Indigenous and Northern Affairs Canada
Affaires autochtones et du Nord Canada

Faro Mine Remediation

Scope Book

srk consulting

PRIMARY WATER TREATMENT (PLANT AND SYSTEM)

A	--	June 29, 2018	S. Jensen		
Rev.	**Status/Description**	**Rev. Date**	**Prepared by**	**Reviewed by**	**Approved by**

Table of Contents

Appendices

1.0 Overview

This scope book covers the design of the closure water treatment plant (CWTP) for the Faro Mine Complex (FMC). The closure water treatment plant is to treat all contact water collected at the FMC. Water treatment at the FMC is expected to be required post-closure.

Feed water from the treatment plant will originate from:

- Faro Pit
- The Down Valley Seepage Interception System (DV SIS)
- The Intermediate pond (IP)
- The Emergency Tailings Area Seepage Interception System (ETA SIS), and
- Sedimentation ponds if runoff reporting to these do not meet effluent standards.

The water treatment plant will use a high-density sludge (HDS) process for removal of dissolved metals, sulphate and other constituents. Treated effluent from the plant will be discharged to Rose Creek. Sludge produced by the treatment process will be pumped to the bottom of Faro Pit Lake for permanent disposal.

The normal operating season for the CWTP will be from May to October each year. The operating season may be shortened if the inventory or flow of contact water requiring treatment is lower than anticipated. Plant start-up will commence each year in mid-April and winterization will be completed in October.

During the operating season, the plant will be staffed by four operators working 12-hour shifts. The water treatment plant operators will also be responsible for operating and maintaining the contact water collection and conveyance system (Scope Book CV-CONV). During the off-season (November to April) the seepage interception systems will continue to operate and the CWTP will require periodic inspection. During this time the treatment plant staff will be reduced to two operators working 12-hour shifts.

2.0 Scope Definition

2.1 Scope Elements

The 30% design defines the design basis for the CWTP including location, treatment capacity, treatment performance, treatment season and other requirements.

The current plan is that detailed geotechnical, mechanical, civil and electrical design of the CWTP will be completed as a package by an engineering design and construction firm in accordance with the standard industry model for supply of such facilities. Detailed design will be based on the design basis developed as part of the 30% design.

2.2 Scope Exclusions

Related activities covered under other tasks include:

- Conveyance of water to and from the CWTP are excluded from the scope and included in the contact water conveyance scope book (see WBS CW-CONV). The boundary between the CWTP and the contact water conveyance system is the water treatment plant building. Connections to the feed water pipes, effluent pipe, recycle pipe and sludge pipe will be made immediately inside of the building walls.
- The site wide electrical distribution system beyond the connection to the CWTP transformer electrical distribution system, is covered under WBS SD-ELEC.
- Communication systems are not included in the CWTP scope (see WBS SD-COMM).

- The levelling and surface preparation of the CWTP footprint is included in the scope for the Bulk Earthworks Pads (SD-PADS). Foundation excavation and surface preparation will be sufficient to lay concrete foundations for the CWTP building and clarifier. Concrete foundations are included in this scope.
- The CWTP may operate in parallel with the interim Water Treatment Plant (IWTP). The IWTP decommissioning schedule is dependent on the construction of the CWTP, but covered under a separate task (see WBS WT-WTPI).

3.0 Prior Work

The following documents have been used to develop the design basis for the CWTP 30% design.

Reference	Design Inputs
Water and Load Balance model for the FMC (SRK, 2018a)	Design treatment capacity Lime demand and operating cost estimate Operating season
Faro Closure Water Treatment Plant Design Capacity Memo (SRK, 2018b)	Design treatment capacity
Faro Water Treatment Onsite HDS Pilot Plant Testing Report (AWT 2018)	Hydraulic residence time and reactor sizing Treatment performance and effluent quality objectives
Estimates of future groundwater and surface water yields from the DV SIS, (RGC 2018)	Design treatment capacity Lime demand and operating cost estimate
Estimates of future groundwater and surface water yields from the ETA SIS and NFRC SIS (SRK 2018c)	Design treatment capacity Lime demand and operating cost estimate
Water Treatment Plant – Plant Siting Cost Benefit Analysis by CH2M Canada Ltd (CH2M 2016)	Water treatment plant location
Faro Treatment Plant Detailed Design Summary by CH2M Canada Ltd + 90% Drawing Package (CH2M 2014)	Power demand and building heating requirements
Water Treatment Plant Class 3 Capital Cost Estimate (CH2M 2013)	Class 4 capital cost estimate
Water Treatment Season Memo (SRK 2017)	Treatment season

4.0 Design

4.1 Objectives

The design objectives for Closure Water Treatment Plant are:

- Treat and discharge all excess contact water collected within the FMC project area during the closure and post-closure periods.
- Produce effluent that meets future discharge standards.
- Produce a high-density sludge that can be pumped to the Faro Pit for permanent disposal.

