FMC211

draft for discussion

Anvil Range Mine, Rose Creek Tailings Facility - 2003 / 2004 Groundwater Modelling – Groundwater Interception Scenarios

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1. Introduction

This report summarizes the results of a series of groundwater pumping scenarios that were run using the Rose Creek Tailings Facility groundwater flow model. This exercise was conducted to provide a preliminary feasibility assessment of possible groundwater collection/interception systems for potentially contaminated groundwater from the Rose Creek Tailings Facility. The MODFLOW based three-dimensional groundwater flow model that was originally developed in 2001 by Gartner Lee Limited for the Rose Creek Tailings Facility was used for this analysis. Details of the model construction, assumptions, data sources and calibration is fully documented in Appendix J of the report entitled *"Rose Creek Tailings Facility, 2001 Hydrogeological and Geochemical Investigations, Faro Mine, Yukon"*.

1.1 Scope of Work

As per the workplan of August 18, 2003, tasks completed as part of this project include:

1. Completion of a the down-valley seepage field program (October 7-9, 2003);
2. Upgrade and re-calibration of the 2002 numerical groundwater flow model;
3. Completion of eight groundwater interception scenarios, including particle tracking to determine interception effectiveness; and
4. First-order cost estimates for construction and operation of various groundwater inception scenarios.

2. Model Upgrade

2.1 Groundwater Discharge Assessment

A prioritydata gap identified in the 2001 groundwater model was the amount and location of groundwater discharge in the area downstream of the Cross Valley Dam (also known as the down Valley area). In order to address this data gap, a groundwater discharge field investigation was completed between October 7 and 9, 2003. This period was chosen because it is after the completion of discharge from the Cross Valley pond had been completed and is believed to represent a time of low surface water flows. The groundwater discharge assessment determined discharge rates over seven reaches of the former Rose Creek channel and the Cross Valley Dam toe drains. Groundwater discharge was determined primarily through detailed stream gauging supplemented by the use of in-stream mini-piezometers and seepage meters (see Lee and Cherry 1978).

Results of the groundwater discharge assessment are illustrated on Figure 1. A summary of the groundwater discharge measurements along the calibrated model discharges is presented in Table 1.

2.2 Model Refinement

Based on a further understanding of the hydrogeological regime and to better address the objectives of this study, the following refinements were made to the numerical flow model:

