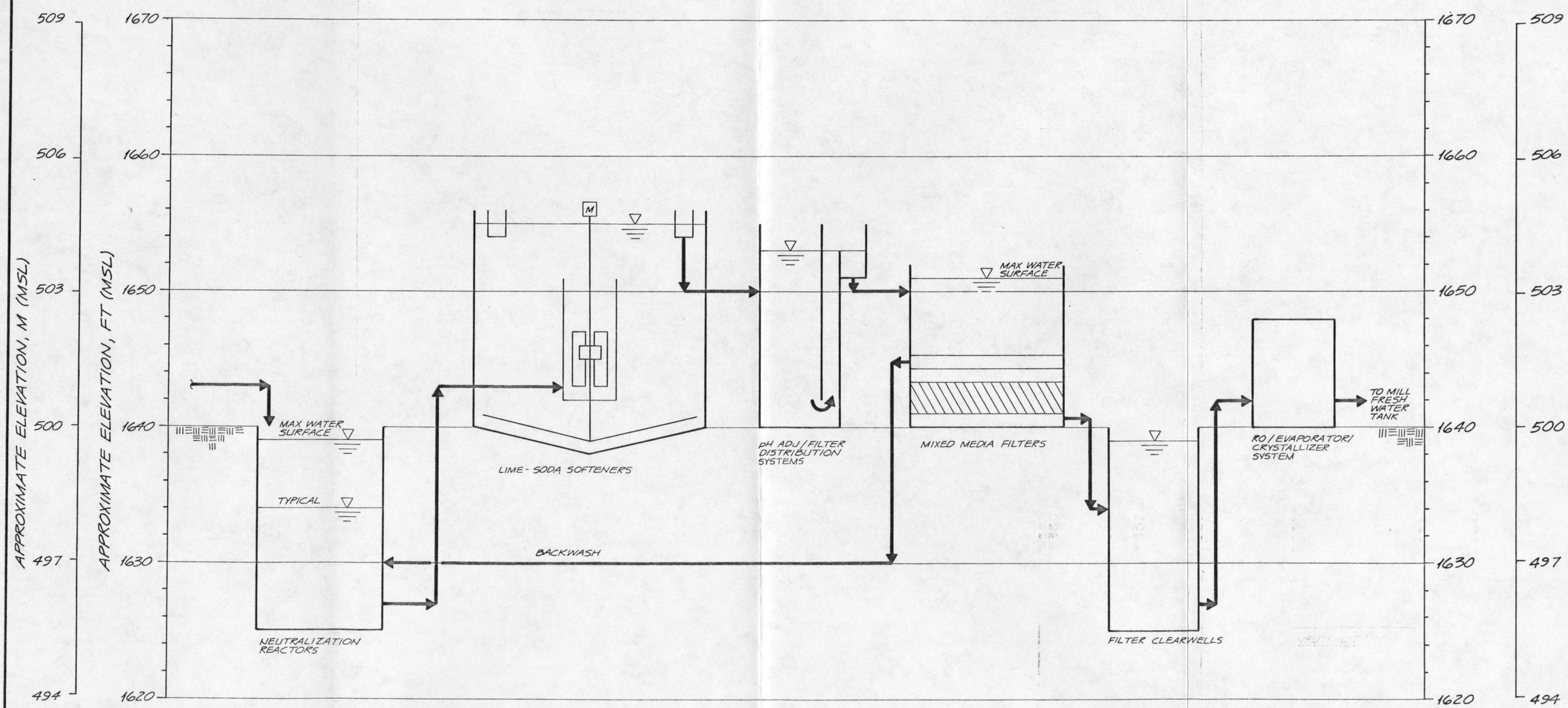
EXXON PROPRIETARY

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE INSTRUMENTATION AND CONTROL LEGEND AND SYMBOLS

SCALE NONE	STATE WISCONSIN		COUNTY FOREST		
DRAWN BY TAG	DATE	CHECKED BY		DATE	
APPROVED BY JSM	DATE	APPROVED BY		DATE	
APPROVED BY MRH	DATE	EXXON		DATE	
DRAWING NO. 051-7-L-026		SHEET ___ OF ___		REVISION NO.	

GBB 5/1981



NOTES:
1. ONLY THE MAIN FLOW STREAMS ARE SHOWN

FIGURE 31

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY HYDRAULIC PROFILE

REVISED	DATE	BY	DESCRIPTION

CH2M HILL

EXXON PROPRIETARY

SCALE NONE	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY OLA	DATE	CHECKED BY		DATE
APPROVED BY JSM	DATE	APPROVED BY		DATE
APPROVED BY MRH	DATE	EXXON		DATE
DRAWING NO 051-7-L-027			SHEET OF	REVISION NO

Neutralization Reactors

The neutralization reactors are designed as complete mix reactors and have been sized based on a hydraulic detention time of 20 minutes at the maximum expected flow rate of contaminated mine water. Additional capacity has also been included to contain one filter backwash for each reactor.

The reactors have been sized to provide an adequate residence time for surge equalization, pH adjustment and oxidation of ferrous iron. The reactors would also serve as a powdered activated carbon contact chamber if organics control becomes necessary. An air diffuser system would be installed to assist in tank mixing and provide oxygen for oxidation reactions.

The two reactors are designed with common wall construction and a sluice gate is provided to permit use of the facility as a single (as opposed to separate) treatment system.

Neutralization Reactor Pumps

The neutralization reactor pumps would lift water from each neutralization reactor to the corresponding reactor clarifier. Three variable speed pumps would be provided, each with a maximum capacity of 381 m^3/hr (1,660 gpm). Under normal operating conditions, two pumps would be operating with one standby. Additional capacity has been included to pump out a filter backwash within 45 minutes.

Lime-Soda Softeners (Reactor Clarifiers)

The carbonate precipitation system would be designed using two 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 two complete clarifier/flocculator mechanisms would be purchased and installed in field erected tanks.

Each softener has been sized to handle the maximum flow rate from the neutralization reactor (381 m^3/hr each). Area requirements for clarification were based on an assumed overflow rate of 2.4 $m^3/hr/m^2$ (1 gpm/ft^2). Each softener would be 14.0 m (46 feet) in diameter. Solids flux to the clarifier section of the softeners would be a conservative 4.3 kg/hr/m^2 (21 lbs/d/ft^2). The hydraulic residence time in the softeners would be approximately 2 hours.

Polymer Mixing and Feed Tanks

The polymer mix and feed tanks were sized to hold a 1-day supply of 0.5 percent polymer solution. Each tank has an operating volume of 15.9m^3 (4,190 gal).

Soda Ash Day Tank

Soda ash would be used for the lime-soda softeners, the brine softener, and for effluent neutralization. The tank was sized to contain a 1-day supply of 10 percent soda ash and would have an operating volume of 87.2m^3 (23,040 gal).

pH Adjustment Tanks/Splitter Boxes

Water would overflow from the softeners to the pH adjustment tanks for neutralization with sulfuric acid. The completely mixed tanks have been sized assuming a minimum hydraulic residence time of 10 minutes.

The neutralized water would then overflow into splitter boxes for distribution to the filtration systems. These units are designed with common wall construction and a sluice gate is provided to permit use of the facility as a single treatment system.

Sulfuric Acid Tank

Sulfuric acid would be used for pH adjustment at the pH adjust tank the reverse osmosis system and the crystallizer feed tank. The sulfuric acid tank has been sized to contain a 5-day supply of H_2SO_4.

Mixed Media Filters

Neutralized water would be gravity filtered in two, parallel mixed media filtration systems consisting of three filter cells each. Each filter system was sized assuming two cells would be on line with one out of service for backwashing. Area requirements were computed assuming a hydraulic loading of 9.8 $m^3/hr/m^2$ (4.0 gpm/ft^2). Each cell would have a filtration area of 17.7 m^2 (190 ft^2)

It was assumed that each filter cell would be backwashed three times per day. The volume of water required for backwashing was computed assuming 5 minutes of 36.6 $m^3/hr/m^2$ (15 gpm/ft^2) bed wash plus 3 minutes of 22.7 m^3/hr (100 gpm) surface wash. Each backwash will require approximately 55.1 m^3 (14,550 gal) of water.

Filter Clearwells

Water from the filtration systems would flow into two filter clearwells. The filter clearwells were sized to contain 1-1/2 filter backwash cycles. The clearwells are designed with common wall construction and a sluice gate has been provided to permit operation of the system as a single treatment facility.

RO Low Pressure Feed Pumps

Filtered water would be pumped to the reverse osmosis system in two stages. The RO low pressure feed pumps (first stage pumps) would take suction from the filter clearwell and pump water through the cartridge filters. The RO booster pumps (second stage pumps) would pump water through the reverse osmosis system.

Three variable speed pumps would be provided for low pressure pumping, each with a capacity of 303 m^3/hr (1,335 gpm). Under normal operating conditions, two pumps would be operating with one standby.

If contaminated mine water does not require further treatment to maintain compliance with WPDES permit limitations, one of these pumps would be used to route treated mine water to the discharge tank or mill freshwater tank.

Although contaminated mine water may not require further treatment, all unit processes have been sized to provide full treatment of this water.

Cartridge Filters

A cartridge filtration system would precede the RO modules and would be located between the RO low pressure and the RO booster pumps.

The filtration system would consist of four cylindrical stainless steel filter housings containing 5 micron cartridge filters. Each filter housing would contain approximately 120 disposable cartridge filters. During normal operation, three filter housings would be on line and one on standby. A rupture disc bypass would be provided on each filter to protect the high pressure booster pumps.

Sodium Hexametaphosphate Tank

The SHMP tank was sized to contain a 2-day supply of 50 percent solution. A 0.4m^3 (100 gal) tank would be provided.

Reverse Osmosis Modules

The reverse osmosis (RO) system would consist of five modules each designed for a maximum capacity of 95.4 m^3/hr (420 gpm). The modules would be arranged with a 4:2:1 taper, and would be operated to recover 80 percent of the feed water as permeate. (With this taper, recoveries of as high as 87.5 percent could be realized if water quality permits.) The remaining 20 percent reject (brine) stream would flow to the RO reject surge tank.

At this level of recovery, the dissolved solids concentration in the reject stream would be below the vendor-recommended solubility limits and should not present any scaling or precipitation problems. In addition, 10 mg/l of sodium hexametaphosphate would be added to the feed water to inhibit scale formation.

