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Memo

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From:	Soren Jensen	**Project No:**	1CA030.020
Cc:	Andrea Bowie, Dylan MacGregor, Daryl Hockley (SRK)	**Date:**	May 13, 2019
Subject:	Water Treatment Plant Design Basis for Faro Permanent Water Treatment Plant		

1 Introduction

The construction and operation of a new water treatment plant is one of the key elements of the remediation plan for the Faro Mine Site. The permanent water treatment plant is intended to treat all contact water collected at the Faro Mine Site for the foreseeable future. The treatment process is a high-density sludge (HDS) process, which neutralizes acidic contact water and removes dissolved metals and other constituents.

Sources of contact water to be treated in long-term operations and maintenance include:

- The Down Valley Seepage Interception System,
- The Intermediate Pond,
- The Emergency Tailings Area Seepage Interception System,
- The North Fork Rose Creek Seepage Interception System,
- The Zone 2 Pit,
- Local runoff and seepage to Faro Pit, and
- Control ponds, if runoff reporting to these do not meet effluent standards.

Treated effluent from the permanent water treatment plant will be discharged to Rose Creek and sludge produced by the treatment process will be pumped to the bottom of Faro Pit Lake for permanent subaqueous disposal.

The interim water treatment system currently in operation at the Faro Mine Site treats water collected by the S-Wells seepage interception system, the Cross Valley Pond, the X13 collection system (Component 2 of the Down Valley Seepage Interception System), the Zone 2 Pit, the Intermediate Pond and local runoff to the Faro Pit. In recent years, the interim water treatment system has operated at near full capacity and has treated between 5 Mm^3/year and 6 Mm^3/year of contact water between April and October. However, treatment capacity of the interim water treatment system is insufficient to treat all contact water collected on site when the new seepage interception systems in the Down Valley and North Fork Rose Creek are constructed and commissioned as part of the remediation works.

The required treatment capacity after remedial works was estimated by evaluating the current contact water balance for the Faro Mine Site and then adding the estimated future contact water contribution from the seepage interception systems that will be constructed and operated as part of the remediation works. Each source of contact water (both current and future) was assigned a probability distribution that accounted for the potential variability in annual flows for that source. Finally, the probability distribution for each of the flows were combined in a Monte Carlo simulation that generated a probability distribution of the required treatment capacity for the permanent water treatment plant.

This document describes the water balance analysis and model assessment that was completed to estimate the treatment capacity for long-term operation of the permanent water treatment plant. Elements of the water balance for the Faro Mine Site is described in Section 2. The analysis and model simulations used to estimate the permanent water treatment plant treatment capacity are described in Section 3 and conclusions are provided in Section 4.

2 Faro Mine Site Water Balance

2.1 Faro Mine Site Contact Water Balance

Contact water captured at the Faro Mine Site is either:

a. Stored on site in the Cross Valley Pond, Intermediate Pond or Faro Pit, or

b. Treated and discharged to Rose Creek.

Accordingly, the annual volume of contact water captured at the Faro Mine Site can be estimates as follows:

Total Contact Water Captured (m^3/year) = Volume Changes in Faro Pit, Cross Valley Pond and Intermediate Pond (m^3/year) + Discharge to Rose Creek (m^3/year)

Table 1 shows a summary of the contact water balance for 2015 to 2018. The annual volume of contact water captured ranged between 3.5 Mm^3 and 4.1 Mm^3 (average 3.8 Mm^3) over the four years. During this period, the total contact water inventory on site was reduced by a total of approximately 4.5 Mm^3 by discharging water treated by the interim water treatment system. Stage storage curves developed in MineSight 3D®, merging LiDAR and bathymetry data, were used to translate historic water level readings to volumes (SRK 2018a).