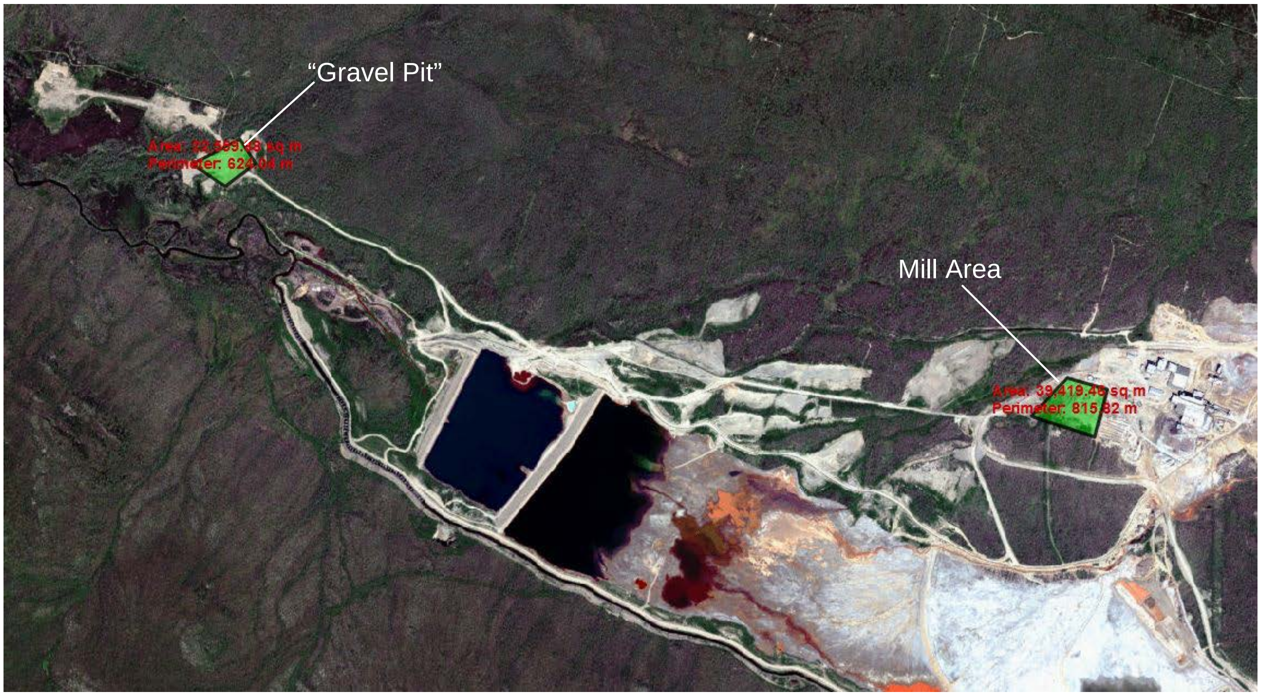
4.2 Design Criteria

Design criteria are summarized in the table below and discussed in the subsequent paragraphs.

Component	Design Criteria
Treatment Plant Location	See location on Drawing WT-WTPP-001 and WT-WTPP-002
Treatment Plant Capacity	Nominal capacity: 60,000 m^3/day Max hydraulic capacity: 75,000 m^3/day
Feed Water	Acid Rock Drainage (ARD) collected in the Faro Pit Lake, DV SIS, ETA SIS, NFRC SIS, S-wells, Zone 2 Pit, and the Intermediate rock drain. Near-neutral runoff collected in sedimentation ponds (if required)
Effluent Quality Objectives	See next table
Feed Water Composition	Near-neutral to Acidic (approximately pH 7 to 2) Total Acidity: 0.1 to 3.0 g/L Sulphate: 900 to 3,300 mg/L Dissolved Iron (ferrous and ferric): 0 to 1,500 mg/L Dissolved Zinc: 30 to 250 mg/L Dissolved Manganese: 10 to 30 mg/L Dissolved Aluminum: 0.1 to 5 mg/L
Lime Dosing System	Quick-lime slaking and dosing capacity: 3.5 tonnes/hr Lime Silo Capacity: 800 tonnes
Total Hydraulic Residence Time in Reactors	Total hydraulic residence time of feed water at nominal capacity: 60 minutes Total reactor capacity: approximately 2,900 m^3
Clarifier	Clarifier rise rate: 1.0 m/hr at nominal flow Diameter: 56.5 m (minimum) Clarifier dome cover required
Sludge production	50 tonnes/day to 1,000 tonnes/day at 25% solids
Operating Season	Nominal: May through October (both included) Contingency: April and November
Filtration	Filter units are not required as part of the base design. However, the plant foot-print and infrastructure must make allowances for filters in case they will be required in the future.