The design temperature of the feed water has been assumed to be 5°C (41°F), considerably lower than the optimum temperature for RO of 25°C (77°F). At 5°C, the flow capacity of the membranes would be reduced to approximately 55 percent of that required for a similar system operating at 25°C. The assumed low feed water temperature increased membrane requirements by approximately 45 percent. One possible method to reduce the increased capital expenditures for the RO membranes would be to install a feed preheater system. This alternative was evaluated and rejected because of significant increases in operating cost.

The membranes would be spiral wound membranes rather than the hollow fine fiber. Spiral wound membranes are considered to be less susceptible to fouling by influent particulates. The membranes would be constructed using cellulose acetate.

RO Reject Surge Tank

The RO reject stream (20 percent of the RO feed water flow rate) would flow to the RO reject surge tank. The tank would be 16.5 m (54 feet) in diameter, 9 m (30 feet) high and located adjacent to the eastern wall of the water treatment building. Total capacity of the tank would be 1,894 m^3

(500,000 gal). The tank was sized to hold 24 hours of RO reject water and would be equivalent to having one evaporator operating at 50 percent capacity for four days. This tank siting criteria was necessitated to permit intermittent operation of the VCE's during the early mine development period when water flow rates could be low. (VCE's have limited turn-down capability and frequent startup-shutdown is not practical.)

Reverse Osmosis Cleaning System

The RO cleaning system would be provided by the reverse osmosis system supplier. Each supplier has a different cleaning procedure, therefore, it is not possible at this time to establish cleaning system criteria.

Evaporator Feed Pumps

RO reject water would be pumped from the RO reject tank to the evaporator by variable speed centrifugal pumps. Three pumps would be provided, each with a maximum capacity of 47.7 m^3/hr (210 gpm). Under normal operating conditions, one pump would feed each evaporator train. One pump would serve as standby.

Evaporator System

The RO reject water would be pumped from the RO reject tank to the evaporator system. The evaporator system would then recover approximately 96 percent of the water in the reject stream for mill reuse. The evaporator residue or brine stream would be pumped to the brine concentration system for further treatment.

It has been assumed that the entire evaporator system would 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, would include all equipment and controls shown in Figure 28. All components included in the evaporator system would be sized by the vendor who designs and supplies the equipment.

The evaporator system would be composed of two parallel trains, each containing a vapor compression falling film type evaporator sized to treat 50 percent of the maximum flow rate of the RO reject stream or 47.7 m^3 (210 gpm). System suppliers have estimated that a maximum of 45.6 m^3/hr (201 gpm) of distillate and 2 m^3 (9 gpm) of brine would be produced from each train. These values represent their best estimates and could vary depending on actual feed water chemistry. Distillate water quality has been estimated at 10 mg/l TDS. Brine water quality would be approximately 19 percent total solids and 17 percent dissolved solids.

The system would also include two boilers; one to provide steam for the barometric condenser, the other for evaporator startup. The startup boiler would be sized to provide steam for either evaporator startup or for the crystallizer's brine heater.

Brine Drying System

The solids concentration in the evaporator's recirculating slurry must be controlled to prevent tube fouling. To control the solids concentration, a portion of the recirculating stream would be purged from the system as an evaporator brine. The brine stream would flow to the brine concentration system for final treatment and disposal.

The first step in the brine drying system would consist of a brine softener for suspended solids removal and precipitation of calcium salts, SiO_2 and metal hydroxides. The overflow from the softener would flow to the crystallizer feed tank for neutralization with sulfuric acid and then pumped to the crystallizer. The forced circulation crystallizer evaporator would crystallize the brine into a 55 percent solids slurry consisting primarily of anhydrous sodium sulfate and sodium thiosulfate. (Direct crystallization is not practical in the VCE because it is a falling film evaporator.) A screen bowl centrifuge would dewater the slurry to a 95 percent solids cake suitable for landfilling. Upon cooling, any water remaining in the cake would combine with sodium sulfate to form Glauber's salt ($Na_2SO_4 \cdot 10H_2O$). The resulting product would have no free water. Depending on quality, the cake may also be suitable for reuse within the paper industry since it will be almost entirely sodium sulfate.

It has been assumed that the crystallizer system would be purchased and installed as a turnkey system. The system, with the exception of the brine softener, reagent feed pumps, crystallizer feed tank, crystallizer feed pumps, conveyor and dumpster would be provided by the crystallizer supplier. All components included in the crystallizer system would be sized by the vendor who designs and supplies the equipment.

Brine Softener

The brine softener would consist of a solids contact clarifier similar to those specified for the lime-soda softening system. Area requirements for clarification have been computed assuming a conservative 8.2 kg/hr/m^2 (40 lbs/d/ft^2). The softener would be 4.6 m (15 feet) in diameter with side water depth of 2.4 m (8 ft). Because of the high temperature (100°C), an insulated, covered tank would be required.

This unit process represents a realistic application of lime-soda softening, but, to the knowledge of the project team, has not been applied to high temperature, high TDS water. It is recommended that the sizing criteria be checked with bench or pilot testing at a similar evaporator installation before final design is completed. Facilities for doing these studies are readily available.

Crystallizer Feed Tank

Brine from the softener would flow by gravity to the crystallizer feed tank. The tank would function as a neutralization, surge equalization and storage vessel for the crystallizer system.

The tank would be a completely mixed, insulated rectangular steel tank with a capacity of 61.3 m^3 (16,200 gallons). It has been sized assuming a hydraulic detention time of 12 hours at the maximum overflow rate from the brine softener.

Crystallizer System

After evaluating several alternative processes for drying the evaporator brine, a forced circulation crystallizer was selected. (See Appendix F)

The crystallizer system would be purchased and installed as a turnkey system. The system would be sized to crystallize a maximum of 731 kg/hr (38,620 lbs/d) of solids. All components in the system would be sized by the vendor who designs and supplies the equipment.

Uncontaminated Mine Water Surge Tank

The uncontaminated mine water surge tank provides flow equalization and residence time for pH adjustment, if required. It will be a one-million gallon tank. A mixer will be installed to insure homogeneity of tank contents and to aid in dissolving any required milk-of-lime additions.

Discharge Tank

The discharge tank is primarily a place where the various water streams can be mixed and monitored prior to release to the environment. It has been sized to provide one-hour residence time at a projected maximum flow rate of 3,104 gpm.

Electrical Distribution

Total connected motor power in the water treatment building, including spares, will be approximately 4,215 kW (5,650 hp). Normal operating power during mature summer operation will be approximately 2,740 kW (3,670 hp).

LAYOUT AND ARRANGEMENT

Figure 32 illustrates an overall site plan of the mill, showing the location of the treatment facility in relation to the remainder of the surface facilities.

Figures 33 and 34 show a conceptual plan of the lower and upper floor of the treatment building and sections taken through the building.

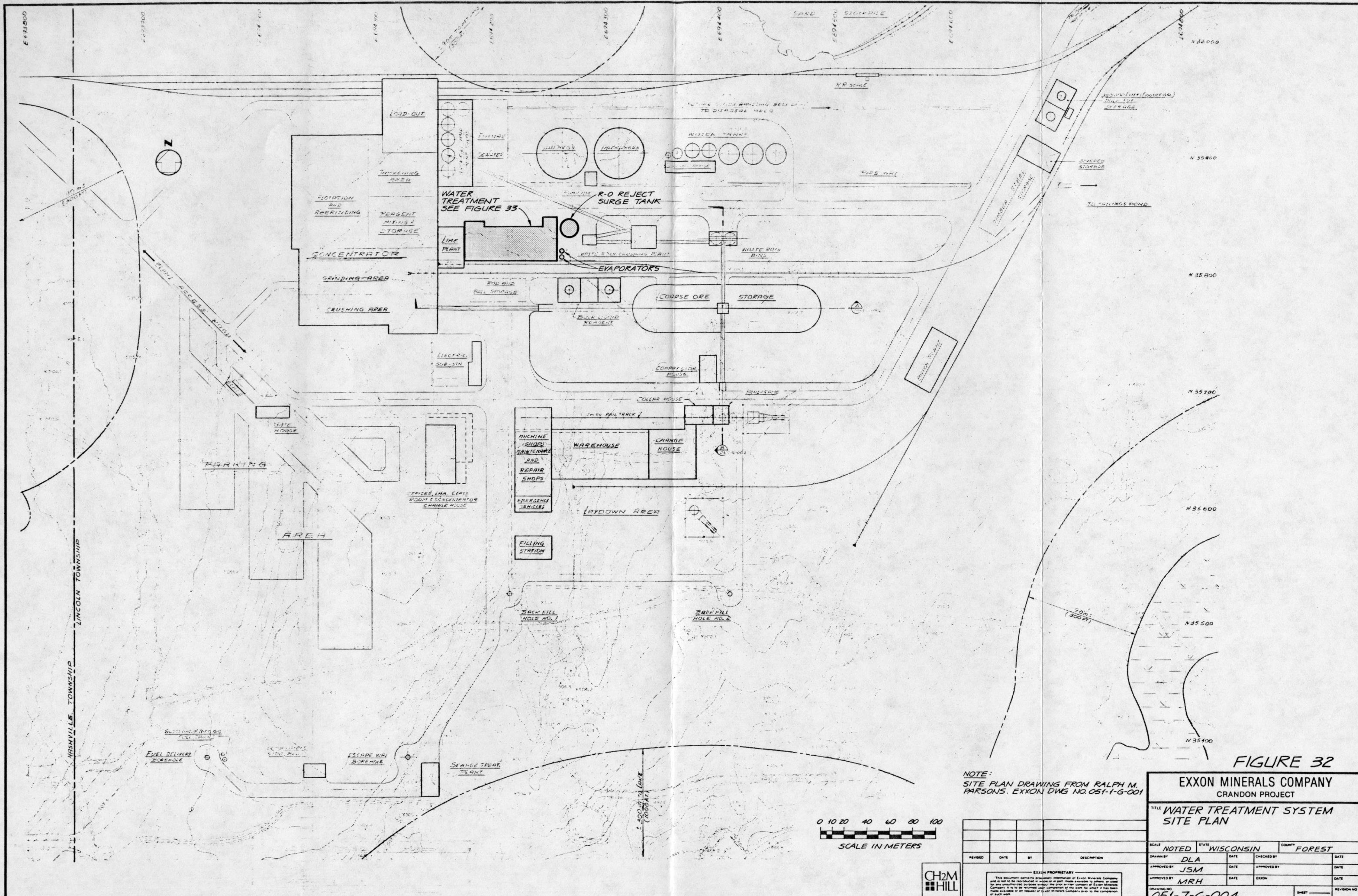
The water treatment building will be a standard metal frame building with insulated walls and roof. Overall building area is approximately 2,575 m^2 (27,700 ft^2).