Currently, most contact water collected in the Faro Pit, the Cross Valley Pond and Intermediate Pond is runoff and seepage that report to surface reservoirs. The only specific groundwater interception is the S-Wells and Zone 2 Pit. Because the current contact water interception system primarily collects surface water (or seepage expressed on surface) it was assumed that the changes in contact water volumes collected in wet or dry years would be proportional to the total annual precipitation on site.

Table 1: Faro Mine Site Contact Water Balance Summary

Year	Units	**2015**	**2016**	**2017**	**2018**
Start	date	1/1/2015	1/1/2016	1/1/2017	1/1/2018
End	date	1/1/2016	1/1/2017	1/1/2018	1/1/2019
Delta Volume Faro Pit	m^3/year	-520,000	-1,600,000	-1,800,000	-340,000
Delta Volume CVP	m^3/year	-13,000	67,000	-55,000	-74,000
Delta Volume IP	m^3/year	92,000	-140,000	20,000	-140,000
Discharged to Rose Creek	m^3/year	4,100,000	5,200,000	5,600,000	4,600,000
Contact Water Captured	**m^3/year**	**3,700,000**	**3,500,000**	**3,700,000**	**4,100,000**
Annual Precipitation	mm/year	522.7	568.2	568.8[A]	-

Source: SRK, X:\01_SITES\Faro\1CA030.019_ClosurePlanning\Task209_WaterCollection_Treatment\Design_Basis\Design_Basis_1CA030_020_REV03_SRJ.xlsx

Note: A – based on preliminary analysis of meteorological data.

Table 2: Precipitation Probability Distribution for Faro Mine Site

Probability	Return Period	Annual Precipitation mm/year
0.995	200 Wet	775
0.99	100 Wet	742
0.98	50 Wet	709
0.95	20 Wet	662
0.9	10 Wet	623
0.8	5 Wet	580
0.571	2.33 Wet	516
0.5	2 Wet	508
0.2	5 Dry	448
0.1	10 Dry	420
0.05	20 Dry	399
0.02	50 Dry	377
0.01	100 Dry	364
0.005	200 Dry	352

Source: SRK, X:\01_SITES\Faro\1CA030.019_ClosurePlanning\Task207_ HydrologyStudies\Deliverables\Baseline Hydrology\ Report Figures _Rev1_VM.xlsx

A hydrological study was completed as part of the remedial works and the precipitation probability distribution for the project is presented in Table 2 (SRK 2019). Total precipitation measured on site ranged from 522.7 to 568.8 mm/year (average 553 mm/year) in 2015 to 2017, which is slightly more precipitation than the estimate's average of 516 mm/year (Table 2). At the time of preparation of this memo, the remaining 2017 and 2018 meteorological analysis was not complete. The water balance results for 2015 to 2017 and the frequency distribution for total precipitation was used in the future treatment capacity estimate as follows:

Total Contact Water Captured in Future Year = 3.7 Mm^3/ 553 mm/year * total annual precipitation

In other words, the estimated volume of contact water collected in future years was calculated by dividing the average volume collected between 2015 and 2017, dividing that volume by the average precipitation over the same period and multiplying by the total annual precipitation (516 mm/year). This method does not account for the fact that the precipitation frequency distribution is skewed towards wetter years. Therefore, the method used here could underestimate long-term mean annual runoff by 5% to 10%.

The assumption that annual runoff scales proportionally with total annual precipitation is also not conservative since the proportion of precipitation that becomes runoff is likely to be higher in wetter years. For example, a 1 in 100 wet year produces about 45% more precipitation than an average year (SRK 2019). However, total runoff is likely to be more than 45% greater in a 1 in 100 wet year than in an average year. Although ample flow data from undisturbed catchments near the Faro Mine Site is available to produce a frequency distribution based on flow, available flow data from developed catchments within the Faro Mine Site is limited and cannot be used to develop a frequency distribution.