Location. The treatment plant location was selected based on a cost-benefit analysis completed by CH2M Canada Ltd. in 2016 (CH2M 2016). The assessment considered two potential locations: the Mill Area and a location downstream of the Cross Valley Pond known as the Gravel Pit (figure below). The Mill Area was found to provide the most technically suitable location for the CWTP, with the lowest cost for infrastructure, largest site size for future expansion, the safest location against flood risk, and a good centralized location for long-term operation. The Gravel Pit area would require less pumping power since most feed would could be conveyed to the plant location by gravity. A reduction in pumping power would reduce annual operating costs. However, the potential savings in annual pumping costs would be applicable only if the operating season could be year-round, as no storage capacity is available at this location for flows collected over winter.

A review by SRK found that the treatment plant season needs to be limited to the open water period to protect the receiving streams during winter low flow conditions (SRK 2017). The implication is that contact water collected over winter would have to be pumped to the Faro Pit for storage irrespective of the CWTP location, negating the sole potential benefit of the gravel pit location. Therefore, the Mill Area location was selected for the CWTP.

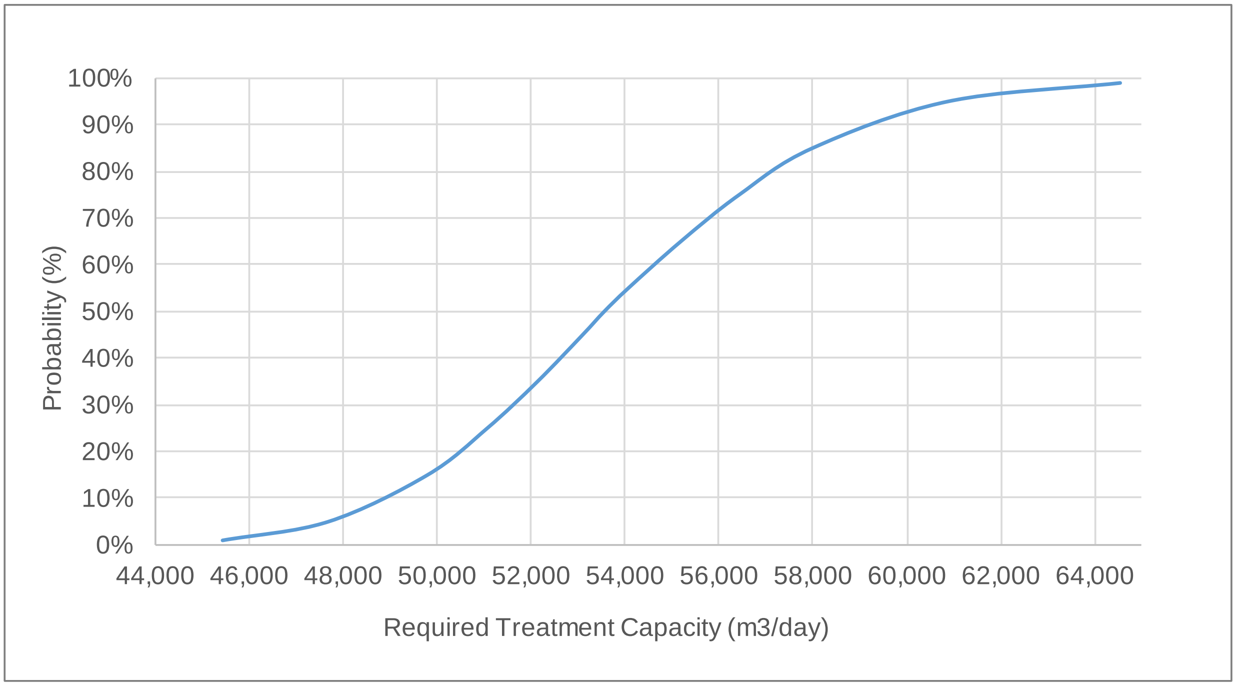


Potential Closure Water Treatment Plant Locations (from CH2M 2016)

Treatment Capacity. The treatment capacity of the CWTP was established by developing a probability distribution of annual inflows to the contact water storage in the Faro Pit. Feed water for the water treatment plant includes contact water intercepted in the DV SIS, ETA SIS, NFRC SIS as well as water collected in the IP, S-wells, Zone 2 Pit and in the Faro Pit Lake. In addition, water collected in surface sedimentation ponds may also require treatment during and immediately after closure implementation.