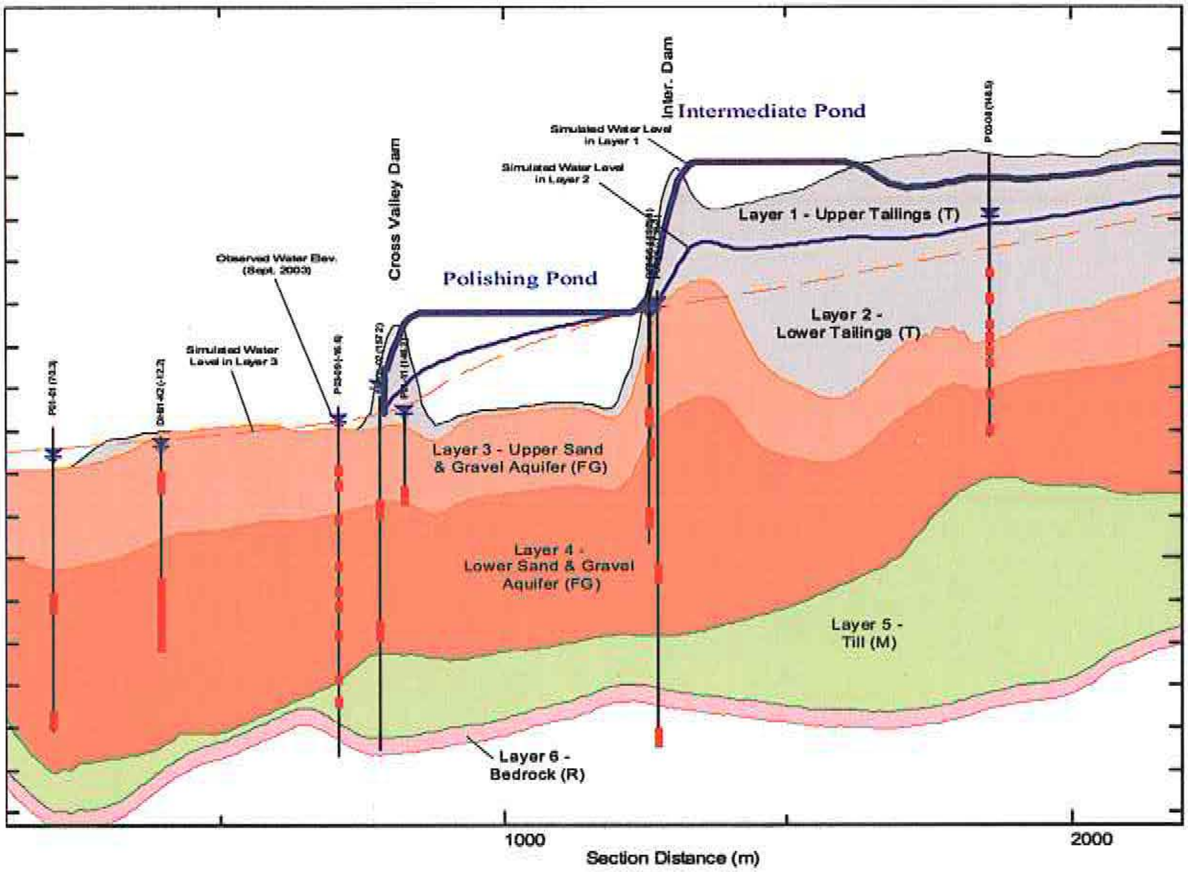
1. The sand and gravel aquifer was divided into two model layers (new layers 3 and 4) representing the upper one third of the aquifer and the lower two thirds as shown on Figure 2. The purpose for this was to allow for modeled interception wells to be placed in the upper third of the aquifer. Both layers were assigned the same hydraulic conductivity values and initial boundary (Ibound) conditions.

2. Moderate adjustments of hydraulic conductivity of the sand and gravel aquifer were made to better match observed water levels that were measured in the existing and the new multilevel wells. The new hydraulic conductivity values are shown on Figure 3.