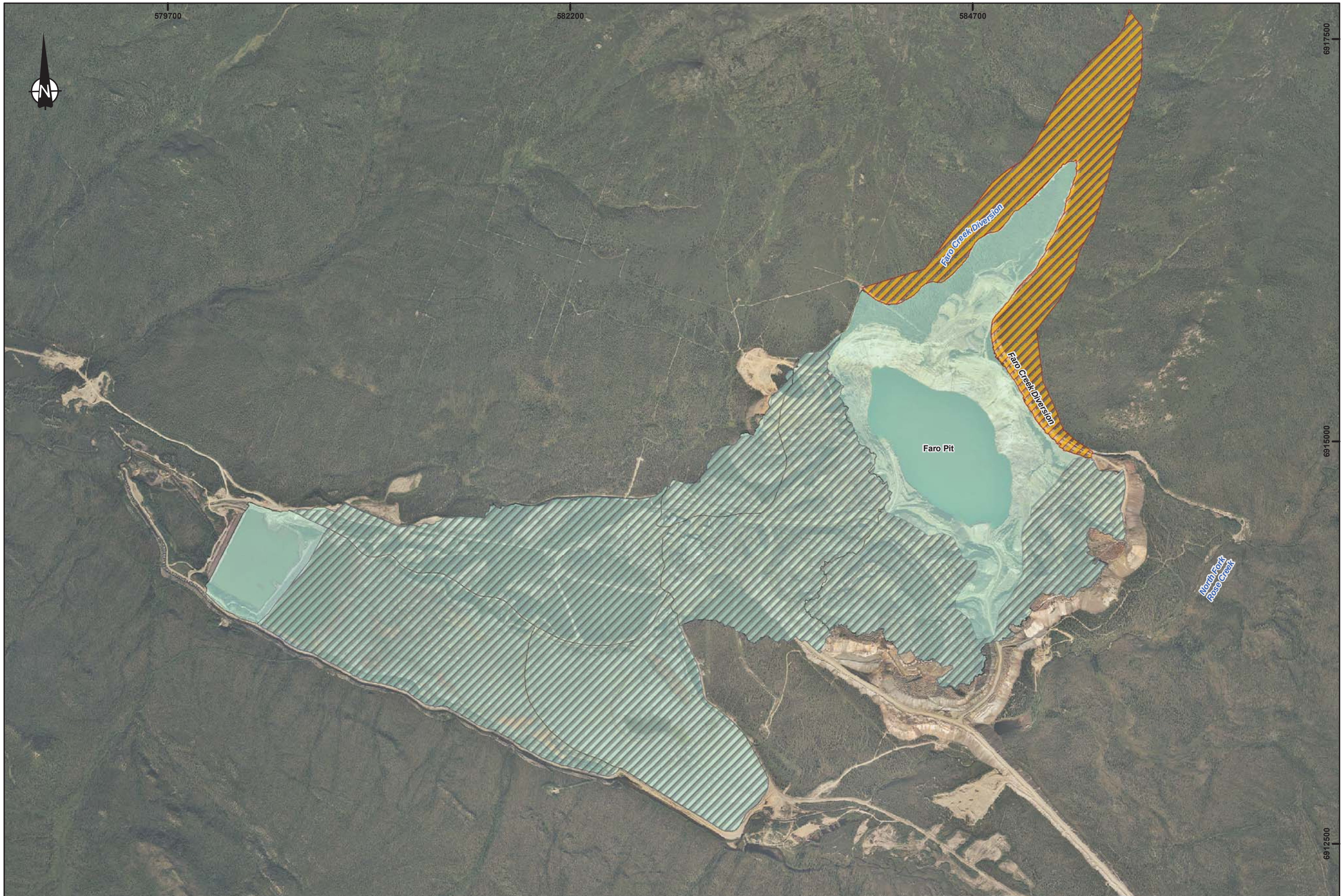
When considering the estimated treatment capacity of the future permanent water treatment plant, the available storage capacity in the Faro Pit mitigates the need to size the treatment plant for low probability, very wet events since contact water inventory can be carried over from one year to the next, if required. This means that slightly non-conservative assumptions used for estimating wet year flows are acceptable since the treatment capacity will not be selected based on those events. As a result, scaling the contact water collection estimates by total annual precipitation was deemed to be an acceptable approximation.