A majority of the pumps and high-pressure control valves will be located in the lower floor to minimize noise in the upper floor. A workshop and spare parts storage area will be provided in the lower floor of the building.

The upper floor of the building will be equipped with bridge cranes for maintenance/repairs on large items of equipment.

All water treatment system equipment shown on the P&ID's except as noted below, will be located within the water treatment building:

- The water treatment feed tank and treatment system feed pumps will be located approximately 230 m


LOAD-OUT
FLOTATION AND REGRINDING
REAGENT MIXING & STORAGE
WATER TREATMENT SEE FIGURE 33
R-O REJECT SURGE TANK
LIME PLANT
CONCENTRATOR
EVAPORATORS
GRINDING AREA
CRUSHING AREA
THICKENERS
WATER TANKS
R.R. SCALE
SAND STORAGE
COVERED STORAGE
TO TAILINGS POND
WASTE ROCK BINS
COARSE ORE STORAGE
ROD AND BALL STORAGE
BULK LIQUID REAGENT
ELECTRIC SUB-STN
COMPRESSOR HOUSE
COLLAR HOUSE
HEADFRAME
MACHINE SHOPS MAINTENANCE AND REPAIR SHOPS
EMERGENCY VEHICLES
WAREHOUSE
CHANGE HOUSE
LAYDOWN AREA
FILLING STATION
PARKING AREA
GATE HOUSE
OFFICES, LAB, CERTS ROOM & CONCENTRATOR CHANGE HOUSE
BACKFILL HOLE NO. 1
BACKFILL HOLE NO. 2
FUEL DELIVERY BOREHOLE
ESCAPE WAY BOREHOLE
SEWAGE TREAT. PLANT
NASHVILLE TOWNSHIP
LINCOLN TOWNSHIP
N 36 000
N 35 900
N 35 800
N 35 700
N 35 600
N 35 500
N 35 400
0 10 20 40 60 80 100
SCALE IN METERS
NOTE:
SITE PLAN DRAWING FROM RALPH M. PARSONS. EXXON DWG NO. 051-1-G-001
FIGURE 32
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE WATER TREATMENT SYSTEM SITE PLAN
SCALE NOTED
STATE WISCONSIN
COUNTY FOREST
DRAWN BY DLA
APPROVED BY JSM
APPROVED BY MRH
DRAWING NO 051-7-G-004
REVISED
DATE
BY
DESCRIPTION
EXXON PROPRIETARY
CH2M HILL
GBB 5/1981

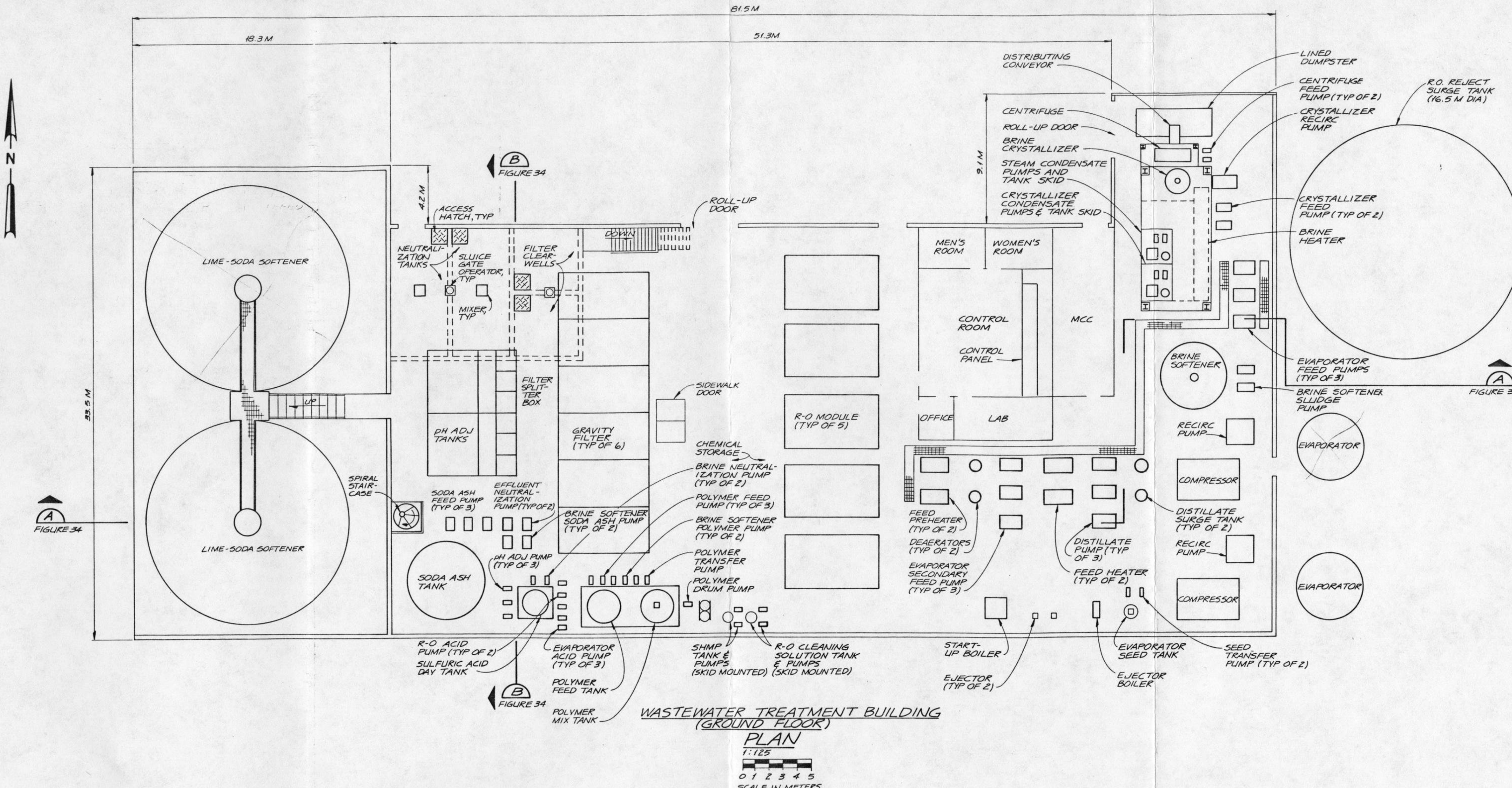


FIGURE 33

EXXON MINERALS COMPANY CRANDON PROJECT	
TITLE: PRELIMINARY LAYOUT OF WATER TREATMENT BUILDING GROUND FLOOR	
SCALE: 1:125	STATE: WISCONSIN / COUNTY: FOREST
DRAWN BY: DLA	DATE / CHECKED BY / DATE
APPROVED BY: MRH	DATE / APPROVED BY / DATE
APPROVED BY	DATE / EXXON / DATE
DRAWING NO: 051-7-G-005	SHEET / OF / REVISION NO

