Appendix C

Wastewater Treatment System and Estimated Effluent Quality to be Discharged to the Treated Water Infiltration System

(from Section 6 and Appendix G of Application sent to MDEQ)

1. Basis of Design for Proposed Wastewater Treatment System

1.1 Treatment Method Overview

A wastewater treatment system will be provided for the collection, treatment, and discharge of wastewaters generated during development, operation, and closure of the Eagle Project mine and ancillary facilities.

During construction of the mine site (prior to the generation of contact water requiring treatment), the collection and treatment facilities will include drainage ditches and non-contact water infiltration basin (NCWIB) Nos. 3 through 6 for collection and infiltration of construction runoff.

During mine development and operations, mine water, temporary development rock storage area (TDRSA) water and storm water runoff from the main operations area will be collected, treated, and discharged to groundwater by way of the treated water infiltration system (TWIS). Storm water runoff from the main operations area will be routed, by way of runoff ditches, to contact water basin (CWB) No. 1 and No. 2. Mine water will be collected in mine sumps and will be pumped to CWB No. 1 and No. 2. TDRSA water will be pumped to CWBs No. 1 and No. 2. These basins will provide wastewater storage and equalization capacity. Wastewater will be pumped from these basins to the waste water treatment plant (WWTP).

As the mine is being closed, mine drainage water will continue to be pumped until all salvageable equipment has been removed and closure operations have been completed. Surface water runoff from the main operations area will continue to be routed to the CWBs until all contact materials have been removed from the mine site. The WWTP and TWIS will continue to operate for as long as required in accordance with the permitted mining plan.

The WWTP will treat wastewater collected and stored in the CWBs and will be designed to produce a treated effluent which will meet the effluent limitations for discharge to groundwater by way of the TWIS. The WWTP will include the following general processes:

- Wastewater storage.
- Main wastewater treatment.
- Concentrate reduction.
- Sludge handling.
- Evaporation/crystallization.

An overview of these treatment processes is provided below. Detailed descriptions of these processes are provided in Section 1.5.1 through 1.5.5. Process flow diagrams for the WWTP are provided in Figures 1-1 through 1-3.

The main wastewater treatment process will include a base treatment system and an advanced treatment system. The base treatment system will include pH adjustment, metals precipitation/sedimentation, and filtration to substantially reduce the mass of dissolved solids present in the wastewater. The advanced treatment system will include a reverse osmosis system and pH adjustment systems as a polishing step to further reduce the concentrations of dissolved solids in the base treatment system effluent. The discharge streams from the main wastewater treatment process will include treated water, metals precipitation sludge, and reverse osmosis concentrate. The treated water will be suitable for discharge to groundwater by way of TWIS. The metals precipitation sludge will be routed to the sludge handling process for dewatering. The reverse osmosis concentrate will be routed to the concentrate reduction process (CRP) for treatment and volume reduction.

The CRP will be provided to maximize the water recovery and correspondingly minimize the volume of concentrate treated by the evaporator/crystallizer process. The CRP will treat the concentrate from the main wastewater treatment process reverse osmosis system. The treatment processes proposed for this system include breakpoint chlorination, softening/metals precipitation, microfiltration, pH adjustment, reverse osmosis, and ion exchange. The discharge streams from the CRP will include treated water, microfiltration sludge, and reverse osmosis concentrate. The treated water will be suitable for discharge to groundwater by way of the TWIS. The microfiltration sludge will be routed to the sludge handling process for dewatering. The reverse osmosis concentrate will be routed to an evaporation/crystallization process for volume reduction or will be incorporated with the underground cemented mine backfill.

The sludge handling process will dewater sludge from the main wastewater treatment process metals precipitation/sedimentation system and sludge from the CRP microfiltration system. A plate and frame filter press will be used for sludge dewatering. Filtrate from the filter press will be routed back to the head end of the CRP for treatment. The dewatered sludge from the filter press will be managed in accordance with applicable regulations.

The evaporation/crystallization process is provided for volume reduction of the reverse osmosis concentrate from the CRP. Distillate from the evaporator will be discharged through the TWIS along with treated water from the main wastewater treatment process. Brine solids from the crystallizer will be managed in accordance with applicable regulations.

1.2 Discharge Standards

The WWTP will be designed to provide a level of treatment sufficient to ensure consistent compliance with Michigan's Part 22 Groundwater Quality Standards. Table 1-1 summarizes wastewater flows and pollutant concentrations and the groundwater quality standards based on background monitoring.

Table 1-1
Wastewater Flows and Pollutant Concentrations

Parameter	Influent Wastewater (2)	Filtered Clarifier Effluent (3)	Reverse Osmosis Permeate (4)	CRP RO Permeate (5)	Evaporator Distillate (6)	Composite Effluent (7)	Part 201 Standard(8)
Flow (gpm)	500	500	223	117	9	350	na
Aluminum, µg/l	140	140	0.4	5.0	0.1	1.9	300
Antimony, µg/l	19	19	0.05	2.7	0.1	1	6
Arsenic, µg/l	33	33	0.08	4.7	0.2	1.7	50
Barium, µg/l	28	28	0.07	4.0	0.1	1.4	2,000
Beryllium µg/l,	1.0	1.0	0.003	0.14	0.01	0.05	4
Boron, µg/l	3,671	3,671	140	250	21	174	500
Cadmium, µg/l	11	11	0.03	1.6	0.07	0.6	5
Calcium, µg/l	63,345	14,000	35	10	0.1	25	no std
Chloride, µg/l	825,963	825,963	250	131,100	5,057	44,000	250,000
Chromium, µg/l	8.5	8.5	0.02	1.3	0.06	0.5	100
Cobalt, µg/l	652	500	1.3	25	1.2	9.2	40
Copper, µg/l	145	145	0.4	21	1.0	7.2	1,400
Fluoride, µg/l	706	706	1.5	120	4.3	41	2,000
Iron, µg/l	6,467	1,000	2.5	5.0	0.07	3.2	2,000
Lead, µg/l	9.0	9.0	0.02	1.3	0.06	0.5	4
Lithium, µg/l	85	85	0.2	12.2	0.6	4.2	170
Magnesium, µg/l	32,317	8,000	20	10	0.1	17	400,000
Manganese, µg/l	992	500	1.3	5.0	0.2	2.4	860
Mercury, µg/l	0.041	0.041	0.00010	0.0059	0.0003	0.0021	2
Molybdenum, µg/l	21	21	0.05	3.0	0.1	1.1	73
Nickel, µg/l	33,403	2,000	5.0	5.0	0.2	4.9	100
Nitrogen (Ammonia), µg/l	10,163	10,163	696	5,569	1,000	2,328	10,000(9)
Nitrogen (Nitrate), µg/l	50	50	10	70	0.1	30	10,000(9)
Phosphorus, total units?	18.5	18.5	0.04	2.3	0.1	0.8	63,000
Potassium, µg/l	9,842	9,842	16	3,580	25	1,200	no std
Selenium, µg/l	26	26	0.07	3.7	0.2	1.3	50
Silver, µg/l	4.3	4.3	0.01	0.6	0.03	0.2	34
Sodium, µg/l	411,536	411,536	310	89,000	3,803	30,000	120,000
Strontium, µg/l	2,031	2,031	1.5	281	13	95	4,600

Table 1-1 *(cont'd)*

Parameter	Influent Wastewater (2)	Filtered Clarifier Effluent (3)	Reverse Osmosis Permeate (4)	CRP RO Permeate (5)	Evaporator Distillate (6)	Composite Effluent (7)	Part 201 Standard(8)
Sulfate, µg/l	167,099	167,099	10	4,800	1,067	1,700	250,000
Thallium, µg/l	7.1	7.1	0.02	1.0	0.05	0.4	2
Vanadium, µg/l	6.3	6.3	0.01	0.9	0.04	0.3	4.5
Zinc, µg/l	351	351	0.9	50	2.3	18	2,400

(1) Wastewater flows are for maximum design capacity (350 gpm of effluent) which is greater than water balance for maximum annual precipitation.