2.2 Clean Cover Runoff

The waste rock and tailings areas will be recontoured and covered as part of the site reclamation. Following cover construction and establishment of vegetation, runoff from covered areas is expected to be unaffected by metal leaching or acidic drainage from site and therefore suitable for direct discharge to Rose Creek. Most surface runoff within the mine area is currently collected and treated as part of the contact water collection system. Figure 1 shows the extent of the current surface runoff collection (green shading) as well as sub-catchments that are expected to produce clean runoff following completion of reclamation, an area of about 620 ha. Relocation of the Faro Creek Diversion means that the catchment upstream of the Faro Pit will increase by about 100 ha after completion of the realignment (orange shaded area in Figure 1).

As reclamation advances and transitions to long-term operations and maintenance, the net reduction in surface catchment area that will report to the contact water collection system will be approximately 520 ha (plus 100 ha from the Faro Creek Diversion and minus 620 ha from clean waste rock cover runoff). Long-term, evapotranspiration from the covered areas is expected to amount to approximately 40% of total annual precipitation, infiltration 20% and surface runoff 40% of total annual precipitation in a year with average precipitation. Using this estimate, the volume of surface runoff directed to Rose Creek from the 520 ha covered area is approximately 1.0 Mm^3/year. In other words, contact water collection is expected to be reduced by 1 Mm^3/year after the completion of all reclamation activities.

From the perspective of the design basis, the long-term reduction in contact water collection is considered a benefit that is likely to reduce future operating costs for water treatment and conveyance but not a factor that influences the design basis. The permanent water treatment plant is required to service the project through approximately 15 years of reclamation works and must therefore be designed to accommodate contact water collected through active remediation and long-term operations and maintenance.



LEGEND

Surface Runoff

- Collected/Additional, Long-Term (100 ha)
- to Rose Creek, Long-Term (620
- Currently Collected

NOTES

1. Coordinate system is NAD 1983 CSRS UTM Zone 8N.

REFERENCES

1. Aerial photo from Peregrine Aerial Surveyors Inc., photography flown August 2012.

0 200 400 600 800 1000
Meters

srk consulting

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

Job No: 1CA030.020
Filename: WLB_Cover_Runoff_SRJ_20190115

FARO MINE

Site-Wide Water and Load Balance Model Report

Surface Runoff Collection, Current and Long-Term

Date:	Approved:	Figure:
Jan. 2019	AJB	1

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2.3 Runoff from the Northeastern Waste Rock Area

Runoff from the Northeastern waste rock area is currently not captured and reports to the North Fork Rose Creek. In active remediation, the waste rock will be resloped and a cover constructed. Runoff from the waste rock cover is expected to be clean and is intended to runoff to the North Fork Rose Creek. Therefore, runoff from this area was not added to the estimate for the required annual treatment capacity for the permanent water treatment plant.

2.4 Down Valley Seepage Interception System

The annual volume of seepage intercepted by the Down Valley Seepage Interception System was estimated by Robertson Geoconsultants Inc. (RGC) and documented in RGC (2019). The average annual flow from the Down Valley Seepage Interception System was estimated at 140 L/s. Approximately 35 L/s of the 140 L/s was estimated to be flow currently captured by in the Cross Valley Pond, which is accounted for by the flow estimates for the current contact water collection system (see Section 2.1). This leaves a net new contact water flow of 105 L/s or approximately 3.5 Mm^3/year.

Actual intercepted flows from the Down Valley Seepage Interception System is uncertain due to the complex groundwater interactions. To account for this uncertainty, a triangular flow distribution was defined in consultation with RGC for use as input to the Monte Carlo model (Figure 2). Again, 35 L/s was subtracted from the upper and lower estimates as this flow was already account for in the current estimate.