REVISED	DATE	BY	DESCRIPTION

CH2M HILL

EXXON PROPRIETARY

G88 5/1981

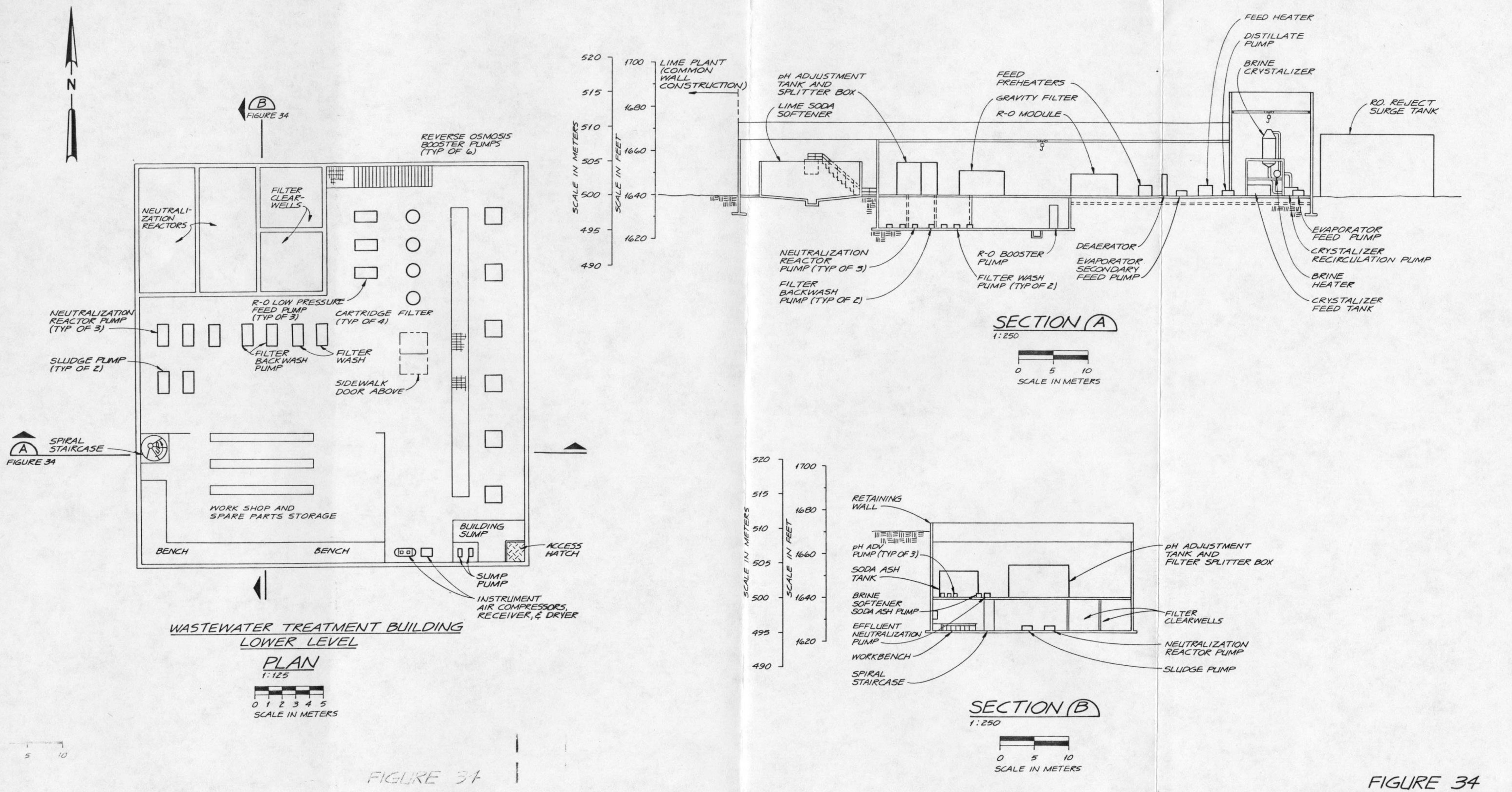


FIGURE 34

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE PRELIMINARY LAYOUT OF WATER TREATMENT BUILDING LOWER LEVEL

SCALE 1:125 STATE WISCONSIN COUNTY FOREST
DRAWN BY DLA
APPROVED BY JSM
APPROVED BY MRH
DRAWING NO 051-7-G-006

CH2M HILL

EXXON PROPRIETARY

G88 5/1961

(754 ft) north and east of the treatment building along with several other large storage tanks.

- o The carbonate precipitation clarifiers will be located immediately adjacent to and west of the treatment building in an enclosed, but unheated section of the building.

- o The vapor compression evaporators will be located immediately adjacent to and east of the treatment building.

- o The RO reject tank, discharge tank, and uncontaminated mine water surge tank will be located immediately adjacent to and east of the treatment building.

The water treatment building should be heated to a minimum of 10 to 15°C (50 to 60°F) year round. Air conditioning would not be required during summer months. The buildings control room, office, laboratory, and workshop should have additional heating for operator comfort. Air conditioning should be considered in these areas during final design of the building.

The building should be provided with toilet facilities, hot and cold running water, and safety showers. A laboratory area has been included in the layout and should 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. Toilet drains will be routed to the sanitary wastewater treatment facility.

CONTROL PHILOSOPHY

The water treatment system is designed to operate with only minimal operator attention.

A central control panel has been provided in the control room for monitoring system performance. It is assumed that key instrument readouts and alarms will be displayed in the main mill control room as well.

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

Influent Flow

Contaminated mine water will be pumped directly to the Contaminated Mine Water Surge Tank from the mine. Reclaim water will be routed to the treatment system at a controlled flow rate from the Reclaim Tank. In the event of high water level in the Contaminated Mine Water Surge Tank, mine water will be diverted to the tailings thickener overflow sump. High water level in the feed tank will sound an alarm. Uncontaminated mine water will be pumped directly to a separate surge tank.

Uncontaminated Mine Water Surge Tank

The uncontaminated mine water surge tank will be operated at variable level. Effluent from the tank will be normally routed to the Discharge Tank and will be monitored continuously for pH, conductivity, and turbidity. If necessary, lime can be added to this tank to provide neutralization. If direct discharge of this water would cause noncompliance with effluent limitations, it would be routed to the mill fresh water tank.

Neutralization Reactors

The neutralization tanks will be constant level tanks except during periods of filter backwashing. Level elements in the tanks will control the speed of the neutralization reactor pumps. High water level elements will activate alarms to warn of impending tank overflow. High-high level switches will shut off respective flow to the water treatment system.

As part of the two-stage pH adjustment systems, lime will be added to the reactors. Lime addition will be controlled with an in-line pH element at the discharge of the neutralization reactor pumps.

Lime-Soda Softening

Lime and soda ash will be added to each softener feed stream. During the mine development period, when influent calcium concentrations may be low, soda ash addition should not be required. Polymer will be added to the centerwell of the reactor clarifiers. Milk of lime addition will be controlled by a pH element in the softener feed well with a feedback override from a pH element at the softener discharge. The drive motor for each clarifier mechanism will equipped with a torque indicator, high torque alarm and high torque shut-off switch.

Soda Ash Feed Pumps

Soda ash is added to each softener feed stream by a variable speed pump. Pump speed is manually set by the operator. The pumps will be interlocked with the low level switch in the Soda Ash Day Tank. An in-line calcium analyzer will be provided in the softener discharge line to assist the operator in optimizing soda ash feed rates.

Polymer Feed Pumps

Polymer is added to each softener by a variable speed pump. Pump speed is manually set by the operator. The pumps will be interlocked with the polymer feed tank low level switch.

Softening Sludge Pumps

Variable speed pumps will pump sludge from the soda softeners to the tailings thickener sump. The pumps will operate on a timed cycle. Speed control will be manually set by the operator.

Polymer Feed and Mix Tanks

The 0.5-percent polymer solution will be prepared in the mix tank by an automatic batch sequencing system. Polymer will then be transferred to the feed tank. Low and high level alarms will be provided.

Sulfuric Acid Feed Pumps

The sulfuric acid feed pumps are variable speed positive displacement pumps. The pumps will be controlled by a signal from a pH element in the pH adjustment tank. The pumps will be interlocked with the low level switch at the H_2SO_4 Day Tank.

Filter Splitter Boxes

Flow to the mixed media filters will be distributed by six overflow weirs. Automatic valves will be used to isolate filters during backwashing. Water level in the splitter boxes will be monitored. High water level will be alarmed to warn operator of impending tank overflow. High level switches will turn off the appropriate neutralization reactor pumps.

Mixed Media Filters

The backwashing cycle for each filter cell will be initiated either by high water level in the filter or on a timed cycle. High water level will activate a control valve at the splitter box to shut off the flow to a filter cell. A low level switch in the filter control system will prevent filter backwashing.

The RO low pressure and booster pumps will be protected by an interlock with a low level switch in the filter clearwell. If the RO pumps fail, a high level switch will turn off neutralization reactor pumps.

SHMP Feed Pumps

The sodium hexametaphosphate (SHMP) feed pump is ratio controlled from the RO system feed flow.

RO Acid Feed Pumps

The RO acid feed pumps are variable speed positive displacement pumps. Pump speed will be controlled by a signal from an in-line pH element in the RO feed line. The pumps will be interlocked with the low level switch at the H_2SO_4 Day Tank.

Reverse Osmosis Cartridge Filters

The cartridge filter holders contain disposable filter elements. Pressure differential alarms for each housing will be provided to signal operator that the filters need to be replaced.

Reverse Osmosis System

To protect the RO system, the conductivity, temperature, and turbidity of the feed water 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 panel. 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 is controlled by the ratio of the reject and feed stream pressures. High conductivity in the reject or product water streams will be alarmed.

Effluent Neutralization Pumps

RO permeate, evaporator distillate and crystallizer distillate will be blended in an in-line mixer. Soda ash will be added at the in-line mixer to adjust the pH. The neutralization pumps will be controlled by an in-line pH element downstream of the mixer. The pumps will be interlocked with a low level switch at the Soda Ash Day Tank.

High conductivity in the final effluent will sound an alarm indicating system malfunction. Effluent pH and turbidity will also be measured continuously.

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 originate at a vendor supplied evaporator control panel.

Evaporator Feed Pumps

The evaporator feed pumps will be variable speed pumps and will be controlled by the operator from the evaporator control panel. The pumps will be interlocked with a level switch in the RO reject surge tank.

Evaporator Acid Feed Pumps

If necessary, H_2SO_4 can be added to the evaporator feed water. The evaporator feed pumps are controlled by in-line pH elements. The pumps are interlocked with a low level switch in the Sulfuric Acid Day Tank.

Evaporator Secondary Feed Pumps

Degasified RO reject water will be pumped to the evaporator with a single speed centrifugal pump. A level controller in the deaerator sump will control the pump discharge flow rate.

Evaporator

The feed into the evaporator is controlled by a level controller in the deaerator sump. High or low water levels in the evaporator and deaerator will be alarmed. The brine discharge from the evaporator is controlled by a level controller in the evaporator sump.

Distillate Pumps

Evaporator condensate is pumped from the Distillate Surge Tank to the Mill Fresh Water Tank (or bypass to the Discharge Tank) with a single speed centrifugal pump. A level controller in the Distillate Surge Tank controls the pump discharge flow rate.

Feed Heaters

Temperature control of the evaporator feed stream is necessary for optimum deaerator operation. The evaporator feed temperature is controlled by regulating the flow of distillate through the feed heater.

Brine Softener

Lime and soda ash will be added to the evaporator brine stream. Polymer will be added at the center well of the reactor clarifier. A pH element in the softener will control milk of lime addition to the feed stream. The pH in the brine softener will be 11.0. The drive motor for the clarifier mechanism will be equipped with a torque indicator and high torque shut off switch.

Brine Soda Ash Feed Pumps

Soda ash is added to the evaporator brine stream by a variable speed progressing cavity pump. Pump speed is manually set by the operator. Each pump will be interlocked with the low level switch in the Soda Ash Day Tank.

Brine Softener Sludge Pumps

Carbonate sludge from the brine softener will be pumped to the tailings thickener sump. The pumps will be variable speed progressing cavity type operated on a timer control. Sludge line flushing water will also be timer controlled.

Brine Neutralization Pumps

The softened evaporator brine will be neutralized with H_2SO_4 in the crystallizer feed tank. The brine neutralization pumps will be variable speed positive displacement pumps. A pH element in the crystallizer feed tank will control the pumps. Each pump will be interclocked with the low level switch in the Sulfuric Acid Day Tank.

Brine System Polymer Pumps

Polymer will be added to the centerwell of the brine softener to minimize turbidity in the overflow. Variable speed progressing cavity pumps will be used to dose the polymer. Pump speed will be manually set by the operator. Each pump will be interlocked with the low level switch in the Polymer Feed Tank.

Brine Concentration System

The brine concentration system will be a forced circulation crystallizing evaporator with solids dewatering (see Appendix H). The system, including all instrumentation and controls will be supplied as a package system. All control functions will be designed by the manufacturer and will originate at a vendor supplied crystallizer control panel.