A probability distribution for each inflow was generated by considering the uncertainty associated with current estimates. The probabilistic inflows were then incorporated in a stochastic Monte Carlo simulation, with 10,000 runs of a one-year duration. In each run, the distribution of each of the contact water sources was randomly sampled and an annual treatment demand was calculated. At the end of the simulation, the 10,000 calculated values for annual treatment demand – expressed in m^3/year – were ranked and percentiles calculated. The required treatment capacity was then calculated assuming an operating season of 180 days and 95% mechanical availability of the plant.

The figure below shows the results. The average flow could be handled by a CWTP with a capacity of approximately 53,500 m^3/day. The 90th percentile contact water flow would require a CWTP with a capacity of approximately 59,000 m^3/day. The nominal capacity selected for the CWTP was 60,000 m^3/day and a hydraulic maximum of 75,000 m^3/day. This was done to provide the future operation with reasonable assurance that the inventory in the Faro Pit Lake can be reduced to the target level each year with a residual risk of about 10% that some of the contact water inventory would have to be carried over to the following year and treated then. The selected capacity would also allow the operation to ramp up treatment during high-flow periods of the year when Rose Creek has greater assimilative capacity, thereby reducing the potential for the treated effluent to affect water quality in the creek.



Annual Water Treatment Capacity Required: Cumulative Probability Distribution

Effluent Quality. The effluent quality objectives stated in the design basis were based on the results of a water treatment trial conducted at the Faro Site in 2017 (AWT 2018). The effluent quality objectives are listed in the table below.

Parameter*	Units	Value	Parameter*	Units	Value
Sulphate	mg/L	1860	Antimony	mg/L	<0.0025
Arsenic	mg/L	<0.0005	Beryllium	mg/L	0.012
Silver	mg/L	<0.0001	Boron	mg/L	<0.25
Aluminum	mg/L	0.037	Chromium	mg/L	<0.005
Cadmium	mg/L	0.000547	Molybdenum	mg/L	<0.005
Cobalt	mg/L	<0.001	Selenium	mg/L	<0.0005
Copper	mg/L	<0.001	Strontium	mg/L	1.9
Iron	mg/L	0.026	Tin	mg/L	<0.025
Lead	mg/L	<0.001	Thallium	mg/L	0.00060
Manganese	mg/L	0.104	Uranium	mg/L	<0.0005
Nickel	mg/L	<0.005	Vanadium	mg/L	<0.025
Zinc	mg/L	0.072			

Note: *Concentrations listed as dissolved parameters

Feed Water Composition. The feed water composition was estimated based on results from the FMC water and load balance model developed by SRK (SRK 2018a). The model considers a range of geochemical source term inputs, including a future scenario where ARD affects all potentially acid generating (PAG) waste rock areas and tailings areas on site. Accordingly, the feed water quality for the

CWTP is expected to become more acidic over time with increasing concentrations of sulphate and dissolved metals. The design basis lists the range of concentrations anticipated through long-term operation.

Lime Dosing Capacity. The capacity of the lime dosing system is based on estimates of total acidity loads in the feed water entering the CWTP, which was estimated based on the FMC water and load balance model. Long-term, the CWTP is expected to require approximately 10,000 tonnes of lime per year and have a daily average consumption of about 55 tonnes or 2.3 tonnes/hr. The specified lime system capacity is 3.5 tonnes/hr, 50% greater than the nominal long-term capacity estimate.

Hydraulic Residence Time. The total hydraulic residence time, and therefore total reactor volume, was based on results of the 2017 pilot trial. The pilot trial demonstrated an improved lime utilization up to a residence time of 45 to 60 minutes (AWT 2018). Extending the residence time beyond 60 minutes did not improve lime utilization. The cost of lime is a significant portion of the annual operating costs for the CWTP. Therefore, even modest improvements in lime utilization will have a meaningful effect on the future annual operating costs.