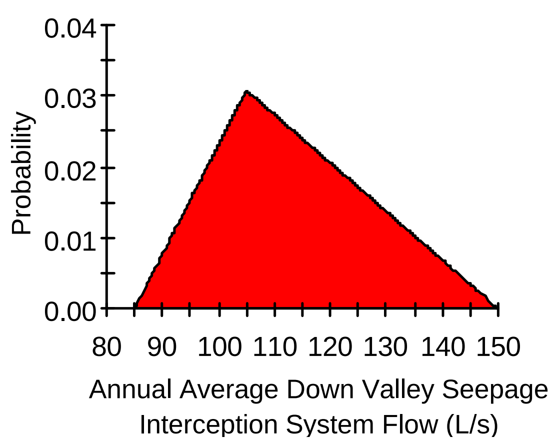


Figure 2: Probability Distribution for Down Valley Seepage Interception System Flow

2.5 North Fork Rose Creek Seepage Interception System

Some seepage that currently reports to the North Fork Rose Creek is captured by the S-Wells Seepage Interception System, however some seepage still reports to the North Fork Rose Creek. After commissioning of the North Fork Rose Creek Diversion, the flow of groundwater in the North Fork Rose Creek Valley is expected to change. The North Fork Rose Creek Seepage Interception System design is evolving in terms of the configuration for long-term operations and maintenance. In addition, it is unclear how the groundwater system in the North Fork Rose Creek Valley will behave once the North Fork Rose Creek Diversion is commissioned. Although seepage rates are uncertain, they are expected to increase and remain modest. Total collection rates were based on a combination of groundwater and surface water collection estimates.

The surface water component was calculated using a runoff analysis for the catchment contributing flow to the North Fork Rose Creek Seepage Interception System. The catchment areas included in the calculation are shown in Table 3. It was assumed that North Fork Rose Creek Diversion was 100% effective, and no runoff from the catchment areas to the east flowed into the North Fork Rose Creek Seepage Interception System. The runoff values were taken from Table 4 and applied to the total catchment area. The 1 in 100 Dry year was used in the lower estimate while the 1 in 100 Wet year was used in the upper estimate. The runoff estimates are presented in Table 5.

Table 3: Catchment Areas Reporting to the North Fork Rose Creek Seepage Interception System

Name	Area (ha)
X2	57
S-Wells	17
Z2 Outwash – Zone 2 Outwash Area	14
NEWR – Northeastern Waste Rock Dumps	65
Total Catchment Area	150

Source: \\VAN-SVR0\Projects \01_SITES\Faro\!040_AutoCAD_GIS\ArcGIS_Projects\20181229_WLB_updates_ABowie\WLB_Fig_4-01_CM-SW_1CA030-020_rev_04.mxd

Table 4: Average Monthly Flows for Different Return Periods (L/s/km^2)

Return Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 in 100 Wet	4.1	3.5	3.1	3.7	46	43	26	21	25	19	21	8.4
Average	3.1	2.6	2.3	3.8	33	32	16	14	14	13	16	6.6
1 in 100 Dry	2.2	1.7	1.4	4.0	21	21	6.3	7.5	3.6	5.9	11	5

Source: \\VAN-SVR0\Projects\01_SITES\Faro\1CA030.019_ClosurePlanning\Task209_WaterCollection_Treatment\Plant_Siting_Tradeoff\ Average_Monthly_Runoff_VM_20171005\ Regional_Runoff_Rev2

Groundwater collection rates were based on a study of groundwater flows in the North Fork Rose Creek Area by BGC (2017). The S-wells contribution is already accounted for under the current water inventory (discussed in Section 2.4) and is not expected to change during long-term operations, therefore, it was not included in the North Fork Rose Creek Seepage Interception System flows. SRK completed some Darcy flow calculation sensitivities to estimate the upper and lower ranges of possible groundwater collection in this area. The results are presented in Table 5.