(2) Influent concentrations are based on composite values in Table 1-2 in Appendix B. Influent wastewater flow rate to the clarifier includes the utility water which is recycled back to the mine and is not treated with the RO process.

(3) Filtered effluent concentration only accounts for precipitation of calcium, cobalt, magnesium, manganese and nickel compounds. The co-precipitation of additional metals have conservatively not been estimated.

(4) Reverse osmosis permeate concentrations are based on estimated permeate quality of double pass RO system in main treatment process.

(5) Concentrate reduction process (CRP) concentrations are based on estimated permeate quality in CRP RO system after the boron ion exchange system.

(6) Evaporator distillate concentrations are based on estimated distillate quality in the evaporator process.

(7) Composite effluent concentrations are based on the combined effluent from the main RO system, CRP RO system and evaporator.

(8) Michigan Part 201 Residential Drinking Water Criteria Table 1, R 299.5744.

(9) The total inorganic nitrogen standard is for ammonia-nitrogen + nitrate nitrogen + nitrite nitrogen.

No Std = No standard specified in Michigan Admin Code R 323.2222 or R 299.5744.

See Attachment 1 for calculations.

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1.3 Design Flows and Pollutant Loading

As shown in Appendix B the primary sources of wastewater for the Eagle Project will include the following:

- Mine drainage water.
- Contact water from the TDRSA.
- Storm water runoff.
- Truck wash contact water.
- Crusher contact water.

The basis for the flows and pollutant concentrations for the mine drainage water, TDRSA contact water, and the storm water runoff from the main operations area is provided in Appendix B. Flows for the truck wash and crusher contact waters are based on typical values for similar mining operations. The pollutant concentrations for the truck wash and crusher contact waters are conservatively estimated as being equivalent to the mine drainage water. The wastewater pollutant concentrations are summarized in Table 1-2 in Appendix B.

1.4 Schematic Flow Diagram

Process flow diagrams for the WWTP are provided in Figures 1 through 3. A description of the WWTP facilities, including the design basis for these facilities, is provided below.

1.5 Description of Treatment Units

The WWTP will include the following general processes:

- Wastewater storage.
- Main wastewater treatment.
- Concentrate reduction.
- Sludge handling.
- Evaporation/Crystallization.

The following sections provide a detailed description of these processes.

1.5.1 Wastewater Storage

A description of the CWB size is provided in Appendix B.

1.5.2 Main Wastewater Treatment Process

A process flow diagram for the main wastewater treatment process is provided in Figure 1. This process will include the following facilities:

- Metals precipitation/sedimentation
- First stage pH adjustment.
- Sand filtration
- First pass reverse osmosis
- Second pass reverse osmosis
- Final effluent pH adjustment

1.5.2.1 Metals Precipitation/Sedimentation

The first step in treatment of the wastewater will be metals precipitation and separation through sedimentation. This step is provided to remove the bulk of metals present in the wastewater. The clarification process will also serve to remove some of the suspended solids present in the wastewater.

Hydroxide precipitation will be used to precipitate out (remove) metals present in the wastewater. This is a well established technology commonly used to remove metals from wastewater.

During hydroxide precipitation, metal removal occurs by adjusting the pH of the wastewater to the point where metals exhibit minimum solubilities and precipitate as metal hydroxides. These precipitates can then be separated from the wastewater through sedimentation. The effectiveness of hydroxide precipitation is dependent on wastewater characteristics such as pH, the form of metal ions present, and the presence of complexing agents. The extent of metals removal by this process is limited by the solubilities of the metal hydroxides generated. The minimum solubilities for most metal hydroxides occur in the pH range of 9 to 11; hence metal precipitation, in general, is optimal within this range. However, each metal hydroxide has a unique point of minimum solubility. The optimum pH for the hydroxide treatment process, corresponding to the maximum overall removal of metals, or corresponding to the maximum removal of key metals, will need to be determined once the WWTP is in operation and may need to be adjusted periodically in response to changing wastewater characteristics. To allow flexibility in operation, the metals hydroxide process will be designed for an operating range of pH 9.0 to pH 11.0.

Lime ($Ca(OH)_2$) and sodium hydroxide (NaOH) are commonly used for metals hydroxide precipitation. The use of lime is proposed for the Eagle Project. The principle precipitation reactions, in the case where lime is used, can be represented with the following general equations:

- $M^{+2} + Ca(OH)_2 \leftrightarrow M(OH)_2\downarrow + Ca^{+2}$
- $2M^{+3} + 3Ca(OH)_2 \leftrightarrow 2M(OH)_3\downarrow + 3Ca^{+2}$

where M^{+2} includes divalent metals such as copper, zinc, lead, nickel, and cadmium, and M^{+3} includes trivalent metals such as aluminum and iron.

In the hydroxide precipitation process, wastewater will be mixed with lime in a reaction tank and will subsequently flow to a solids contact-type clarifier. Rapid mixing of lime and wastewater and subsequent precipitation of heavy metals will occur in the reaction tank. Flocculation and settling of the precipitates will occur within the clarifier and will result in the formation of metal hydroxide solids in the bottom of the clarifier. Polymer addition will be used as required to optimize the solids sedimentation process. Solids generated by the precipitation process will be pumped from the clarifier to the sludge handling process for dewatering. Effluent from the clarifier will be routed to the downstream gravity filters.

The facilities for the metals precipitation/sedimentation process will include a reaction tank equipped with a mixing system, lime storage, a lime solution make-up and feed system, a solids contact-type clarifier, a polymer feed system, sludge pumping, and instrumentation for monitoring and control purposes.

One reaction tank and one clarifier will be provided. In the event that the metals precipitation/sedimentation system is out of service for repairs or maintenance, wastewater will either be temporarily stored in the CWBs or will be bypassed around the precipitation/clarification system to the gravity filters.

Design flows and sizing parameters for the metals precipitation/clarification system are provided in Table 1-2. The projected filtered effluent quality is shown in Table 1-1. The projected filter effluent concentrations listed in Table 1-1 only account for precipitation of calcium, cobalt, magnesium, manganese and nickel compounds. The co-precipitation of additional metals has not been estimated.

1.5.2.2 pH Adjustment

The wastewater pH will be adjusted to between 9.0 and 11.0 in the metals precipitation process. The pH of the wastewater will be adjusted back down to the 6.5 to 7.5 range after the metals precipitation/clarification process to minimize the potential for scaling of the downstream reverse osmosis membranes. A sulfuric acid storage and feed system will be provided for pH control purposes. An in-line pH control system is proposed. Design flows and sizing parameters for the pH adjustment system are provided in Table 1-2.