Clarifier. The clarifier is to be designed for a rise rate of 1.0 m/hr, which is equal to a diameter of 56.5 m. A rise rate of 1.0 m/hr is standard for HDS process design. The clarifier will be constructed with a dome cover to protect it from the extreme climate in the Yukon Territory.

Sludge. The production of sludge was calculated based on loadings of dissolved metals and sulphate in the CWTP feed water. Sludge production will be relatively low in the early phase of the operation but is expected to ramp up to approximately 1,000 tonnes/day after large-scale onset of ARD.

Filtration. Filtration of the effluent from the CWTP is not likely to be required. Operated properly, the clarifier can produce effluent with low to negligible concentrations of suspended solids. However, the design basis requires that a foot-print be dedicated to accommodating a filter plant in case filtration will be needed to meet future discharge standards.

4.3 Process Design

The process used by the CWTP is a standard HDS lime water treatment process. A process flow diagram is included in Drawing WT-WTP-003.

In February 2014, CH2M Canada Ltd. issued a 90% design package for a HDS water treatment plant for the FMC. The design and associated drawings generally meet the design basis described in Section 4.2, with the following important exceptions:

- Treatment capacity increased to 60,000 m^3/day nominal and 75,000 m^3/day max hydraulic from 44,100 m^3/day nominal and 54,500 m^3/day max.
- Total hydraulic retention time changed from 30 minutes to 60 minutes. Change in hydraulic retention time and treatment capacity increased reactor volumes by a factor of 3 from a combined reactor volume of 1,080 m^3 to a combined volume of approximately 2,900 m^3.
- Slaking capacity was increased to 3.5 tonnes/hour from approximately 1.5 tonnes/hour.

The 30% design of the CWTP is limited to an update of the process design basis as listed in **Error! Reference source not found.**. Updated geotechnical, civil, mechanical, electrical and architectural designs will be prepared for the 60% design package.

4.4 Drawings

Detailed design of the CWTP will require a comprehensive package of drawings that illustrate the civil, electrical, mechanical, architectural and process design. As discussed above, CH2M Canada Ltd. issued a 90% design package for a HDS water treatment plant for the FMC in February 2014. The design and associated drawings generally meet the design basis described in Section 4.2 above, although the size of reactors, clarifier, lime slaker and some piping require modification.

Irrespective of any design changes, the drawing package is representative in form and content of a detailed HDS plant design. Only three overview drawings are provided here:

Drawing No.	Title	Revision	Status
0	Title Page		
WT-WTPP-001	Closure Water Treatment Plant Location	A	Draft
WT-WTPP-002	Closure Water Treatment Plant Example 3D Rendering	A	Draft
WT-WTPP-003	Closure Water Treatment Plant Process Flow Diagram	A	Draft

4.5 Forward Works

None at this stage of design

5.0 Implementation

5.1 Schedule Considerations

As noted above, it is expected that detailed design and construction of the CWTP will be out-sourced. The major steps involved in this process will be:

- Preparation of basis of design and tender documents (by SRK/INAC)
- Tendering and contract award (by INAC or Construction Manager)
- Detailed design (by supplier)
- Major equipment procurement (by supplier)
- Construction (by supplier)
- Commissioning and completion of operations manual (by supplier)
- Transition to operations.

Regarding overall timing, the CWTP must be completed before reclamation and closure disturbances overwhelm the capacity of the current system. Ideally, the CWTP would commence full operations before the following tasks generate significant increases in contact water volumes:

WBS Title	WBS Code	Relationship to WBS WT-WTPP
Down Valley Seepage Interception System	CW-DVIS	Full operation of the Down Valley Seepage Interception System will generate additional volumes of contact water. Interim operation could also generate enough water to require the CWTP.
Construction Water Management	MA-CONW	The control ponds will have the capacity to pump water into the Faro Pit, potentially causing a significant increase in water treatment needs.
Waste Rock Landform	MA-WRDL	Re-sloping of waste has a risk of generating large volumes of contaminated water.
Interim Water Treatment Plant Decommissioning	WT-WTPI	The new CWTP will need to be fully operational before the IWTP is decommissioned.

5.2 Critical Temporary Works

A construction laydown area will be required. Other temporary works will be defined in later stages of design.

5.3 Monitoring Requirements

Construction activities for the CWTP will be confined to the existing mill site. Erosion and sediment control plans will be necessary.