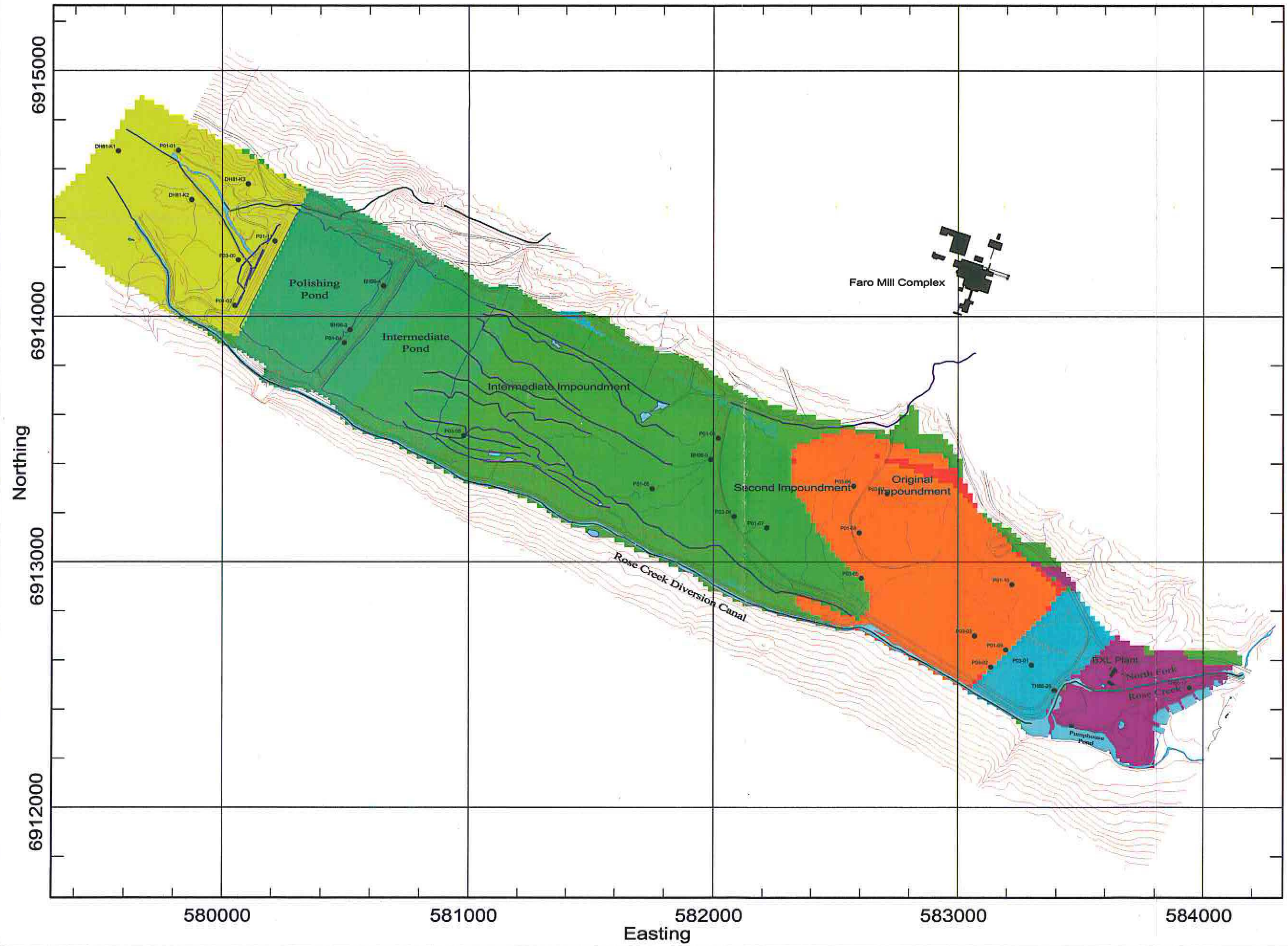
3. The7 leakage from the Cross Valley Pond was reduced. Hydraulic conductivity for the sediments lining the Cross Valley Pond was reduced in order to better match heads observed in the sand and gravel aquifer (model layers 3 & 4). This area was originally modeled as having a K value of 3×10^{-7} m/s, but this was reduced to 9×10^{-8} m/s. This change results in a reduction of modeled net leakage from the pond of 17.6 L/s (from a total leakage of 51.4 L/s to 33.8 L/s). Figure 2 also shows simulated heads in this area. Observed heads in monitoring wells are shown on this figure with small water level symbols.

Figure 1. Down Valley Groundwater Discharge

Figure 2. Model Layers at Cross Valley Dam area



4. Addition of gravelly surficial materials (Layers 1 & 2) at toe of Intermediate Dam to more accurately model the known dam construction. The 2001 model assumed a uniform blanket of fine grained material lining the Cross Valley Pond (hydraulic conductivity zone 45, see Figure J15 of the original modelling report). However, it was recognized that this is not likely representative of the gravelly material forming the submerged downstream toe of the Intermediate Dam. Therefore a new zone (41) was applied to the toe bench of the Intermediate Dam with an assumed hydraulic conductivity of 5×10^{-5} m/s. The dam core was left intact with a hydraulic conductivity of 3.4×10^{-7}. The effect of this change is that more water now reports to the Cross Valley Pond from the aquifer. This is about 1.6 L/s, primarily along the northern portion of the Intermediate Dam toe. Furthermore, about 30% of the particles released as part of the "existing conditions" scenario report to the Cross Valley Pond (see Figure 4.) Most of these particles come from the Intermediate Pond area.