1.5.2.3 Gravity Filters

Effluent from the solids contact clarifier will flow to the gravity sand filters. The primary function of the gravity filter system will be to remove suspended solids that could clog or damage the downstream reverse osmosis system.

A single-media filter system is proposed. Instrumentation will be provided for monitoring and control of the filter system. Multiple filter units will be provided to allow continued wastewater treatment in the event that one of the filters is down for maintenance or repairs. The filter system will be designed to meet peak flow conditions with one of the filters off line. The filters will be equipped with automatic backwash systems. The backwash water will be routed to the CRP.

A gravity filter effluent storage tank will be provided. This tank will provide water for backwashing of the filters, will serve as a pumping wet well for the downstream reverse osmosis pumps, and will serve as a pumping wet well for the mine utility water pumps. The tank will be sized consistent with the flow rates and operating requirements of the three pumping systems served. Design flows and sizing parameters for the gravity filter system are provided in Table 1-2.

Table 1-2
Design Criteria for Major Wastewater Treatment System Processes

Process/Equipment	Design Flow (gpm)	Design Criteria[3]	
Contact Storage Basins	350[1]	Storage capacity	= 15 days
Main Wastewater Treatment Process:			
Metals Precipitation Tank	500[2]	Reaction time	= 15 minutes
		pH range	= 9.0 – 11.0
Solids Contact Clarifier	500[2]	Hydraulic loading rate	= 0.2 gpm/ft^2 effective area
Gravity filters	500[2]	Hydraulic loading rate	= 5 gpm/ft^2
Double Pass Reverse Osmosis	350	Percent recovery	= 67%
Final Effluent pH Adjustment Tank	350	Reaction time	= 5 minutes
		pH range	= 6.5 – 7.5
Final Effluent Storage Tank	350	Storage Capacity	= 60 minutes
Concentrate Reduction Process:			
Reaction Tank No.1	140	Reaction time	= 30 minutes
(Breakpoint Chlorination)		pH range	= 7.0 – 8.0
		Chlorine: ammonia	= 8:1 – 10:1 weight
Reaction Tank No.2	140	Reaction time	= 10 minutes
(Softening/Metal Precipitation)		pH range	= 9.0 – 11.0
Microfiltration System	140	Concentrate slurry	= 0.15 gpm/ft^2
pH Adjustment Tank	140	Reaction time	= 10 minutes
		pH range	= 6.5 – 7.5
Weak Acid Ion Exchange	205	Volume flow rate	= 2.5 gpm/ft^3
Reverse Osmosis	205	Percent recovery	= 93%
Boron Ion Exchange	140	Volume flow rate	= 1.0 gpm/ft^3
Sludge Handling Process:			
Sludge Storage Tank	5	Storage capacity	= 24 hr
Plate and Frame Filter Press	5	Flow capacity	210 ft^3/day
		Solids capacity	22-25 % solids
		Dewatered solids	
Sludge Storage Area		Storage capacity	14 days
Evaporator/Crystallizer Process:			
Evaporator/Crystallizer	10	Capacity	100% RO concentrate flow
Crystallizer Solids Storage Area		Storage capacity	14 days

(1) Design capacity of WWTP is 350 gpm.
(2) Influent wastewater flow rate through the clarifier and gravity filters includes the utility water which is recycled back to the mine and is not treated with the RO process.
(3) The design criteria may change based upon final equipment selection.

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1.5.2.4 First Pass Reverse Osmosis System

Effluent from the gravity filters will be pumped to a reverse osmosis system. This system will provide polishing of the metals precipitation/sedimentation system effluent with respect to heavy metals and will also remove other contaminants not removed by the metals precipitation/sedimentation system such as sodium, chlorides, sulfate, etc.

Reverse osmosis (RO) is a treatment process which uses semi-permeable membranes to remove inorganic and organic constituents from wastewater. RO separation of high molecular weight molecules, such as organic compounds, is achieved through physical "straining". RO separation of low molecular weight wastewater constituents, such as metals and inorganic salts, is achieved through electro-chemical interactions between the membrane surface and the ions in solution. The basic principles of operation for an RO system are as follows. A wastewater feed stream is passed tangentially across the membrane surface and is driven by applied hydrostatic pressure through the membrane. Constituents present in the wastewater are rejected at the membrane surface and become concentrated in the "reject" or "concentrate" stream while purified "permeate" or "product water" passes through the membrane. This process separates the membrane system feed stream into two new aqueous streams, the purified "permeate" stream and the concentrated "reject" or "concentrate" stream.

Typical RO rejection rates for most anions and cations commonly found in wastewater have been established and published by RO equipment manufacturers based on laboratory testing and/or historical operating performance data. Although, RO removal efficiencies will vary from application to application, due to differences in water chemistry and operating parameters, the published RO removal efficiencies provide a reasonable engineering basis for determining probable system performance. For the present evaluation, permeate water quality is provided by U.S. Filter (Industrial Water Systems Division). Permeate water quality is based on operating experience and project specific operating parameters. The projected effluent quality for the RO system is presented in Table 1-1.

Two RO process trains will be provided for the first pass system. Each train will be designed for 50% of the peak design flow rate. The two trains will be operated in parallel. This configuration will allow continued operation of the RO system in the event that either of the RO trains is off line for maintenance or repairs. Each train will include a high pressure feed pump, cartridge pre-filters, multiple RO element arrays, and miscellaneous control and monitoring devices. Instrumentation will be provided for monitoring and control of the RO system.
Storage and feed facilities for chemicals used for minimization of biological fouling (biocides) and/or chemical scaling (anti-scalants) will be provided for use as required. A membrane cleaning system will also be provided for maintenance of the RO membranes. Membrane cleaning wastewater will be routed to the CRP for treatment.

The RO concentrate will be routed to the CRP. The RO permeate will be routed to the second pass RO system. Design flows and sizing parameters for the first pass reverse osmosis system are provided in Table 1-2.

1.5.2.5 Second Pass Reverse Osmosis System

Effluent from the first pass RO system will be pumped to the second pass RO system. The second pass system is provided for additional removal of contaminants. Additionally, the second pass RO system will remove boron from the permeate stream.

The rejection rate of boron by RO membranes is relatively low in the neutral pH range that the first pass RO system will be operated at. In the neutral pH range, boron is typically present as undissociated boric acid which is not readily rejected by RO membranes. However, at elevated pH levels, boron takes the form of dissociated borate which is more readily rejected by RO membranes. At pH levels in the 10.0 to 11.0 range, RO boron rejection rates above 90% can be achieved.

Note that operation of the first pass RO system at an elevated pH range is not practical due to the high potential for membrane scaling. Because of the relatively high wastewater constituent concentrations in the feed stream to the first pass RO system, the potential for membrane scaling by metal hydroxides, calcium precipitates, etc., would be an operational concern at elevated pH levels. For this reason, boron removal in the first pass RO system is not practical. However, the second pass RO system will be treating the treated permeate from the first pass RO system and, consequently, the potential for membrane scaling at elevated operating pH levels will be minimized. Therefore, the second pass RO system will be used for boron removal.