6.0 References

Applied Water Treatment (AWT). 2018. Faro Water Treatment Onsite HDS Pilot Plant Testing Report. Prepared for SRK Consulting. REV03. 14 May 2018.

CH2M Canada Ltd. 2016. Faro Mine Remediation Project. Water Treatment Plant – Plant Siting Cost Benefit Analysis. Memorandum prepared for Government of Yukon. Issued August 26, 2016. Project number 660403.

CH2M Canada Ltd. 2014. Faro Mine Remediation Project. Faro Treatment Plant Detailed Design Summary. Memorandum prepared for Government of Yukon. Issued February 28, 2014. Project number 472645.13.WT.DD.03.

CH2M Canada Ltd. 2013. Faro Mine Remediation Project. Water Treatment Plant Class 3 Capital Cost Estimate. Memorandum prepared for Government of Canada as represented by Aboriginal Affairs and Northern Development Canada and the Government of Yukon. Issued October 8, 2013. Project number 436662.13.SD.CO.

Robertson Geo-Consultants (RGC). 2018. 2017 Update of Water and Load Balance Model for Rose Creek Tailings Area (RCTA), Faro Mine, Yukon. Memo prepared for SRK Consulting. February 23, 2018.

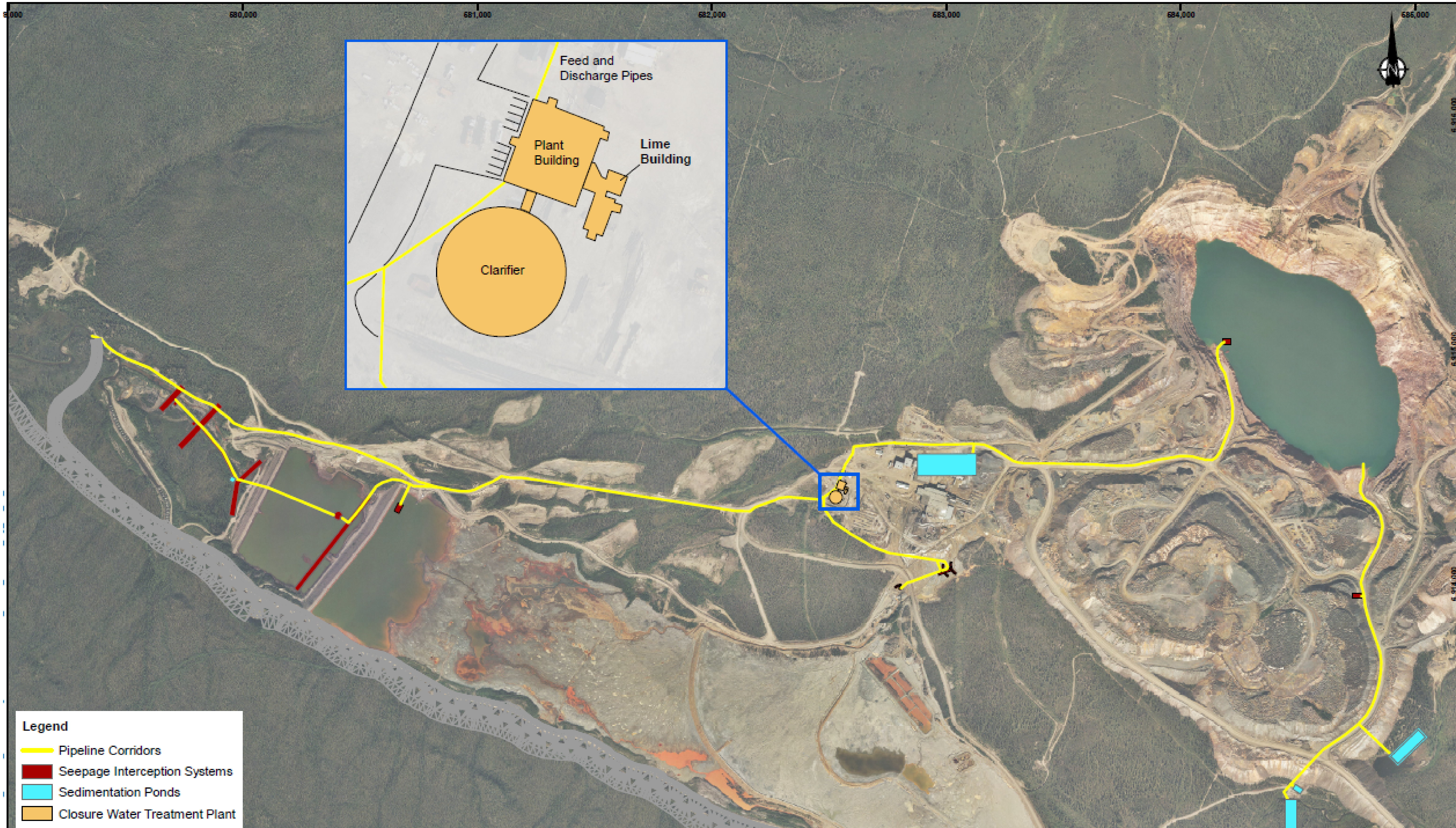
SRK, 2018a. Faro Mine Complex Water and Load Balance Model. Report prepared for Aboriginal Affairs and Northern Development Canada (INAC). June 2018.