LEGEND:
- Groundwater Monitoring Locations
- Particle Tracks
- Model Rivers
- Model Drains

+ Hydraulic Conductivity of Sand & Gravel (Layer 3 & 4)
0.00015 — 0.001 — 0.002

NOTES:
- Original drawing produced in colour

SCALES: 1:15000 Scale — 0, 200, 400, 600 metres

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Aquifer (Layers 3 & 4)
Model Hydraulic Conductivity

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Drawing No. 3

5. The recharge applied to the tailings areas was reduced. The initial model applied a constant 125 mm/yr across the model. However, in consideration of the likely increased evapotranspiration losses anticipated for the bare tailing surface, the modeled recharge to these areas was reduced by 25% to 95 mm/yr. Further work is recommended to validate this assumption.
6. Other minor model "housekeeping", such a removal of problematic cells (e.g. isolated, thin, perched cells, etc.), was also performed.

Detailed refinement of the model geometry (e.g. stratigraphic contacts) based on the 2003 drilling has not yet been completed, however drilling results are generally consistent with the existing model geometry and the model is considered suitable for the purpose of this report.

2.3 Model Calibration

Along the with model refinements outlined above, the model was calibrated to the water elevations observed in September 2003. The following pond elevations were used (prorated between water level measurements on September 18 and 24, 2003):

1. Cross Valley Pond – 1028.94 m ASL
2. Intermediate Pond – 1046.7 m ASL

The model drains in the Down Valley area were calibrated to match the discharge rates observed in October 2003. Results of the modeled discharges for these drains are presented in Table 1.

Table 1. Summary of Observed and Modelled Groundwater Discharges in Down Valley Area.

Drain / Reach	Measured (Flow (L/s)	Calculated Groundwater Discharge(L/s)	Modeled Groundwater Flux (L/s) [2]	Channel Geometry Used in Model		
				Average Width	Average Water Depth	Channel Depth
NW Interceptor (at road) [1]	5.3	-5.3	0.21	1.5	0.1	1
X11	10.9	10.9	-10.6	1.5	0.2	1
Weir 3	4.2	4.2	-4.2	0.5	0.05	1.5
X12	0.6	0.6	-0.54	0.75	0.1	1.5
X13	24.5	8.7	-8.7	1.5	0.1	3.5
FRCC#4	28.2	3.72	-3.6	2.5	0.15	3
FRCC#2	33.9	5.72	-0.86	4.2	0.15	3
FRCC#1	40.12	6.17	-6.4	15.5	0.15	2.5
Total Down Valley Groundwater Discharge	**34.8**	-	**-34.7**	-	-	-

[1] *All water from NW Interceptor goes to ground at end of spillway. Likely re-emerges by confluence with Rose Cr.*

2 negative numbers indicates water leaving the model

The water balance for the upgraded model is as follows:

Table 2. Volumetric Water Budget for 2003/2004 Rose Creek Numerical Groundwater Model

Water IN	L/s	Water OUT	L/s
From Upstream aquifer	23.1	Seepage to North Fork Rose Creek	1.94
Seepage from North Fork Rose Cr.	0.01	Seepage to Rose Creek Diversion Canal (Upper/Original Section)	0.52
Seepage from Rose Creek Diversion Canal (Lower Section)	1.38	Old Rose Creek Channels (downstream of Cross Valley Dam)	10.6
Seepage from North Wall Interceptor Ditch	0.18	Toe Seepage at Cross Valley Dam	23.8
Seepage from Intermediate Pond	3.27	Runoff Intermediate Tailings Surface (Tailings surface drains)	1.07
Net Seepage from Cross Valley Pond	33.8	To Downstream Aquifer	32.3
Recharge	9.9		
Total Modelled Inputs *	**79.1**	**Total Modelled Outputs ***	**78.7**

** Total as reported by MODFLOW water balance summary, includes some in-out terms accounted for as net items above.*

The upgraded model mass balance error was **0.42%** (errors of less than 2% are generally considered acceptable). Total modelled flow in the aquifer at the downstream extent of the model (e.g. X14 area) is 32.3 L/s.