Two RO process trains will be provided for the second pass system. Each train will be designed for 50% of the peak design flow rate. The two trains will be operated in parallel. Each train will include a high pressure feed pump, cartridge pre-filters, multiple RO element arrays, and miscellaneous control and monitoring devices. Instrumentation will be provided for monitoring and control of the RO system. Storage and feed facilities for chemicals used for minimization of biological fouling (biocides) and/or chemical scaling (anti-scalants) will be provided for use as required. A membrane cleaning system will also be provided for maintenance of the RO membranes. Membrane cleaning wastewater will be routed to the CRP for treatment.

With the exception of boron, the combined first pass and second pass RO system will be designed for operation at a combined recovery rate of approximately 67%. This means that 67% of the RO feed stream will be recovered as product water ("permeate") and 33% of the feed stream will end up in the concentrated reject stream ("concentrate"). The estimated recovery rate is based on meeting effluent quality objectives and on membrane scaling considerations.

The RO concentrate will be routed to the CRP. The RO permeate will be routed to the final effluent pH adjustment tank. Design flows and sizing parameters for the second pass reverse osmosis system are provided in Table 1-2. Projected effluent limits for the RO system are provided in Table 1-1.

Note that alternate processes for boron removal may be considered during the design phase of the Eagle Project. An ion exchange system using boron selective resin may also be evaluated. These types of systems can provide a level of boron removal comparable to the proposed RO system. Final selection of a boron removal system will be based on economic and technical considerations at the time of final engineering.

1.5.2.6 Final Effluent pH Adjustment

Prior to discharge to the TWIS, the pH of the main WWTP final effluent will be adjusted as required to achieve a pH in the range of 6.5 to 7.5. A pH adjustment tank will be provided for this purpose. Sodium hydroxide and sulfuric acid storage and feed systems will be provided for pH control purposes. Note that final effluent from the main wastewater treatment process, the evaporation/crystallizer process, and the CRP, will all be directed to this tank for final pH adjustment prior to discharge. Design flows and sizing parameters for the final effluent pH adjustment system are provided in Table 1-2.

1.5.2.7 Final Effluent Storage

An effluent storage tank will be provided for short term storage of WWTP final effluent. The effluent storage tank water will be continuously monitored for conductivity. In the event that the final effluent conductivity exceeds operational limits, the effluent will be automatically pumped from the storage tank back to the CWBs for reprocessing through the WWTP. Design flows and sizing parameters for the final effluent storage tank are provided in Table 1-2.

1.5.2.8 Effluent Pumping

Pumps will be provided to transfer final effluent from the effluent storage tank to the TWIS. Two pumps will be provided with each pump being sized for 100% of the TWIS design flow capacity.

1.5.2.9 Treated Water Infiltration System

The TWIS is described in Appendix D.

1.5.2.10 Treated Wastewater Reuse

As shown in Figure 1-1, some of the treated wastewater will be reused in the mine operations. Partially treated wastewater, taken after the metals precipitation/sedimentation and gravity filtration processes, will be routed to a utility water storage tank. This water will be used for various mine operations. Note that the utility water represents an internal recycle loop in the mine overall water balance; the utility water eventually will return to the WWTP after use in the mine operations. The impact of the utility water internal recycle loop is that the metals precipitation/sedimentation and gravity filtration processes will be sized for a higher flow rate than the downstream wastewater treatment processes. Projected utility water requirements for the Eagle Project are shown on the project water balance in Appendix B.

1.5.3 Concentrate Reduction Process

The CRP will be provided to maximize water recovery for the WWTP and correspondingly minimize the volume of concentrate treated by the evaporation\crystallization system. The CRP will treat the concentrate from the main wastewater treatment process RO system. The RO system for the CRP will be designed to operate at a recovery rate of approximately 93%. This means that 93% of the main wastewater feed stream to the RO system will be recovered as product water and 7% of the feed stream will end up as concentrate.

A process flow diagram for the proposed CRP is provided in Figure 2. This process will include the following facilities:

- Breakpoint chlorination (ammonia removal)
- Softening/Metals Precipitation
- Microfiltration (solids separation)
- pH adjustment
- Ion exchange (metals/inorganic salt removal)
- Reverse osmosis (volume reduction)
- pH adjustment
- Ion exchange (boron removal)

The CRP will result in two waste streams and a treated wastewater stream. The waste streams will include an RO concentrate stream which will be routed to the evaporator/crystallizer system for volume reduction and a microfiltration system sludge slurry which will be routed to the sludge handling process for dewatering. The treated wastewater stream will be discharged to the main wastewater treatment process final effluent pH adjustment tank.

Note that alternate CRPs may be considered during the final design and construction phase of the Eagle Project. One alternative that may be considered is an evaporator/crystallizer system. This type of system could provide the same process functions as the system outlined above. Final selection of a CRP will be based on economic and technical considerations.

1.5.3.1 Breakpoint Chlorination

Ammonia present in the raw wastewater feed stream will be rejected and concentrated by the reverse osmosis membranes used in the main wastewater treatment process. The ammonia will be present in the RO concentrate which will be routed to the CRP. A breakpoint chlorination process will be used to remove the ammonia from the RO concentrate. In this process, chlorine will be added to the wastewater. The chlorine oxidizes the ammonia through a progression of oxidation products including monochloramine, dichloramine, nitrogen trichloride, and finally nitrogen gas. The point at which nearly all the ammonia in the wastewater is oxidized to nitrogen gas, and additional application of chlorine results in free chlorine residual in the wastewater, is referred to as breakpoint chlorination. The stoichiometric weight ratio of chlorine to ammonia required to reach the breakpoint is 7.6:1. In practice, additional chlorine may need to be applied to account for consumption of chlorine in competing reactions. The optimal pH for breakpoint chlorination is typically in the range of 7.0 to 8.0.

The breakpoint chlorination process will occur in the first of the two reaction tanks proposed for the CRP. Liquid sodium hypochlorite will be used as a chlorine source. Sodium hydroxide and sulfuric acid will be used for pH control in the reaction tank. Chemical storage and feed equipment will be provided. A mixer will provide rapid mixing of the wastewater and chlorine solution. Instrumentation will be provided for monitoring and control of the breakpoint chlorination process. Design flows and sizing parameters for the breakpoint chlorination process are provided in Table 1-2.

1.5.3.2 Softening/Metals Precipitation

A softening/metals precipitation process will be provided to remove metals from the main wastewater treatment process RO concentrate stream. The purpose of this process is to allow operation of the downstream RO system at a higher water recovery rate while minimizing the potential for scaling of the membranes by calcium and heavy metal precipitates.

Sodium hydroxide will be added to raise the RO concentrate pH into the range of 9.0 to 11.0. In this pH range, the solubilities of the heavy metals present in the wastewater will be sufficiently reduced so that the metals will precipitate as metal hydroxides. Additionally, the solubilities of calcium and magnesium salts are minimal in this pH range and, consequently, calcium will precipitate out as carbonates while magnesium will precipitate out as a hydroxide.