SRK, 2018b. Faro Mine Complex Closure Water Treatment Design Capacity. Memo prepared for Aboriginal Affairs and Northern Development Canada (INAC). June 2018.

SRK, 2018c. [Hydrogeology memo/report on NFRC or scope book]. Memo prepared for Aboriginal Affairs and Northern Development Canada (INAC). June 2018.

APPENDIX A

DRAWINGS



DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE

REFERENCE DRAWINGS

REVISIONS

PROFESSIONAL ENGINEERS STAMP

srk consulting

Faro Mine Remediation Project
Projet d'assainissement de la mine Faro

DESIGN: SRJ	DRAWN: SRJ	REVIEWED:
CHECKED: JF	APPROVED:	DATE: 24 June 2018
FILE NAME:		

Faro Mine

SRK JOB NO.: 1CA030.020

Faro Mine Remediation Plan

DRAWING TITLE: Closure Water Treatment Plant Location and Contact Water Conveyance

DRAWING NO.	SHEET	REVISION NO.
WT-WTPP-001	1 of 3	A

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
REFERENCE DRAWINGS		REVISIONS									

PROFESSIONAL ENGINEERS STAMP

srk consulting

Faro Mine Remediation Project
Projet d'assainissement de la mine Faro

DESIGN: SRJ	DRAWN: SRJ	REVIEWED:
CHECKED: JF	APPROVED:	DATE: 24 June 2018
FILE NAME:		