3. Groundwater Interception Scenarios

The purpose of the groundwater interception strategy is to develop a first-order estimate of the level of effort required to capture all, or a portion of, the potential groundwater contamination originating from the Rose Creek tailings impoundment. Although there are no immediate downgradient groundwater users (e.g. domestic water supply), there is concern that zinc contaminated groundwater will discharge to fish bearing surface water (e.g. Rose Creek).

The simulations presented herein represent a simple pump and treat strategy – that is potentially contaminated groundwater is pumped from the aquifer via a series of interception wells. This contaminated water would then be pumped to the existing mill water treatment plant and ultimately released back to Rose Creek. The issue of water treatment is not covered in this work. Furthermore, the current work does not consider any changes to the current hydrogeological regime of the site, other than the pumping wells. For example, no consideration was given to change of pond elevations, cover systems, or significant changes in other surface water interactions. Additionally, the current work does not consider other remedial options such as in-situ treatments, passive treatments, diversion, capping, stabilization or other alternatives.

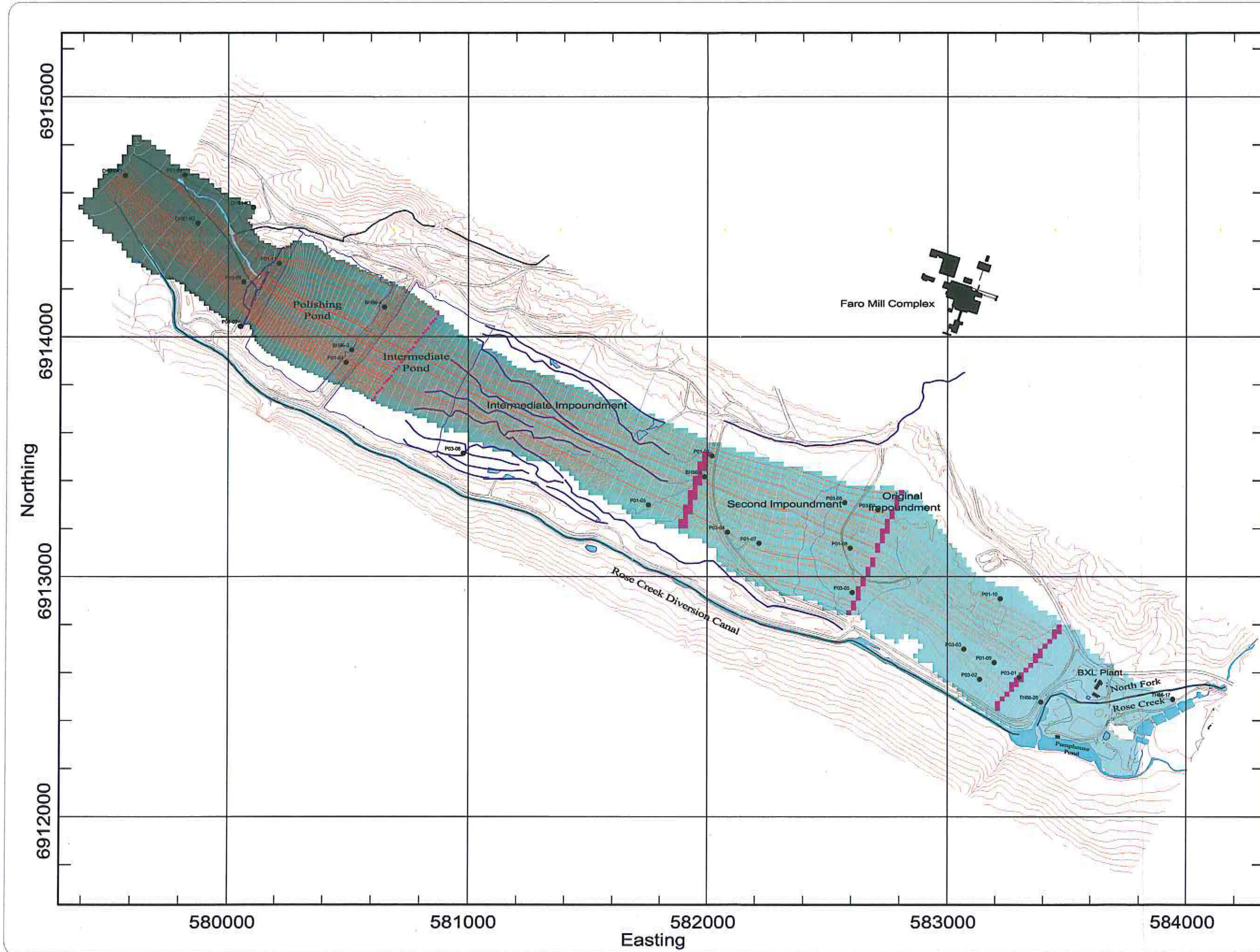
3.1 Conceptual Model

Potential contaminants of concern (PCOC) consist primarily of zinc with sulphate used as a relatively recalcitrant indicator parameter. Conceptually, the PCOC originates from the tailings mass. Water flows generally downward through the mass, driven primarily by precipitation falling on the tailings surface. The water becomes contaminated while moving through the tailings mass. This water then originates from the base of the tailings deposits into the underlying native soils. There is no liner between the tailings and the native sediments, other than a discontinuous, thin native organic soil that may have been left in-situ before tailings deposition. These native sediments consist primarily of glaciofluvial sand and gravel consisting the Rose Creek aquifer. Flow in the aquifer is