Crystallizer Feed Pumps

The crystallizer feed pumps will pump the softened evaporator brine to the crystallizer. The pumps will be single speed centrifugal pumps taking suction from the crystallizer feed tank. A level controller in the tank will control the pump discharge flow rate. The pumps will be interlocked with level switches in the feed tank and in the brine crystallizer.

Brine Feed Heater

The recirculating brine is heated with steam from the evaporator startup boiler in a two pass heat exchanger.

The steam flow rate will be ratio controlled by the liquid level in the crystallizer body. The steam control valve will be interlocked with a low level switch in the crystallizer.

Crystallizer Vapor Condensate Pumps

Water vapor from the crystallizer will be condensed and mixed with evaporator distillate and RO permeate. The condensate will be pumped by a single speed centrifugal pump. A level controller in the vapor condensate tank will control the pump discharge. Condensate conductivity will be recorded and alarmed.

Discharge Tank

Effluent from the Discharge Tank will be monitored continuously for pH, conductivity, and turbidity. Flow proportional composite samples will be collected at the discharge of the tank for daily monitoring.

EQUIPMENT LISTS AND DUTY SPECIFICATIONS

Tables 14 through 18 illustrate sizing and duty specifications for major pumps, tanks, mixers, heat exchange units and other miscellaneous items of equipment required for the water treatment system.

CHEMICAL CONSUMPTION RATES

Annual chemical consumption rates have been computed for the reagents to be used in the treatment system. The annual rates are based on 360 operating days per year, and are summarized in Table 19.

OPERATIONS

The water treatment plant is designed to operate 24 hours per day, essentially year-round.

Instrumentation has been provided to permit essentially unattended operation of the system. Although the overall treatment process is relatively complex, the system should require little minute-to-minute operator attention.

Elements which are critical to operation of the system have, for the most part, been provided with a standby unit to minimize system downtime for repairs.

EFFLUENT MONITORING

Treated effluent from the treatment system will be measured continuously for conductivity pH, and turbidity. A flow proportional composite sampler has been provided to obtain daily samples for effluent monitoring as may be required by the WPDES permit for the Crandon Project. Since no permit has been drawn up, no attempt has been made to assess what testing may be required by the permit.

Table 14
PUMP SCHEDULE

Equipment No.	Service/Name	Size	Specification	Material	Motor Power	
PU-7-05-001 -002 -003	Neutralization Reactor Pump	98.0 m^3/hr to 381 m^3/hr (427 gpm to 1,660 gpm) @ 89.5 kPa (13.0 psig)	Frame mounted end suction centrifugal; variable speed.	Bronze fitted cast iron.	(typ. for multiple units) 18.6kW	(25 hp)
PU-7-05-004 -005	Softening Sludge Pump	23 m^3/hr (100 gpm) @ 103.4 kPa (15 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	3.73 kW	(5.0 hp)
PU-7-05-006 -007 -008	Soda Ash Feed Pump	2.8 m^3/hr to 3.4 m^3/hr (12.3 gpm to 14.8 gpm) @ 59.7 kPa (10 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	1.49 kW	(2.0 hp)
PU-7-05-009	Polymer Drum Pump	1.14 m^3/hr (5.0 gpm) @ 59.7 kPa (10 psig)	Positive displacement; progressing cavity.	Chrome plated 316 SS rotor with viton stator.	0.75 kW	(1.0 hp)
PU-7-05-010	Polymer Transfer Pump	11.4 m^3/hr (50 gpm) @ 119.4 kPa (20 psig)	Positive displacement; progressing cavity.	Chrome plated 316 SS rotor with viton stator.	2.24 kW	(3.0 hp)
PU-7-05-011 -012 -013	Polymer Feed Pump	0.25 m^3/hr to 0.35 m^3/hr (1.1 gpm to 1.45 gpm) @ 89.5 kPa (13.0 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	0.37 kW	(0.5 hp)
PU-7-05-014 -015 -071	H_2SO_4 Feed Pump	0.03 m^3/hr (0.12 gpm) @ 59.7 kPa (10.0 psig)	Positive displacement; diaphragm pump.	Alumina ceramic ball valves, alloy-20 seats, viton process and hydraulic diatubes.	0.37 kW	(0.5 hp)
PU-7-05-016 -017	Filter Surface Wash Pump	23 m^3/hr (100 gpm) @ 687 kPa (100 psig)	Frame mounted end suction centrifugal; single speed.	Bronze fitted cast iron.	7.46 kW	(10 hp)
PU-7-05-018 -019	Filter Backwash Pump	647 m^3/hr (2,850 gpm) @ 119.4 kPa (20.0 psig)	Vertical frame mounted with suction elbow; single speed.	Bronze fitted cast iron.	37.3 kW	(50 hp)
PU-7-05-020 -021 -022	RO Low Pressure Feed Pump	98.0 m^3/hr to 303.2 m^3/hr (427 gpm to 1,335 gpm) @ 344.5 kPa (50.0 psig)	Frame mounted end suction centrifugal; variable speed.	Bronze fitted cast iron.	37.3 kW	(50 hp)
PU-7-05-023 -024	Building Sump Pump	38.6 m^3/hr (170 gpm) @ 447.9 kPa (30 psig)	Vertical wet-pit centrifugal; single speed.	Bronze fitted cast iron	11.2 kW	(15 hp)
PU-7-05-025 -026	SHMP Feed Pump	0.004 m^3/hr (0.019 gpm) @ 344.5 kPa (50.0 psig)	Positive displacement; diaphragm pump.	Manufacturer's standard.	0.37 kW	(0.5 hp)
PU-7-05-027 -028	R-O Acid Feed Pump	0.01 m^3/hr (0.04 gpm) @ 344.5 kPa (50.0 psig)	Positive displacement; diaphragm pump.	Alumina ceramic ball valves, alloy-20 seats, viton process and hydraulic diatubes.	0.37 kW	(0.5 hp)
PU-7-05-029	Reverse Osmosis Cleaning Solution Transfer Pump	- - - - - - PER RO	MANUFACTURER'S	SPECIFICATIONS	- - - - - -	
PU-7-05-030 -031 -032 -033 -034 -035	Reverse Osmosis Booster Pump	95.4 m^3/hr (420 gpm) @ 3.445 kPa (500 psig)	Vertical can-type; turbine pump.	Bronze fitted fabricated steel suction and discharge head.	131 kW	(175 hp)
PU-7-05-036 -037 -038	Evaporator Feed Pump	39.7 m^3/hr to 47.7 m^3/hr (175 gpm to 210 gpm) @ 344.5 kPa (50 psig)	Frame mounted end-suction centrifugal; variable speed.	Bronze fitted cast iron.	5.60 kW	(7.5 hp)

Table 14
(continued)

Equipment No.	Service/Name	Size	Specification	Material	Motor Power	
PU-7-05-039 -040 -041	Evaporator Acid Feed Pump	0.01 m³/hr (0.04 gpm) @ 344.5 kPa (50.0 psig)	Positive displacement; diaphragm pump.	Alumina ceramic ball valves, alloy-20 seats, viton process and hydraulic diatubes.	0.37 kW	(0.5 hp)
PU-7-05-042 -043 -044	Evaporator Secondary Feed Pump (Spare)	------- PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS -------				
PU-7-05-045 -046 -047	Distillate Pump	------- PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS -------				
PU-7-05-048 -049	Evaporator Recirculation Pump	------- PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS -------				
PU-7-05-050 -051	Seed Tank Transfer Pump	------- PER EVAPORATOR SYSTEM MANUFACTURER'S SPECIFICATIONS -------				
PU-7-05-052 -053	Effluent Neutralization Pump	0.004 m³/hr (0.02 gpm) @ 344.5 kPa (50.0 psig)	Positive displacement; diaphragm pump.	Manufacturer's standard.	0.37 kW	(0.5 hp)
PU-7-05-054 -055	Brine Softener Soda-Ash Feed Pump	0.4 m³/hr to 0.7 m³/hr (1.9 gpm to 3.0 gpm) @ 137.8 kPa (20.0 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	0.56 kW	(0.75 hp)
PU-7-05-056 -057	Brine Softener Sludge Pump	1.1 m³/hr (5.0 gpm) @ 206.7 kPa (30 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	0.75 kW	(1.0 hp)
PU-7-05-058 -059	Brine Neutralization Pump	0.22 l/hr to 0.27 l/hr (1.4 gpd to 1.7 gpd) @ 68.9 kPa (10 psig)	Positive displacement; diaphragm pump; variable speed.	Alumina ceramic ball valves, alloy-20 seats, viton process and hydraulic diatubes.	0.37 kW	(0.5 hp)
PU-7-05-060 -061	Crystallizer Feed Pump	5.5 m³/hr to 6.7 m³/hr (24.3 gpm to 29.7 gpm) @ 206.7 kPa (30.0 psig)	Frame mounted end-suction centrifugal; constant speed.	Bronze fitted cast iron.	2.24 kW	(3.0 hp)
PU-7-05-062 -063	Steam Condensate Pump	------ PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS ------				
PU-7-05-064	Crystallizer Recirculation Pump	------ PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS ------				
PU-7-05-065 -066	Crystallizer Vapor Condensate Pump	------ PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS ------				
PU-7-05-067 -068	Centrifuge Feed Pump	------ PER CRYSTALLIZER SYSTEM MANUFACTURER'S SPECIFICATIONS ------				
PU-7-05-069 -070	Brine Softener Polymer Pump	0.001 m³/hr (0.03 gpm) @ 137.8 kPa (20.0 psig)	Positive displacement; progressing cavity; variable speed.	Chrome plated 316 SS rotor with viton stator.	0.37 kW	(0.5 hp)