Table 5: Summary of the North Fork Rose Creek Flow Estimates

Component	Flow Estimates (L/s)		
	Lower	Average	Upper
Surface Water Contribution	3	5	12
Groundwater Contribution	6	9	13
Total	9	14	25

Source: \\VAN-SVR0\Projects\01_SITES\Faro\1CA030.019_ClosurePlanning\Task209_WaterCollection _Treatment\Plant_Siting_Tradeoff\Seasonal_Treatment\ Faro_ScreeningWT_SeasonalDischarge_1CA030-019_R08_ad_ajb_mcn

Figure 3 shows the assumed triangular probability distribution that has a central value of 14 L/s, a minimum of 9 L/s and a maximum of 24 L/s.

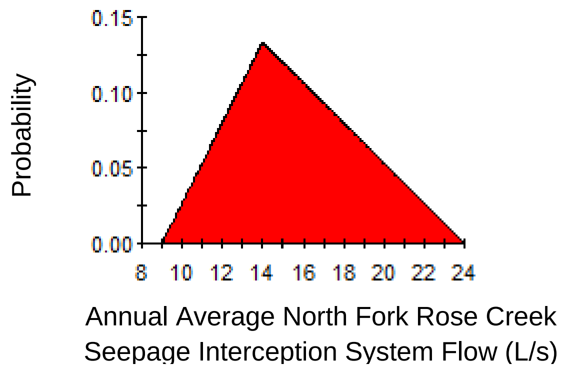


Figure 3: Probability Distribution for Down Valley Seepage Interception System Flow

2.6 Emergency Tailings Area Seepage Interception System

Contact water that will be collected at the Emergency Tailings Area Seepage Interception System used to report to the Intermediate Pond or to the Rose Creek Aquifer. Up until 2019, up to 10 L/s of contact water was lost through the coarse tailings to the Rose Creek Aquifer (RGC 2019) with the remaining contact water flowing to the Intermediate Pond. Since the Emergency Contact Water is included in the current contact water inventory (discussed in Section 2.1), the Emergency Tailings Area Seepage Interception System was assigned a constant flow of 10 L/s, which represents a conservative assumption around contact water capture.

2.7 Faro Creek Diversion

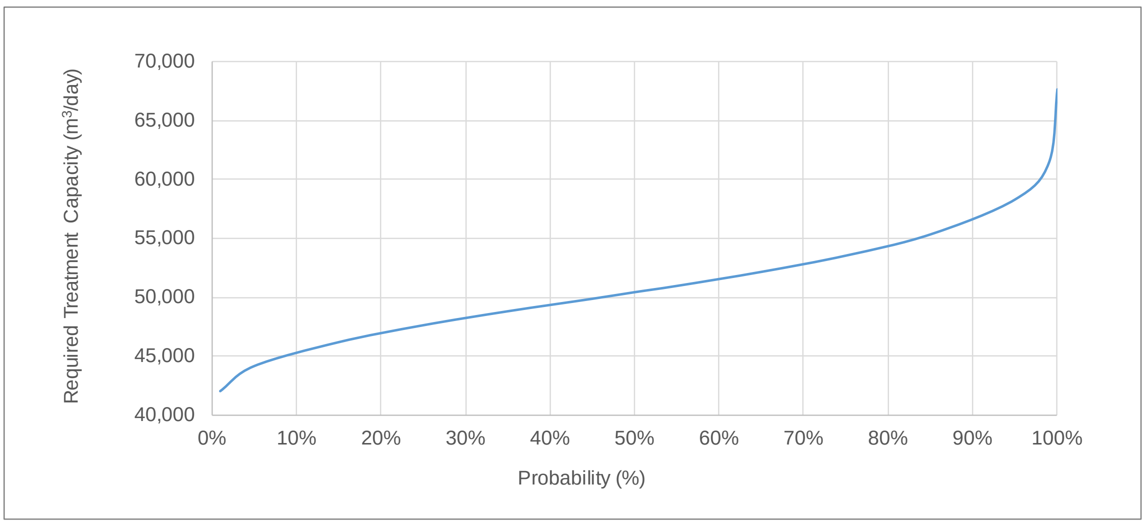
Water currently reporting to the Faro Pit includes water that by-passes the Faro Creek Diversion. The annual volume that by-passes the diversion is difficult to estimate, but could be as high as 1 Mm^3. The remedial works includes upgrades to the Faro Creek Diversion. Although this may result in a reduction of clean water bypassing the diversion, it is not possible to develop a reliable estimate of improvements to the diversion efficiencies. Therefore, a reduction in by-pass was not incorporated in the estimates for the permanent water treatment plant treatment capacity.