The softening/metals precipitation process will occur in the second of the two reaction tanks proposed of the concentration reduction process. Sodium hydroxide will be introduced into the wastewater in the reaction tank. A mixer will provide rapid mixing of the sodium hydroxide and the wastewater. A coagulant, such as ferric chloride, will be added to the reaction tank as required to coagulate the precipitates into larger size floc which can be more readily removed from the wastewater stream. The precipitates formed in the softening/metals precipitation process will be removed from the wastewater stream by the downstream microfiltration system.

The softening/metals precipitation process will also be designed for silica removal. Silica removal may be required to prevent scaling of the downstream reverse osmosis membranes. Silica can be removed from wastewater through magnesium hydroxide co-precipitation. Silica is removed through magnesium silicate formation and adsorption of silica onto magnesium hydroxide floc. Where insufficient magnesium is initially available in the wastewater for precipitation of silica to the level required, magnesium can be added. Chemical storage and feed facilities are proposed for adding magnesium chloride to the wastewater to optimize silica removal. Magnesium chloride will be added to the first of the two reaction tanks proposed for the CRP. Silica precipitation will occur in the second of the two reactions tanks under elevated pH conditions.

The softening/metals precipitation process facilities will include a reaction tank, a reaction tank mixing system, chemical storage and feed facilities for sodium hydroxide and ferric chloride, and instrumentation for monitoring and control purposes. Design flows and sizing parameters for the softening/metals precipitation process are provided in Table 1-2.

1.5.3.3 Microfiltration

A microfiltration system is proposed for separation of the solids generated in the softening/metals precipitation process. The solids removed by the microfiltration system will be discharged to the sludge handling process. The product water from the microfiltration system will be discharged to the downstream reverse osmosis and ion exchange treatment systems.

Microfiltration is a process in which wastewater is passed tangentially across the face of microfiltration membranes. The wastewater is forced through the membrane surface by applied hydrostatic pressure. Solids are rejected by the membrane surface and are retained in the microfiltration concentrate. The primary mechanism for removal of solids, in a microfiltration system, is physical "straining". The degree of solids rejection will depend on the size and shape of the solids relative to the size of the membrane pores. Microfiltration membranes typically have pore sizes in the range of 0.1 to 3.0 microns with the pore size being selected based on the requirements of the given application.

Under the proposed configuration, wastewater from the softening/metals precipitation process will be discharged into the microfiltration system "concentrate tank". The wastewater will then be pumped from this tank to the microfiltration system where the feed stream will be separated into a solids concentrate stream and a permeate (product water) stream. The permeate stream will be routed to downstream treatment processes. The concentrate stream will be recirculated back to the microfiltration concentrate tank where it will mix in new wastewater coming in from the softening/metals precipitation process. A portion of the solids slurry in the microfiltration concentrate tank is periodically pumped to the solids handling process for dewatering.

The main components of the microfiltration system include the concentrate tank, the microfiltration feed pumps, the microfiltration modules, the microfiltration cleaning system, and instrumentation for monitoring and control purposes. Three microfiltration process trains are proposed. Each train will be designed to accommodate 33% of the peak design flow. The three trains will be designed for parallel operation. The proposed configuration will allow continued operation of the microfiltration system if one of the process trains is off line for maintenance or repairs.

A cleaning system will be provided for maintenance of the microfiltration membranes. Sodium hydroxide, sulfuric acid, and sodium hypochlorite are typically used in the cleaning process. Chemical storage and feed facilities will be provided for these chemicals. Additionally, a cleaning water tank and cleaning water feed system will be provided. Membrane cleaning wastewater will be routed back to the microfiltration system concentrate tank with eventual discharge to the sludge handling system. Design flows and sizing parameters for the microfiltration process are provided in Table 1-2.

1.5.3.4 pH Adjustment

Permeate from the microfiltration system will be routed to a pH adjustment tank. As indicated previously, the pH of the wastewater will be increased to between 10.0 and 11.0 for the softening/metals precipitation process. This pH will be maintained through the microfiltration system. The pH of the microfiltration permeate will adjusted back down into the neutral range in the pH adjustment tank. The pH reduction is required for optimization of the downstream treatment processes.

The pH adjustment system will include a reaction tank, a tank mixer, and chemical feed equipment. Sodium hydroxide and sulfuric acid storage and feed systems will be provided for pH control purposes. Design flows and sizing parameters for the final effluent pH adjustment system are provided in Table 1-2.

1.5.3.5 Weak Acid Ion Exchange System

Microfiltration permeate from the microfiltration pH adjustment tank will be routed to the reverse osmosis feed storage tank. The permeate will be pumped from this tank to the downstream ion exchange and reverse osmosis systems. Biocide will be added to this tank as required to limit growth of bacteria on the downstream reverse osmosis membranes.

Additionally, sodium bisulfite will be added to this tank as required to remove any chlorine residual present in the wastewater from the upstream breakpoint chlorination process. Removal of chlorine residual is required to protect the downstream ion exchange resins and RO membranes. Chemical storage and feed systems will be provided.

Microfiltration system permeate will be pumped from the RO feed storage tank to a weak acid ion exchange system. The ion exchange system is provided to further reduce the level of heavy metals and inorganic salt cations remaining in the wastewater after the softening/metals precipitation and microfiltration processes. Reduction of these wastewater constituents will allow operation of the downstream RO system at a higher level of recovery and will thereby minimize the RO concentrate flow to the downstream evaporator/crystallizer process. The potential for membrane fouling through precipitation of metal hydroxides and inorganic salts increases with the RO recovery rate due to the increasing concentrations of these constituents within the RO system as a function of increasing recovery rate. Reducing the concentrations of these constituents in the initial RO feed stream will result in lower concentrations within the RO system, will reduce the potential for membrane fouling, and will thereby allow a higher recovery rate.

The proposed ion exchange system will include feed pumps, multiple ion exchange columns, an ion exchange regeneration/backwash system, and instrumentation for monitoring and control purposes. Two ion exchange columns will be provided with each column being designed to handle 100% of the design peak flow. The columns will be operated in parallel. This configuration will allow continued operation of the ion exchange system in the event that either of the columns is off line for regeneration, maintenance, or repairs. The regeneration process will use acid to regenerate the ion exchange column resin. Regeneration waste will be routed back to the head end of the CRP for treatment. Design flows and sizing parameters for the ion exchange system are provided in Table 1-2.

1.5.3.6 pH Adjustment

A pH adjustment system will be provided to control the pH of the wastewater going from the ion exchange system to the downstream reverse osmosis system. Processing of the wastewater through the weak acid ion exchange system will result in a reduction of the wastewater pH. A sodium hydroxide storage and feed system will be provided for pH adjustment. In-line pH control is proposed.

1.5.3.7 CRP Reverse Osmosis

Effluent from the weak acid ion exchange (IX) system will be pumped to the CRP RO system. The primary function of the CRP RO system will be reduction of the final volume of the waste stream discharged from the CRP. Additionally, the CRP RO system will provide polishing of the IX effluent, further reducing the concentrations of any residual heavy metals or inorganic salts present in the IX effluent.