Table 15
TANK SCHEDULE

Equipment No.	Service/Name	Size/Operating Volume	Specification/Material
TK-7-05-001	Neutralization Reactor	4.1 m x 9.0 m x 4.6 m (13.3 ft x 29.5 ft x 15 ft) Vol = 156 m^3 (41,250 gal) each compartment	Below grade square concrete tank; coal-tar epoxy coated.
TK-7-05-002 -003	Lime-Soda Softener	14.0 m dia; 4.6 m S.W.D. (46 ft dia; 15 ft S.W.D.)	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.
TK-7-05-004	Soda Ash Day Tank	5.5 m dia; 4 m height (18 ft dia; 13 ft height) Vol = 87.4 m^3 (23,100 gal)	Cylindrical fiberglass reinforced plastic tank; open top.
TK-7-05-005	Polymer Mix Tank	2.7 m dia; 3.05 m height (9 ft dia; 10 ft height) Vol = 15.9 m^3 (4,200 gal)	Cylindrical fiberglass reinforced plastic tank; open top with mixer support bridge.
TK-7-05-006	Polymer Feed Tank	2.7 m dia; 3.05 m height (9 ft dia; 10 ft height) Vol = 15.9 m^3 (4,200 gal)	Cylindrical fiberglass reinforced plastic tank; open top.
TK-7-05-007	H_2SO_4 Day Tank	1.8 m dia; 2.1 m height (6 ft dia; 7 ft height) Vol = 3.8 m^3 (1,000 gal)	Cylindrical carbon steel tank; closed top.
TK-7-05-008	pH Adjust Tank	4.3 m x 4.9 m x 4.3 m (14 ft x 16 ft x 14 ft) Vol = 63.2 m^3 (16,700 gal) each compartment	Rectangular concrete tank with overflow weir and mixer support bridge; tank discharge to filter splitter box; coal tar epoxy coated.
TK-7-05-009	Splitter Box	- -	Concrete splitter box for filter feed; coal tar epoxy coated.
TK-7-05-010 -011 -012 -013 -014 -040	Mixed Media Filter	3.05 m x 5.8 m x 3.7 m (10 ft x 19 ft x 12 ft) Filter media depth = 762 mm (30 in)	Concrete basin with underdrains, surface wash backwashing, piping collection troughs and flow control valves; mixed media filter with 3 layers: anthracite coal, silica sand, and garnet; coal tar epoxy coated concrete; package includes automatic backwashing controller.
TK-7-05-015	Filter Clearwell	4.5 m x 4.4 m x 4.6 m (14.7 ft x 14.3 ft x 15 ft) Vol = 98.8 m^3 (22,000 gal) each compartment	Below grade rectangular concrete tank; coal tar epoxy coated.
TK-7-05-016	Building Sump	30 m x 5.0 m x 3.05 m (9.8 ft x 16.4 ft x 10 ft) Vol = 45.4 m^3 (12,000 gal)	Below grade rectangular concrete tank; coal tar epoxy coated.
TK-7-05-017	SHMP Mix Tank	0.9 m dia; 0.9 m height (3 ft dia; 3 ft height) Vol = 0.38 m^3 (100 gal)	Cylindrical fiberglass reinforced plastic tank; open top with mixer support.
TK-7-05-018	Cleaning Solution Tank	- - - - - - - - - - - - - - P E R R O M A N U F A C T U R E R ' S	S P E C I F I C A T I O N - - - - - - - - - - - - - -
TK-7-05-019	Reverse Osmosis Reject Surge Tank	16.5 m dia; 9 m height (54 ft dia; 30 ft height) Vol = 1,894 m^3 (500,000 gal)	Carbon steel tank, concrete pad, erected in place; coal tar epoxy lined.
TK-7-05-020 -021	Deaerator	- - - - - - - - - - P E R E V A P O R A T O R M A N U F A C T U R E R ' S	S P E C I F I C A T I O N - - - - - - - - - -
TK-7-05-022 -023	Distillate Surge Tank	- - - - - - - - - - P E R E V A P O R A T O R M A N U F A C T U R E R ' S	S P E C I F I C A T I O N - - - - - - - - - -
TK-7-05-024 -025	Seed Tank	- - - - - - - - - - P E R E V A P O R A T O R M A N U F A C T U R E R ' S	S P E C I F I C A T I O N - - - - - - - - - -
TK-7-05-026 -027	Shear Tank	- - - - - - - - - - P E R E V A P O R A T O R M A N U F A C T U R E R ' S	S P E C I F I C A T I O N - - - - - - - - - -
TK-7-05-028	Brine Softener	4.6 m dia; 2.4 m S.W.D. (15 ft dia; 8 ft S.W.D.)	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.

Table 15
(Continued)

Equipment No.	Service/Name	Size/Operating Volume	Specification/Material
TK-7-05-029	Crystallizer Feed Tank	7.3 m x 3.7 m x 2.6 m (24 ft x 12 ft x 8.5 ft) Vol = 61.3 m^3 (16,200 gal)	Rectangular steel tank; insulated and coated with coal tar epoxy; covered top with provisions for mixer support.
TK-7-05-030	Brine Crystallizer	Per Manufacturer's specification.	Forced circulation type crystallizer to crystallize maximum of 5.1 m^3/hr of softened evaporator brine; solids production of 955 kg/hr.
TK-7-05-031	Steam Condensate Tank	Per Manufacturer's specification.	As supplied with brine crystallizer.
TK-7-05-032	Vapor Condensate Tank	Per Manufacturer's specification.	As supplied with brine crystallizer.
TK-7-05-033 -034 -035 -036	Lined Dumpster	5.5 m x 2.2 m x 0.5 m (18 ft x 7.3 ft x 3.5 m) Vol = 13 m^3 (17 yd^3)	Rectangular steel dumpster with plastic lining; compatible with rolloff truck hoist system; hinged top and rear door.
TK-7-05-037	Instrument Air Receiver Tank	0.9 m dia; 1.8 m height (3 ft dia; 6 ft height) Vol = 1.1 m^3 (300 gal)	Cylindrical steel pressure tank; as supplied with instrument air compressor package.
TK-7-05-038	Uncontaminated Mine Water Surge Tank	19.9 m dia; 12.2 m height (65 ft dia; 40 ft height) Vol = 3,790 m^3 (1,000,000 gal)	Carbon steel tank, concrete pad, erected in place; coal tar epoxy lined.
TK-7-05-089	Discharge Tank	11.0 m dia; 7.6 m height (36 ft dia; 25 ft height) Vol = 705 m^3 (186,000 gal)	Carbon steel tank, concrete pad, erected in place; coal tar epoxy lined.

Table 16
MIXER SCHEDULE

Equipment No.	Service/Name	Size/Type	Specification	Shaft and Prop. Mat.	Motor Power
MX-7-05-001 -018	Neutralization Reactor Mixer	56 rpm; 1,676 mm (66 in.) dia. impeller.	Single impeller with stabilizing fins, axial flow; top entering.	316 S.S. shaft and impeller.	5.6 kW (7.5 hp)
MX-7-05-002 -003	Lime Soda 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.	2.2 kW (3 hp)
MX-7-05-004	Polymer Mix Tank Mixer	233 rpm; portable mixer.	Dual propeller with stabilizing ring; top entering.	304 S.S. shaft and impeller.	1.5 kW (2 hp)
MX-7-05-005 -019	pH Adjustment Tank Mixer	56 rpm; 1,473 mm (58 in.) dia. impeller.	Single impeller with stabilizing fins axial flow; top entering.	316 S.S. shaft and impeller.	3.7 kW (5 hp)
MX-7-05-006	SHMP Mix Tank Mixer	1,750 rpm; 96 mm (3.8 in) dia. impeller.	Direct drive single impeller axial flow; clamp mount.	316 S.S. shaft and impeller.	0.25 kW (0.3 hp)
MX-7-05-007	In-Line Mixer	406 mm (16 in.) dia. in-line static mixer.	Dual turbulent in-line mixer.	Fiberglass reinforced plastic.	-------
MX-7-05-008	Cleaning Solution Tank Mixer	-------------- PER RO MANUFACTURER'S SPECIFICATION -------------			
MX-7-05-009	In-Line Mixer	406 mm (16 in.) dia. in-line	Dual turbulent in-line mixer.	Fiberglass reinforced plastic.	-------
MX-7-05-012 -013	Seed Tank Mixer	---------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------			
MX-7-05-010 -011	Evaporator Feed In-Line Mixers	152 mm (6 in.) dia. in-line static mixer.	Dual turbulent in-line mixer.	316 S.S.	-------
MX-7-05-014 -015	Shear Tank Mixer	---------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION ----------			
MX-7-05-016	Brine Softener Mixer	Turbine agitator; variable speed 3.3 to 13.3 rpm.	Variable speed dirve with reducers; 4 to 1 variation; as supplied with softener mechanism.	Manufacturer's Standard.	2.2 kW (3 hp)
MX-7-05-017	Crystallizer Feed Tank Mixer	56 rpm; 1,473 mm (58 in.) dia. impeller.	Single impeller with stabilizing fins, axial flow; top entering.	316 S.S. shaft and impeller.	7.5 kW (10 hp)
MX-7-05-020	Uncontaminated Mine Water Surge Tank Mixer	56 rpm; 3,050 mm (120 in.) dia. impeller	Dual impeller with stabilizing fins, axial flow top entering	316 S.S. shaft and impeller.	75 kW (100 hp)

Table 17
HEAT EXCHANGER EQUIPMENT SCHEDULE

Equipment No.	Service/Name	Size/Material	Specification
HX-7-05-001 -002	Feed Preheater	Per evaporator manufacturer's specification.	47.7 m^3/hr maximum flow capacity; plate and frame type heat exchanger; titanium plates capable of working pressures of 1,033 kPa (150 psig).
HX-7-05-003 -004	Barometric Condenser	Per evaporator manufacturer's specification.	Barometric condenser utilizing feed water as the cooling medium; condenser will provide vacuum for the feed deaerator.
HX-7-05-005 -006	Feed Heater	Per evaporator manufacturer's specification.	47.7 m^3/hr maximum flow capacity; plate and frame type heat exchanger; titanium plates capable of working pressures of 1,033 kPa (150 psig).
HX-7-05-007 -008	Evaporators No. 1 and 2	- - - - - - - - - - - - - - - -	47.7 m^3/hr 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. One manufacturer of VCE systems estimates that total installed horsepower of the VCE system will be 4,200 hp.
HX-7-05-009	Start-Up Boiler	Per evaporator and crystallizer manufacturer's specification.	Boiler will be used for evaporator start-up or crystallizer feed heater; natural gas fired boiler with rated capacity of 13,800 lbs/hr; operating capacity 5,000 kg/hr (11,000 lbs/hr).
HX-7-05-010	Ejector Boiler	Per manufacturer's specification.	Boiler will be used with ejectors; natural gas fired boiler with rated capacity of 1,136 kg/hr (2,500 lbs/hr); operating capacity 909 kg/hr (2,000 lbs/hr).
HX-7-05-011	Brine Feed Heater	Per crystallizer manufacturer's specification.	Double pass heat exchanger utilizing steam energy and compatible with forced circulation crystallizer.
HX-7-05-012	Steam Condenser	Per crystallizer manufacturer's specification.	Spiral heat exchanger suitable for condensing steam from the brine feed heater.