primarily horizontal with no significant vertical gradients within the aquifer. This conceptual model was generally demonstrated by the initial (fall 2003) monitoring results from the 2003 multi-level well installations. The multi-levels indicate downward gradients in the tailing, but almost no vertical gradients within the aquifer. Therefore, in much of the study area, there are no significant gradients to move contaminated water deep into the aquifer, other than dispersive processes. The exception to this is the area of the Cross Valley Pond. Leakage from the pond is believed to displace flow from upgradient in the aquifer, thereby "pushing" contaminated groundwater deeper into the aquifer (see Figures 8.1 or 8.3 of the 2001 Tailings assessment report). Lastly, hydraulic "short-circuiting" (e.g. failed wells casings) may allow contaminated water to move to unexpected places within the flow system.

3.2 Formulation of the Problem

Based on the above-described conceptual model, the groundwater interception strategy can focus primarily on the upper portion of the flow system within the aquifer. This upper portion of the aquifer should contain the bulk of the contaminated groundwater, if present. The crest of the Intermediate dam was selected as the line of interception. The location of the interception wells are shown on Figure 5 as a series of yellow triangles. This location is at the downstream extent of the tailings and could potentially capture all contaminants originating from the upstream impoundment. A location further downgradient from the tailings is not desirable because under the current operation, the leakage from the Cross Valley Pond would likely displace contaminated groundwater deeper into the aquifer, making recovery more expensive and difficult. The crest of the dam was selected as opposed to the downstream toe bench because it is further from the Cross Valley Pond. It is likely that some of the water recovered by a system described above would be water drawn from the Cross Valley Pond. Therefore, moving further from this pond is desirable in order to reduce pumping and treating of relatively "clean" water from the Cross Valley Pond.