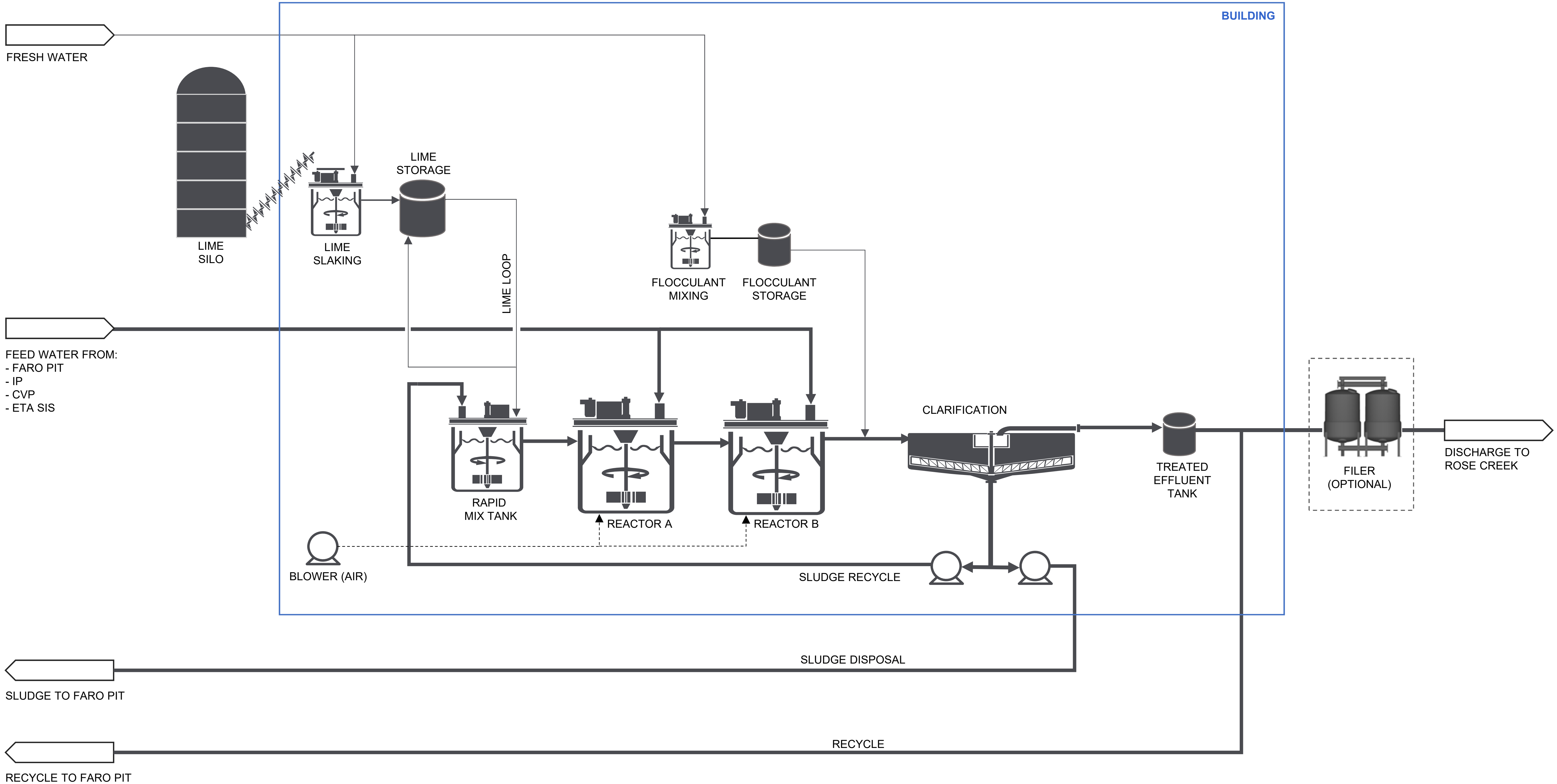
Faro Mine

SRK JOB NO.: 1CA030.020

Faro Mine Remediation Plan

DRAWING TITLE:
Closure Water Treatment Plant
Example 3D Rendering

DRAWING NO.	SHEET	REVISION NO.
WT-WTPP-002	2 of 3	A



DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
REFERENCE DRAWINGS		REVISIONS									

PROFESSIONAL ENGINEERS STAMP

srk consulting

Faro Mine Remediation Project
Projet d'assainissement de la mine Faro

DESIGN: SRJ	DRAWN: SRJ	REVIEWED:
CHECKED: JF	APPROVED:	DATE: 24 June 2018
FILE NAME:		

Faro Mine

SRK JOB NO.: 1CA030.020

Faro Mine Remediation Plan

DRAWING TITLE: Closure Water Treatment Plant Location Process Flow Diagram

DRAWING NO. WT-WTPP-003 | SHEET 3 of 3 | REVISION NO. A

APPENDIX B

QUANTITIES

Detailed quantity estimates are not normally created at the 30% design level for water treatment plants. Major equipment and construction items to be included in a 30% cost estimate are as follows:

Major Cost Items for CWTP

Erosion Protection	Overhead Crane Rails
Mobilize Concrete Plant & Trucks	WTP Building Interior Finishing
De-Mobilize Concrete Plant & Trucks	Potable Water Tank & Pump
Survey	Final Excavation Lime Silo Foundation
Third Party QC Testing	Lime System Foundation
Grade WTP Site	Lime System Supply and Erect
Import Structural Fill	Test Lime System
Permanent Erosion Control	Lime System Pedestrian Bridge
Pig Stations	Polymer System
Construct Thickener Tunnel	Reactor Installation
Construct Thickener Base	Blower Installation
Construct Thickener Walls	Piping to Thickener
Insulated Panels on Thickener Walls	WTP Inside Piping
Pedestrian Bridge WTP to Thickener	Electrical System
Install Thickener Mechanism & Test	Fans & Heaters
Final Excavation WTP Building Foundation	Instrumentation
Form & Place Foundation Walls	SCADA System
Backfill Foundation Walls	MCC
WTP French Drain System	Sludge Recycle Pumps
Install Underslab Utilities	Sludge Waste Pumps
Fine Grade & Place Granular Base	Recycle Water Pumps
Form & Place Concrete Slab	Process Water Pumps
Form & Place Equipment Pads	Lime Slurry Pumps
Supply and Erect WTP Building	Sump Pumps
Access Platforms	Start Up and Equipment Test

APPENDIX C

SUMMARY OF SUPPORING WORK

None at this stage of design

APPENDIX D

EXCERPTS OF IMPORTANT HISTORICAL WORK

None at this stage of design