Table 18
MISCELLANEOUS EQUIPMENT SCHEDULE

Equipment No.	Service/Name	Size/Material	Specification
SM-7-05-001 -002 -003	Composite Sampler	Manufacturer's standard.	Automatic sampler with refrigerated storage compartments; sampler provided with all necessary instrumentation for time proportional and flow proportional sampling.
BL-7-05-001 -002	Compressor	Per evaporator manufacturer's specification.	Single stage centrifugal type vapor compressor with electric drive motor and adjustable inlet guide vanes.
CY-7-05-001 -002	Hydrocyclone	-------- PER EVAPORATOR MANUFACTURER'S SPECIFICATION --------	
CY-7-05-003	Brine Centrifuge	Per crystallizer manufacturer's specification.	Screen bowl centrifuge for dewatering 100°C brine crystallizer slurry to 95 percent solids; cake discharge to distributing conveyor.
FL-7-05-001 -002 -003 -004	Reverse Osmosis Cartridge Prefilter	Disposable 5 micron cartridge filters capable of filtering 157 m^3/hr (693 gpm)	Feed water stream to reverse osmosis units filtered as required by R-O supplier; filters shall be Fulflo, Filterite, or equivalent; cartrige core and filter casing 316 stainless steel.
FL-7-05-005	Reverse Osmosis Cleaning Solution Cartridge Filter	------------ PER R-O MANUFACTURER'S SPECIFICATION ------------	
FL-7-05-006 -007 -008 -009 -010	Reverse Osmosis Module	5 modules each rated for 20 percent of design 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 87.5 percent water recovery at 5°C.
CV-7-05-001	Distributing Conveyor	Capacity to convey 731 kg/hr (38,620 lbs/d) of 80°C, 95 percent solids cake; materials per manufac-standard.	The conveyor should be able to receive and automatically distribute dewatered crystallized brine from the centrifuge discharge to a lined dumpster; the conveyor should swivel about a support base to evenly distribute the centrifuge cake into the dumpster.
BL-7-05-003 -004	Instrument Air Compressor	3.7 kW (5 hp) compressor.	------------------------------------
CV-7-05-002 -003	Bridge Crane	-------------------	Bridge supplied should have the capacity to lift and move 1.15 times the weight of any equipment located in the water treatment building.

Table 19

WATER TREATMENT SYSTEM
ESTIMATED ANNUAL TYPICAL REAGENT CONSUMPTION

Reagent	Metric Tons/Year*	Tons/Year*
Lime (CaO)	312	343
Soda Ash (Na_2CO_3)	2,811	3,092
Sulfuric Acid (H_2SO_4)	415	457
Sodium Hexameta Phosphate (SHMP)	35	38
Polymer	21	23

*Assumes RO/VCE treatment of all contaminated water.

GLT63/14

Effluent quality from the treatment system should be extremely stable, with little, if any, measurable fluctuations from day to day. Some slight seasonal variations can be expected and some variations from year-to-year can be expected as the mine development proceeds.

SLUDGE PRODUCTION AND DISPOSAL

Sludge will be generated at three unit operations within the water treatment system.

The Carbonate Precipitation system will generate a calcium-carbonate, metal-hydroxide sludge which will be pumped to the tailings pond for ultimate disposal.

The VCE brine softening system will generate a calcium salt, SiO_2 and metal hydroxide sludge which will be pumped to the Tailings Pond for ultimate disposal.

Dewatered brine from the crystallizing evaporator/centrifuge will be essentially pure sodium sulfate and sodium thiosulfate.

When the dewatered brine is conveyed to the dumpster, it will be very warm and will still contain 5 to 10 percent water by weight. As the brine cools, it will solidify into a mixture of sodium thiosulfate ($Na_2S_2O_3$), anhydrous sodium sulfate (Na_2SO_4) and Glauber's salt ($Na_2SO_4 \cdot 10\ H_2O$). No "free" water will remain. The solidified brine product will be transported to a chemically secure landfill for disposal.

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.) Depending on thiosulfate concentrations in the brine, there is a possibility that an oxidant would have to be added to the crystallizer feed tank (to oxidize thiosulfate to sulfate and thereby increase the purity of sodium sulfate in the final product.) It is recommended that the system be designed and permits acquired based on landfilling the dried brine. 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.

Table 20 illustrates projected volumes of the three types of sludges to be generated at the water treatment plant.

SPECIAL SPARE PARTS

Most critical pieces of equipment in the water treatment system have been provided with installed standby units. From a cost and operational standpoint, however, it is not practical to provide standby units for all items of equipment. (One example of such units are the compressors for the Vapor Compression Evaporators, which are 2,000 hp units and extremely expensive. VCE manufacturers indicate that standby units are not recommended.)

The following special spare parts, over and above normally recommended "routine" spare parts inventories, are recommended to ensure that downtime can be kept to a minimum following problems with major items of water treatment plant equipment.

- One set of membranes for one RO module
- 10 percent of the number of tubes for one VCE
- One spare rotating element for one VCE vapor compressor
- One spare brine recirculation pump for one VCE
- One complete spare set of tubes for the crystallizing evaporator heater
- One spare hydrocyclone
- One spare set of tubes for crystallizer vapor condenser

Metallurgy in all processing units will be selected to minimize corrosion problems in the system.

CONTINGENCY PLANS

Every attempt has been made to design maximum flexibility into the water treatment system. The following paragraphs illustrate contingency plans which are available to counter unanticipated operating problems, if they were to develop:

Table 20

WATER TREATMENT SYSTEM
ESTIMATED TYPICAL SLUDGE PRODUCTION

	Dry Solids[5]		Sludge Volume[5]	
	MT	Ton	m^3	acre-feet
Daily Sludge Production				
Carbonate Precipitation[1]	13.4	14.8	218	0.18
Brine Softening[2]	3.8	4.2	9.8	0.008
Dried Brine[3]	13.3	14.6	6.3	0.005
Annual Sludge Production				
Carbonate Precipitation[1]	4,824	5,327	78,480	64.8
Brine Softening[2]	1,367	1,512	3,528	2.9
Dried Brine[3]	4,789	5,258	2,268	1.8
Sludge Produced over the Life of the Crandon Project[4]				
Carbonate Precipitation[1]	144,700	159,800	2,354,000	1,944
Brine Softening[2]	41,000	45,400	106,000	87
Dried Brine[3]	143,700	157,800	68,040	53

[1]Based on the assumption that carbonate sludge will settle to only 6 percent in the clarifier.

[2]Based on the assumption that the gypsum content of this sludge will allow settling to 20 percent.

[3]Based on vendor estimate of a 95 percent cake concentration and a density of 127 lb/ft^3. Weight includes Glauber salt waters of hydration.

[4]Based on an assumed operating life of 30 years.

[5]Assumes RO/VCE treatment of all contaminated water.

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- o If the concentration of organic compounds are higher than anticipated in the influent to the treatment system, powered activated carbon can be added to the Neutralization Tanks. Adsorbed organics and carbon would be settled out in the Carbonate Precipitation systems and be pumped to the tailings pond with the carbonate sludge.

- o If the concentration of Fe^{+2} is higher than expected in contaminated mine seepage water, the air sparging system in the neutralization reactors will be turned on to oxidize Fe^{+2} to Fe^{+3}, which would then be removed in the Carbonate Precipitation systems.

- o If contaminated mine seepage water were to contain colloidal solids which are not removed by the proposed system, several contingency options are available:

  - increase polymer dosage
  - add additional coagulants (one example might be the addition of ferric salts if SiO_2 is a problem)
  - install smaller mesh cartridge filters upstream from the RO units

- o If foaming problems occur in the VCE's, it would be possible to add foam suppressing reagents to the RO reject tank, which supplies feedstock to the VCE's.

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Section XX
CONSTRUCTION SCHEDULE

Based on current projections, Exxon anticipates that construction of the mine shaft will begin early in 1986. During the first 18 months of actual construction, water discharged from the mine will be essentially uncontaminated groundwater and will not require treatment beyond simple sedimentation. Exxon projects that contaminated mine seepage water will be first encountered in late 1987, requiring that at least a portion of the water treatment system be installed and operational by that time.

Figure 23 (Section XVII) illustrates that by the third year of mine development, the required capacity of the water treatment system will be approximately 75 to 80 percent of the capacity required during full production of the mill.

Since essentially the entire system may be required within 15 to 20 months after startup, it does not at this time appear cost-effective to construct the system in increments. Based on this preliminary assessment, the schedule below is based on the assumption that the entire water treatment system will be designed and constructed to be operational by October 1987. The schedule will be refined and opportunities for capital deferral will be identified during subsequent engineering studies.

To achieve the desired startup date, the following design/construction schedule is suggested:

Activity	Date
Begin Final Design and Preparation of Bid Packages for Major Equipment Systems (RO, VCE, Crystallizer, etc.)	August 1, 1985
Let Bid Packages for Major Systems (RO, VCE, Crystallizer, etc.)	November 15, 1985
Award Contracts for Purchase of Major Systems	January 1, 1986
Complete Final Design of Water Treatment System	March 1, 1986

Award Contract for Construction . . . . May 1, 1986

Complete Construction, Begin
Startup and Troubleshooting of
System Operation . . . . September 1, 1987

System Fully Operational. . . . . October 1, 1987

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Section XXI
MANPOWER REQUIREMENTS

Four full-time operators will be required to provide round-the-clock operator attention, 7 days per week. 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 will require 3 to 4 weeks of training prior to plant startup to receive instruction in operation of the system. Table 21 illustrates routine operator duties which should be assigned to the operations staff.

It is assumed that one of the mill superintendents will provide supervision of the treatment plant staff and that effluent monitoring and testing will be coordinated through the mill laboratory staff. No O&M costs have been included for superintendence.