The effectiveness of a pumping scenario was evaluated by use of simple particle tracking. Particle tracking is accomplished by using the MODPATH code. In this task, a series of particles are released from the base of the tailings, into the Rose Creek aquifer. The migration of the particles along the groundwater flow path is then simulated by the model. To evaluate the effectiveness of a pumping scenario, the relative percentage of particles being captured by pumping wells was used. For example, if 50 particles were released across the tailings impoundment, and 25 of those particle reported to wells, where the other 25 flowed past the wells and out of the downstream end of the model, then the scenario was assumed to capture 50% of the contaminant in the aquifer. The simple particle tracking does not account for dispersion nor any other attenuation mechanisms. Therefore, from a contaminant attenuation perspective, this approach is conservative. A series of three transects across the tailings impoundment as shown on Figure 4 were used as particle sources. Particles were released from the middle on the lower tailings (Layer 2). Areas where the tailings are underlain by till (model Layer 5) were not assessed as these are unlikely to transmit a significant mass of contaminant relative to that that can be mobilized by the sand and gravel aquifer. Depending on the scenario run, between 160 and 210 particles were used in the simulations. Particle tracks for current (non-pumping) conditions were run to illustrate the modeled fate of such particles (see Figure 4).



LEGEND:
- Groundwater Monitoring Locations
- Particle Sources
- Particle Tracks
- Model Rivers
- Model Drains

NOTES:
- Original drawing produced in colour

SCALES

1:15000 Scale

0 200 400 600

metres

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Particle Sources and Tracks Under 2003 Conditions

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Drawing No. 4

3.3 Pumping Scenarios

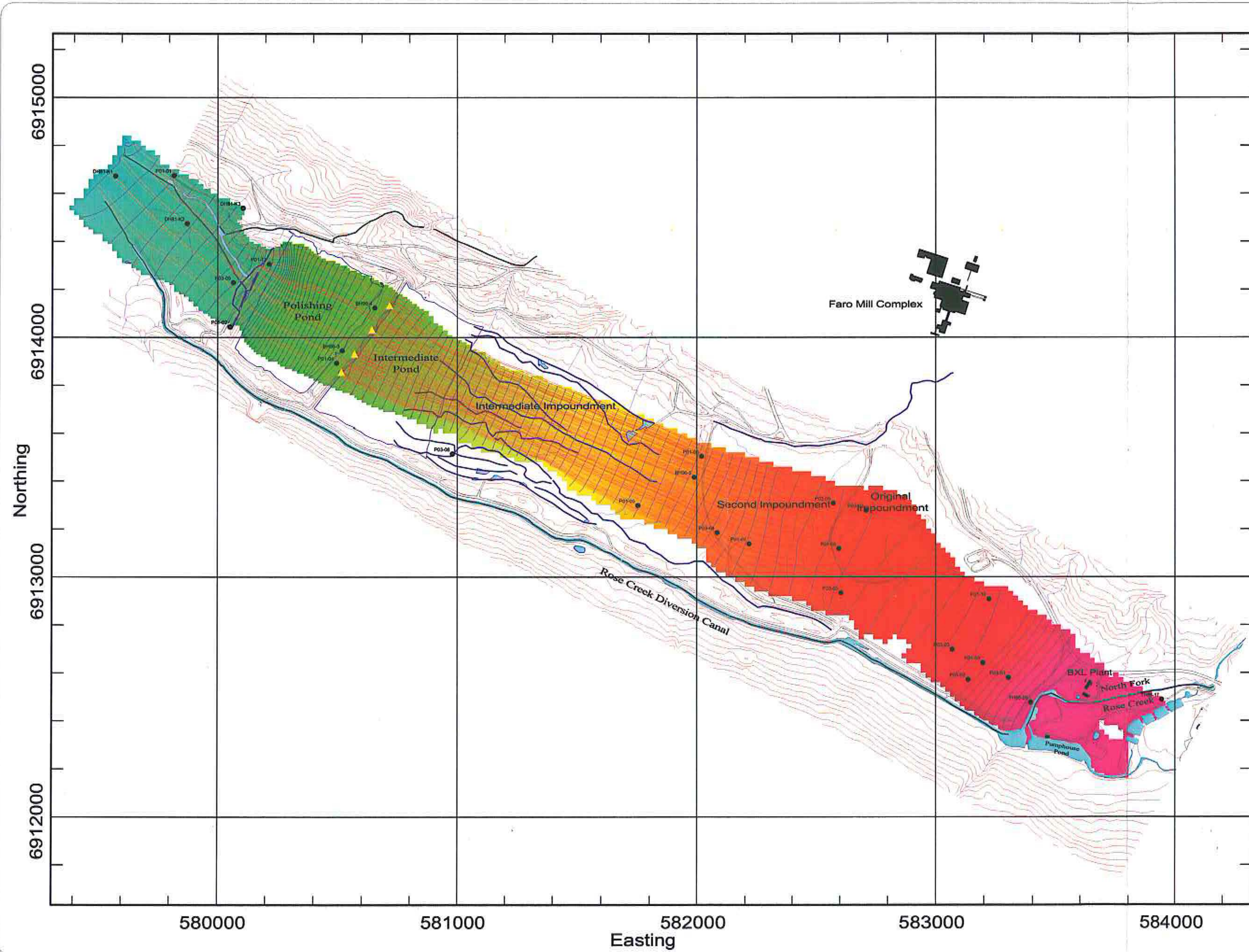
A series of eight scenarios were run to assess the viability of contaminant interceptions. The scenarios consist of 4, 8 or 16 wells pumping at various rates. Table 3 lists the scenario details and resulting capture effectiveness. Note that multiple other intermediate scenarios were run in the development of those listed, however these intermediate scenarios were not documented or saved. The particle tracks and interceptions are illustrated for Scenarios 1 and 6 on Figure 5 and Figure 6 respectively. Scenarios 7 and 8 are discussed separately below. The well locations are illustrated as small yellow triangles.