Two RO process trains will be provided. Each train will be designed for 50% of the peak design flow rate. The two trains will be operated in parallel. This configuration will allow continued operation of the RO system in the event that either of the CRP RO trains is off line for maintenance or repairs. Each train will include a high pressure feed pump, cartridge pre-filters, multiple RO element arrays, and miscellaneous control and monitoring devices. Storage and feed facilities for chemicals used for minimization of biological fouling (biocides) and/or chemical scaling (anti-scalants) will be provided for use as required. A membrane cleaning system will also be provided for maintenance of the RO membranes. Membrane cleaning wastewater will be routed back to the head end of the CRP for treatment.

The RO system will be designed for operation at a recovery rate of approximately 93%. The estimated recovery rate is based on effluent quality requirements and on membrane scaling considerations. Permeate from the RO system will be routed to the downstream ion exchange system for additional treatment. Concentrate from the RO system will be routed to the evaporator/crystallizer process for final volume reduction. Design flows and sizing parameters for the RO system are provided in Table 1-2.

1.5.3.8 Boron Ion Exchange

Boron removed by the main wastewater treatment process will be contained in the RO system concentrate routed to the CRP. Boron will not be significantly removed from the wastewater by softening/metals precipitation process, the microfiltration system, the weak acid ion exchange system, or the reverse osmosis system used in the CRP. Therefore, a final stage treatment system will be used for boron removal. An ion exchange system using boron selective resin will be used for this purpose.

The boron selective ion exchange system will include a pH control system, feed pumps, multiple ion exchange columns, and an IX resin regeneration/backwash system. The pH control system will be used to increase the pH of the RO system effluent to the 10.0 to 11.0 range. In this pH range, boron will be predominantly present in the dissociated borate form which is more readily removed by the IX resin. Three IX columns will be provided with each column being designed to handle 33% of the peak design flow. The three columns will be operated in parallel. This configuration will allow continued operation of the IX system in the event that one of the columns is off line for regeneration, maintenance, or repairs. Effluent from the IX system will be routed to the final effluent pH adjustment tank where it will be combined with effluent from the main WWTP and discharged to the TWIS. The boron ion exchange system will either be regenerated on-site, or the ion exchange columns will be shipped to an off-site vendor for regeneration. If regeneration takes place on-site, the regenerate will be pumped to the evaporator. Design flows and sizing parameters for the boron IX system are provided in Table 1-2. The projected effluent quality for the IX system is shown in Table 1-1.

1.5.4 Sludge Handling Process

A sludge handling process will be provided to dewater sludge discharged from the main wastewater treatment process solids contact clarifier and sludge from the CRP microfiltration system. A process flow diagram for the sludge handling process is provided in Figure 3. The sludge handling process will include the following equipment:

- Sludge storage tank
- Sludge feed pump
- Plate and frame filter press
- Filtrate pump station
- Chemical feed equipment

Sludge from the solids contact clarifier and the microfiltration system will be pumped to the sludge storage tank. This tank will provide short term storage and equalization of the sludge. A pumping system will be provided to transfer sludge from the storage tank to the filter press.

A plate and frame filter press is proposed for sludge dewatering. Polymer and/or coagulant will be added to the sludge, prior to the filter press, as required to optimize the sludge dewatering characteristics. The sludge will be dewatered to a 20% or greater solids content.

Filtrate from the filter press will flow to a pump station wet well and will then be recirculated back to the head end of the CRP for treatment. Dewatered sludge will be contained in a storage area and will be managed in accordance with applicable regulations. Design flows and sizing parameters for the sludge handling process are provided in Table 1-2.

1.5.5 Evaporator/Crystallizer Process

Reverse osmosis concentrate from the CRP will either be discharged to the evaporator/ crystallizer process or will be incorporated into the cemented mine backfill. An evaporator/ crystallizer system will used to treat concentrate in excess of that which can be used in the mine backfill operations, to treat concentrate during those periods of time when the backfill system is not in operation, or to treat concentrate in the event that it is determined to not be suitable for use in the cemented backfill. A process flow diagram for the proposed evaporator/crystallizer process is provided in Figure 3.

The evaporator/crystallizer system will remove water from the RO concentrate. The objectives of this process are to minimize the volume of the RO concentrate and to generate a waste material that can be more readily managed in accordance with applicable regulations. A covered, contained storage area will be provided for temporary storage of the waste solids.

The water removed from the RO concentrate during the evaporation/crystallization process will initially be in a vapor form. This vapor will be returned to a liquid form through a condensation process. The resulting "distillate" will be treated water meeting groundwater quality standards. The distillate will be routed to the final effluent pH adjustment tank where it will be combined with effluent from the main WWTP and discharged to the TWIS.

Chemicals, including acid and/or anti-scalants, may be used, if required, to minimize fouling of the evaporator/crystallizer heat exchange surfaces. Chemical storage and feed systems will be provided as required. Design flows and sizing parameters for the evaporator/crystallizer process are provided in Table 1-2.

1.6 Description of Sludge Management

Two waste materials will be generated by the WWTP. The first waste material will be sludge from the sludge handling system. This system will dewater sludge generated by the main wastewater treatment process solids contact clarifier and sludge generated by the CRP microfiltration system. The dewatering process is anticipated to generate a sludge with a solids content of 20% or higher. The second waste material will be waste solids generated by the evaporator/crystallizer system.

The waste solids from the sludge handling system and the evaporator/crystallizer system will be managed in accordance with applicable regulations. Covered, contained storage areas will be provided for temporary storage of the solids.

In addition to solids generated by the wastewater treatment process, the CWBs will accumulate solids from the settling of suspended solids contained in the runoff and other wastewaters entering the basins. The solids that accumulate in the basins will be removed as required. The solids from the CWBs will be disposed of in the cemented mine backfill.

1.7 Instrumentation and Controls

The WWTP will include computerized automated control of the WWTP components. Displays associated with the computerized automated controls will provide the WWTP operators with information concerning key WWTP operating data such as wastewater flow rates and pH; the levels of the CWBs, reaction tanks, effluent storage tank, and chemical feed tanks; and the operating status of the major WWTP equipment and alarms. The operator will also be able to control the major WWTP operating functions, such as starting and stopping equipment, adjusting set point pHs and dosage rates for treatment chemicals, and selecting automatic or manual control of key treatment equipment and processes.

1.8 Adverse Weather Strategies

The WWTP equipment, with the exception of the solids contact clarifier, will be located in a building. The equipment will be operable under all weather conditions. Additionally, discharge to the TWIS will be maintained throughout the year since the system will be a buried infiltration gallery (Appendix D).

1.9 Quality Control

The WWTP will be rigorously operated, controlled, maintained, and monitored in order to consistently provide a treated wastewater of sufficient water quality to meet the design discharge standards. A quality control program will be developed to ensure consistently reliable performance of the WWTP. Key components of the quality control system will include the following:

- A certified WWTP operator experienced in the operation and maintenance of the treatment processes and equipment used in the wastewater water treatment system.
- Standardized routine operation and maintenance procedures
- Instrumentation systems designed to allow remote operator monitoring of all critical WWTPs operations.
- Standardized procedures for routine calibration of all wastewater system instrumentation devices such as flow meters, pH meters, ORP meters, conductivity meters, etc.
- Standardized procedures for storage and handling of wastewater treatment chemicals.

- Standardized procedures for approved alternate modes of operation in the event that an individual treatment process is out of operation.