3 Simulation and Results

The estimated distributions of current flows from site and flows from the sources that will come online in long-term operations and maintenance were incorporated in a Monte Carlo Simulation. In the simulation, a total of 10,000 one-year scenarios were run. In each scenario, flow from each of the defined inputs were sampled randomly from each distribution. Each simulation would calculate the total volume of contact water captured. At the end of the simulation, the 10,000 values of calculated total contact water volumes were ranked and a probability distribution of the results was generated.

Estimates of the required annual treatment capacity were calculated by dividing the total contact water volume by the number of operating days. The permanent water treatment plant was assumed to discharge treated water each year from May 15 to October 30 and the mechanical availability of the plant was assumed to be 95%, which corresponds to a total of 160 effective operating days.

Figure 4 shows the result of the probabilistic simulation, which was converted to permanent water treatment plant treatment capacity by dividing by 160 effective operating days. The results show that there is an 85% probability that the permanent water treatment plant can treat all contact water collected in one year if the treatment capacity is 55,000 m^3/day, which means that there is a 15% chance that some volume of contact water will have to be carried over to the next operating year or that the treatment season will have to be extended. At a capacity of 61,000 m^3/day, there is a 99% probability that the contact water collected in any one year can be treated and discharged. On average, the treatment capacity required by the permanent water treatment plant according to this analysis would be 51,000 m^3/day.



Source: SRK, Design_Basis_1CA030_020_REV03_SRJ.xlsx

Figure 4: Probability Distribution for Permanent Water Treatment Plant Treatment Capacity

4 Conclusion

SRK recommends a treatment capacity of 61,000 m^3/day for the following reasons:

- The method used to calculate contact water yield in wet and dry years (Section 2.1), could underestimate annual runoff by 5% to 10%.
- The recommended capacity is only 20% greater than the estimated capacity required in an average year.
- The flow distributions used to generate estimates of annual treatment volumes are based on best available information but are uncertain. The selection of a treatment capacity that is slightly conservative reduces the risk of under-sizing the permanent water treatment plant.
- The analysis above did not consider some factors such as the value of operational flexibility. For example, it is possible that the rate of discharge from the permanent water treatment plant must be paced to follow the variability of flow in Rose Creek, rather than operate at a constant though-put for the duration of the treatment season. A greater treatment capacity would allow the operations to make better use of the assimilative capacity in the creek during periods of high flow.

This memorandum, Water Treatment Plant Design Basis for Faro Permanent Water Treatment Plant, was written by

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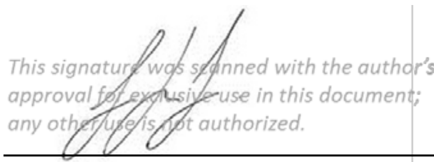

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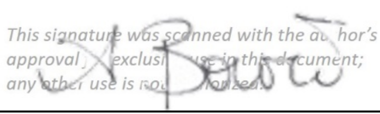
And reviewed by



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5 References

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