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.

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Table 21

WATER TREATMENT SYSTEM OPERATOR DUTIES

Item	Frequency	Remarks
Mix Polymer	Daily	Maximum 1 day supply 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	
Calibrate Ca Element	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.
Preventative Maintenance and Lubrication	Daily	
Clean-up/Housekeeping	Daily	
Inspect Filter Media for Fouling	Daily	
Dried Brine Disposal	Daily	

Section XXII
CAPITAL COST ESTIMATES

ASSUMPTIONS

Capital cost estimates were prepared for the preferred water treatment system and for the sanitary wastewater treatment system. During preparation of the estimates, the following assumptions were made:

General

1. The cost estimates are based on July 1, 1982, prices. The estimates were prepared with an estimated accuracy of ±20 percent with a 50 percent probability of a 10 percent or greater overrun.

2. Equipment costs are FOB Crandon (2 percent added to quotes if not quoted FOB Crandon).

3. Average wage rate for all crafts was assumed to be $15.74/hr.

4. A payroll burden of 36 percent was assumed.

5. Vendor quotes were marked up by 15 percent to cover vendor bias and special construction features.

6. Neat-line concrete quantities were marked up by 18 percent to allow for growth and wastage.

7. No contractor insurance is included in these cost estimates.

8. A 0.8 labor productivity factor was used in estimating labor.

9. This estimate does not include any construction contingency. It is assumed that contingency will be added by Exxon.

10. Cost data has been obtained from the following sources:

    a) Vendor quotations.

    b) "Means 1982" - Building Construction Cost Data, 1982 by R.J. Means Co.

c) "Richardson" - Process Plant Construction Estimating Standards, by Richardson Engineering Services, Inc.

d) Marshall Evaluation Service, Marshall and Swift Publication Co.

11. A 10-percent allowance for engineering, legal, and administrative costs was added to the total estimated cost, excluding the VCE and crystallizing Evaporator systems, for which turnkey quotations were obtained. A 5-percent allowance for these two systems was added.

12. In general, the cost estimate for the water treatment system includes only construction within the battery limits of the water treatment plant.

13. No metallurgical studies were included in this project. All piping between unit operations was priced as carbon steel (or plastic piping for some reagent systems). VCE and crystallizer metallurgy (and, therefore, costs) are based on vendor recommendations.

Building

1. The building cost estimate is based on a pre-engineered steel building with insulation, heating, lighting, a small, simple lab/office area, and few doors. It has been assumed that the south wall of the building will be a retaining wall (by Exxon - no costs included). It has further been assumed that the west wall of the enclosure around the softeners will consist of the wall of the lime preparation building (by Exxon - no costs included). The cost for a steel frame building with block and brick walls and concrete roof would be at least twice the cost developed and used in this report.

Mechanical

1. The cost estimates do not include any allowance for reagent piping or utility piping to the water treatment building. It has been assumed that other estimates will cover the cost of piping to and from the building.

2. Influent and effluent piping to and from the building is not included in the estimate.

3. No costs are included for reagent bulk storage and/or mixing equipment.

4. Sanitary effluent piping outside the treatment building was not included in the estimates.

Electrical

1. Electrical and Instrumentation and Control (I&C) costs were calculated based on percentage of total facility costs. The percentages used are based on CH2M HILL records of actual construction costs of similar water treatment facilities.

2. Electrical cost "percentages" are based on the assumption that power will be supplied to the building MCC's at the appropriate voltage. Electrical costs do not include transformers and/or feeder cables to the buildings.

Sanitary Treatment System

1. Collection piping for sanitary wastewater is not included in this cost estimate.

2. Since the exact locations of the septic tank and absorption fields have not been defined, an arbitrary assumption was made that 1,000 feet of force main will be required between the two locations. Four-foot burial in unpaved areas was assumed.

3. The cost estimate for the absorption field was based on construction of two square absorption fields, each 2,995 m^2 (0.74 ac). No costs are included for construction of standby fields.

CAPITAL COST ESTIMATES

Appendix G contains detailed breakdowns of the cost estimates prepared for the two treatment systems. The cost estimates are summarized as follows:

System	Estimated Capital Cost
PREFERRED WATER TREATMENT SYSTEM	
General	$ 184,000
Site Work	8,380
Concrete	193,840
Building	913,830
Pumps	389,160
Tanks	1,170,510
Mixers	174,925
RO System	2,740,200
VCE	6,376,000
Crystallizer and Boilers	1,284,000
Mechanical	490,430
Electrical and Instrumentation	2,092,000
Add for Labor Productivity	104,700
Total Direct Cost	$16,120,000
Indirect Costs	574,000
Sales Tax	593,000
Builder's Fee	1,257,000
Engineering	1,409,000
TOTAL ESTIMATED COST	$19,953,000
SANITARY WASTEWATER TREATMENT SYSTEM	
Total Direct Cost	$ 146,200
Indirect Costs	34,400
Sales Tax	4,900
Builder's Fee	18,000
Engineering	30,500
TOTAL ESTIMATED COST	$ 234,000

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Section XXIII
OPERATING AND MAINTENANCE COST ESTIMATES

ASSUMPTIONS

Operating and maintenance cost estimates were prepared for the preferred water treatment system and for the sanitary wastewater treatment system. During preparation of the estimates, the following assumptions were made:

1. Labor costs for plant operators are assumed to be \$33,464 per man-year, including all fringe benefits.

2. Electrical costs are assumed at 3.9¢ per kilowatt-hour.

3. Chemical consumptions are based on Mature-Summer operation of the mill. Reagent costs are based either on vendor quotations or chemical costs provided by Exxon.

   Chemical costs used in these estimates are as follows:

Chemical	Estimated Cost
Lime (CaO)	\$76.00/ton
Polymer	\$2.50/lb
H_2SO_4 (93%)	\$70.00/ton
Scale Inhibitor	\$0.8/lb
Na_2CO_3 (98%)	\$159.00/ton
Natural Gas	$\$3.75/10^6$ BTU

4. Annual maintenance costs are assumed at 10 percent of identifiable equipment cost.

5. Operating labor in the reagent preparation/MOL preparation areas are not included in this estimate.

6. Estimated O&M costs are based on 360 days/year, 24 hours per day operation of the water treatment system.

7. A 6 mg/l polymer dosage has been assumed.

8. Annual O&M costs are stated in mid-1982 costs.

9. A boiler efficiency of 80 percent has been assumed.

10. VCE electrical requirement has been assumed to be 87.2 kWh/1,000 gal of feed.

11. RO membrane replacement cost has been assumed to be \$0.18/1,000 gal of feed.

12. Operating motor power has been assumed to be 90 percent of connected motor power.

OPERATING AND MAINTENANCE COST ESTIMATES

Estimated annual operating and maintenance costs for the two systems is summarized as follows:

Preferred Water Treatment System

Item	Estimated Annual Cost
Reagents	
CaO	$ 26,000
Na_2CO_3	492,000
H_2SO_4	32,000
Scale Inhibitor	61,000
Polymer	115,000
Electricity	966,000
Natural Gas	478,000
RO Membrane Replacement	163,000
Operating Labor (4)	134,000
Maintenance	941,000
Laboratory Analysis	75,000
Miscellaneous	27,000
TOTAL ESTIMATED ANNUAL O&M COST	$3,510,000

Sanitary Wastewater Treatment System

Item	Estimated Annual Cost
Operating Labor	$ 10,000
Maintenance	4,500
Electrical	100
Sludge Disposal	400
Miscellaneous	4,000
TOTAL ESTIMATED ANNUAL O&M COST	$ 19,000

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GLOSSARY OF TERMS USED IN REPORT

BATEA	- EPA defined "best available treatment economically achievable
BPCTCA	- EPA defined "best practicable control technology currently available"
Backfill Drainage Water	- Water which drains from backfilled sands
Bench Testing	- Testing that is performed using laboratory scale testing apparatus
Blowdown	- The volume of water removed from a recycle water circuit.
BOD	- Biochemical Oxygen Demand
COD	- Chemical Oxidation Demand
Concentrates	- The valuable minerals or products obtained from the ore processing operation
Concentrator	- That portion of the surface facilities where ore is separated into concentrates and reject materials
DNR	- Wisconsin Department of Natural Resources
Effect Matrix	- A computer subroutine describing the "effect" a unit process has on a number of constituents as water passes through the unit process
EPA	- U.S. Environmental Protection Agency
Fines	- Fine crushed ore particles which are generated in the mill crushing operation, normally routed to the Tailings Pond
Freeboard	- The vertical distance between the water surface and top of a containment structure
Flotation	- The ore concentration process to be employed at the Crandon Mill
gpm	- Gallons per minute
Ion	- An electrically charged molecule or atom
Grout	- A pumpable slurry of cement or other binding agent forced into a crevice to seal the crevice.

Link	- A computer representation of process water flow stream
m^3/hr	- Cubic meters per hour
MTPD	- Metric Tons Per Day, equal to 2,205 pounds per day
Massive Ore	- A rock containing greater than 50 percent sulfide minerals
Mill	- See concentrator
Mine Seepage	- Water which seeps into the mine from surrounding areas
Node	- A computer representation of a unit process
Ore	- A mineral or minerals of sufficient quality and quantity which may be mined for profit
Orebody	- Generally a solid and fairly continuous mass of ore
Pilot Testing	- Testing that is performed using small scale testing apparatus
Reagents	- Chemicals added to enhance the performance of a unit operation
Sands	- Coarse rock particles which are generated in the mill crushing operation, normally used to backfill the mine
Sludge	- Sediments or residue generated in the treatment of water
Stringer Ore	- A rock containing 2 to 50 percent sulfide minerals
Stope	- A segment of the orebody which has been or is being mined
Tailings	- see Fines
TGD	- Thousands of gallons per day
TSS	- Total Suspended Solids

TSS_A and TSS_N - In development of the water use model, it was necessary to track two "classifications" of suspended solids. TSS_A describes solids formed as precipitates (i.e., metal hydroxides, metal sulfides, calcium sulfate, calcium carbonate, etc.) in treatment processes. TSS_N describes solids present in the water from mining and milling operations (fines, sands,etc.). Total suspended solids in any stream is the sum of TSS_A and TSS_N.

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