- Standardized procedures for responding to WWTP alarm conditions including immediate shutdown of all WWTPs if effluent quality may be compromised by the event triggering the alarm.

- Routine testing of raw wastewater, final effluent, and effluent from intermediate treatment processes as required to verify proper and consistent system performance.

- Standardized procedures for routing treated water from the effluent storage tank back to the CWBs in the event that the effluent quality does not meet the design discharge standards.

- Wastewater laboratory personnel certified in all analyses required for monitoring of the WWTP.

- Standardized wastewater sample collection, sample analysis, and analysis reporting procedures.

- Implementation of a laboratory quality assurance/quality control plan.

1.10 Operation and Maintenance

The general duties associated with operation will include:

- Monitor the operating status of wastewater treatment processes and equipment.

- Monitor the wastewater influent and effluent quality and make necessary process adjustments to maintain the required level of treatment.

- Collect samples for testing.

- Daily inspection of equipment.

- Record keeping.

- Coordination of routine maintenance or repairs.

- Troubleshooting.

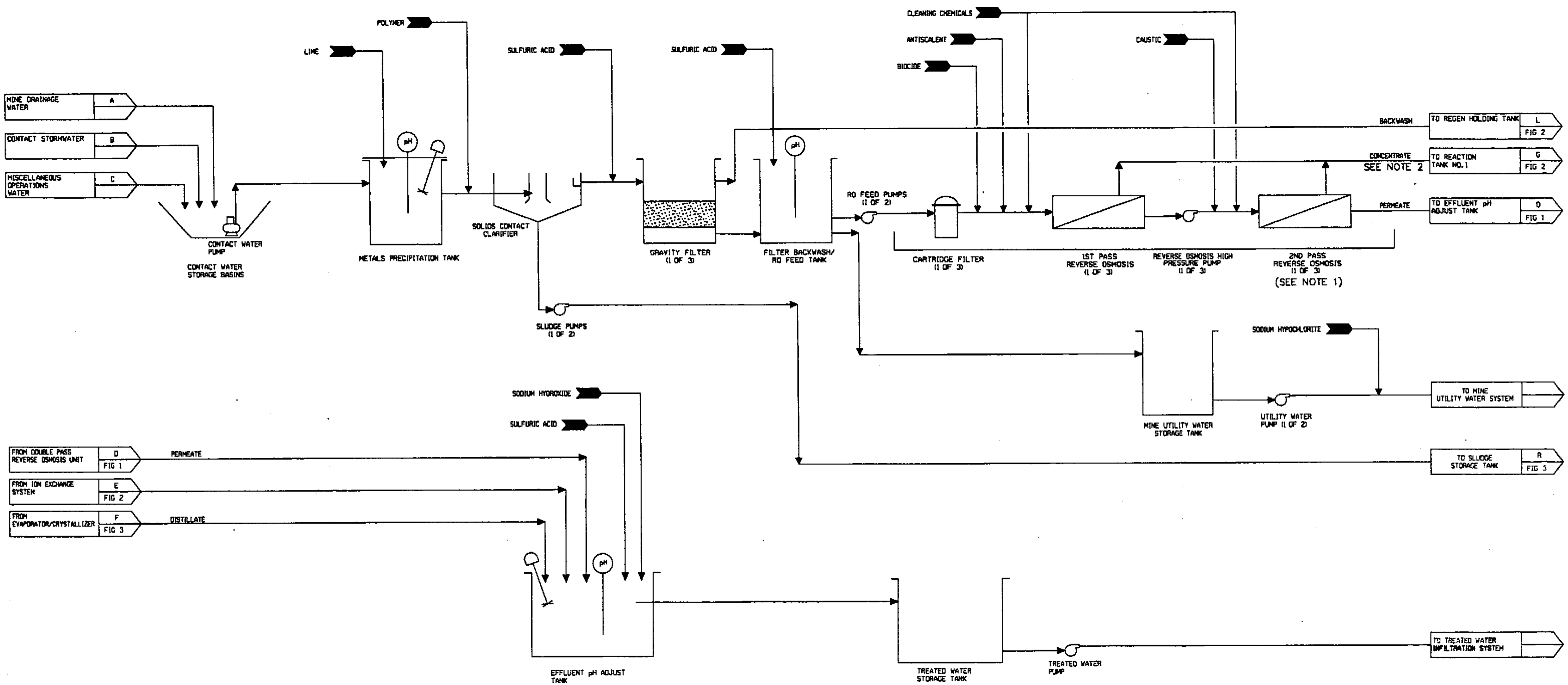
- Facilities management.

Preventative maintenance will be a priority for the project. Facility systems which will require routine maintenance include the following:

- Monitoring and control instrumentation.
- Chemical storage, handling, and feeding systems.
- Reverse osmosis membranes

- Microfiltration membranes
- Ion exchange resins
- Evaporator/crystallizer equipment
- Electrical distribution system.
- Plant utilities, e.g., heating, ventilating, instrument air, non-potable water.
- Pumps and process equipment.

MAIN WASTEWATER TREATMENT PROCESS



NOTES:

1. AN ION EXCHANGE SYSTEM (FOR BORON REMOVAL) MAY BE ADDED IN LIEU OF CAUSTIC ADDITION PRIOR TO THE SECOND PASS RO UNIT.
2. RO CLEANING WASTEWATER WILL BE ROUTED TO REACTION TANK NO.1.

Foth Infrastructure & Environment, LLC				
REVISED	DATE	BY	DESCRIPTION	
CHECKED BY:	JJF1		DATE: MAR. '07	
APPROVED BY:	SVD1		DATE: MAR. '07	
APPROVED BY:			DATE:	

Kennecott Eagle Minerals

FIGURE 1

PROCESS FLOW DIAGRAM
MAIN WASTEWATER TREATMENT PROCESS

Scale: NONE	Date: MARCH, 2007
Prepared By: JRB2	Project No. 04W018

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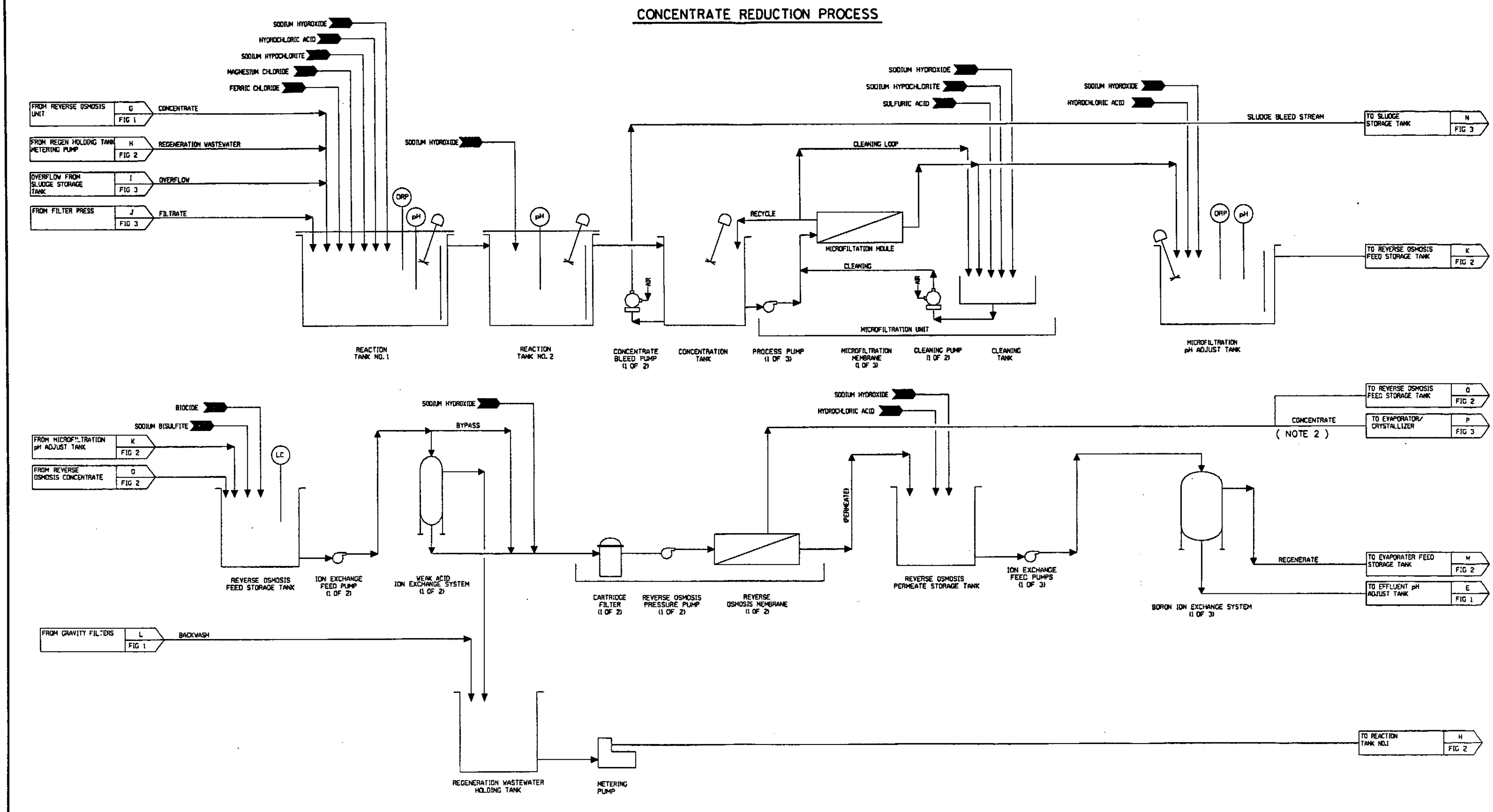

NOTES:

1. CONCENTRATE REDUCTION PROCESS BASED ON INFORMATION SUPPLIED BY U.S. FILTER COMPANY.
2. RO CLEANING WASTEWATER WILL BE ROUTED TO REACTION TANK NO.1.

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JJF1	DATE: MAR. '07
APPROVED BY:	SVD1	DATE: MAR. '07
APPROVED BY:		DATE:

Kennecott
Eagle Minerals

FIGURE 2
PROCESS FLOW DIAGRAM
CONCENTRATE REDUCTION PROCESS

Scale: NONE	Date: MARCH, 2007
Prepared By: JRB2	Project No. 04W018

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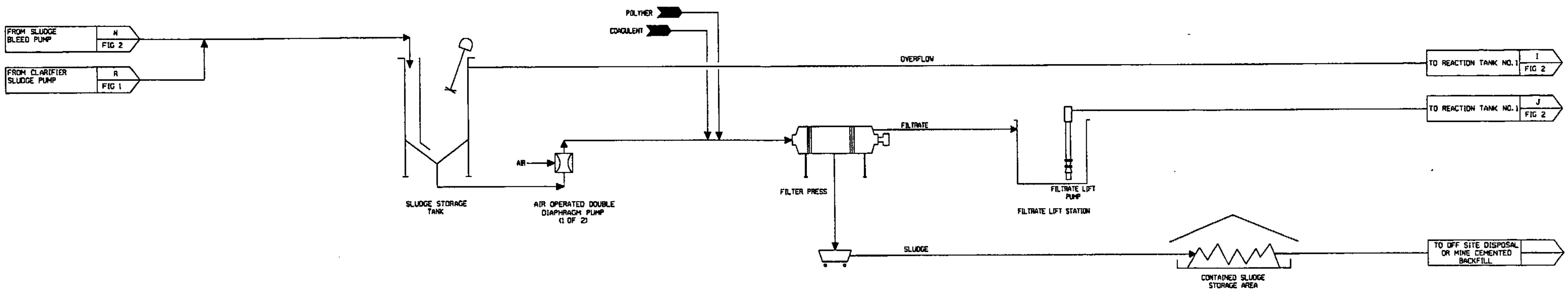
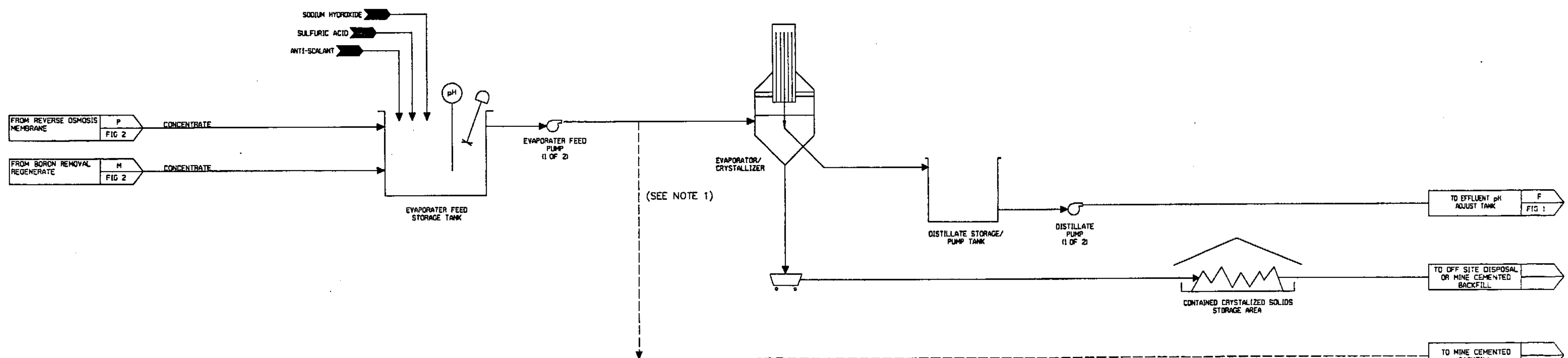
SLUDGE HANDLING PROCESS



EVAPORATION/CRYSTALLIZATION PROCESS



NOTES:

1. THE CONCENTRATE MAY BE PROCESSED WITH THE CEMENTED BACKFILL IN LIEU OF EVAPORATION.

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	JJF1	DATE: MAR. '07
APPROVED BY:	SVD1	DATE: MAR. '07
APPROVED BY:		DATE:

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FIGURE 3
PROCESS FLOW DIAGRAM
SLUDGE HANDLING AND
EVAPORATION/CRYSTALLIZATION PROCESSES

Scale: NONE	Date: MARCH, 2007
Prepared By: JRB2	Project No. 04W018

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