3.3.1 Aquifer Capture Scenario

Scenarios 7 and 8 were developed to address the "worst-case" scenario. Under these scenarios, the objective is to capture all of the water flowing in the aquifer upgradient of the Intermediate Dam as opposed to capture of only contaminants in the upper portion of the aquifer. This scenario considers the concern that all water in the aquifer could become contaminated. To simulate this scenario, the particles were released at various depths across the entire aquifer thickness (Layers 3 and 4). A series of 16 interception wells were placed in both layers of the aquifer (see Figure 7).

Table 3. Summary of Groundwater Interception Scenarios

Scenario No.	Number of Wells	Pumping Rate per Well (L/s)	Total Pumping Rate (L/s)	Capture Rate Effectiveness (%)	Comment
1	4	3	12	81%	Results illustrated on Figure 5
2	4	5	20	92%	
3	8	1	12	66%	
4	8	2	16	90%	
5	8	2	16	51%	Wells completed in lower portion (Layer 4) of aquifer to see if results are significantly different
6	16	1.4	22.4	98%	Higher rate of tailings water capture, results illustrated on Figure 6
7	16	2	32	86%	Wells completed to capture all water in aquifer (wells in Layers 3 and 4). Results illustrated on Figure 7
8	16	3.5	56	100%	



LEGEND:

- Groundwater Monitoring Locations
- Extraction wells - 4
- Particle Tracks
- Model Rivers
- Model Drains

Scenario 1 - Modeled Heads in Layer 3 (Upper FG)

Contour Line Start: 1010 Step: 0.5 Stop: 1070

1010 1020 1030 1040 1050 1060 1070

NOTES:

- Original drawing produced in colour
- 4 wells pumping at 3 L/s each from Layer 3 (upper sand & gravel aquifer, FG)
- Model run - T_4.MDF

SCALES

1:15000 Scale

0 200 400 600

metres

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Groundwater Interception
4 Wells Pumping at 3 L/s

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Site Name:	FARO	File Name:	RoseCr03.map

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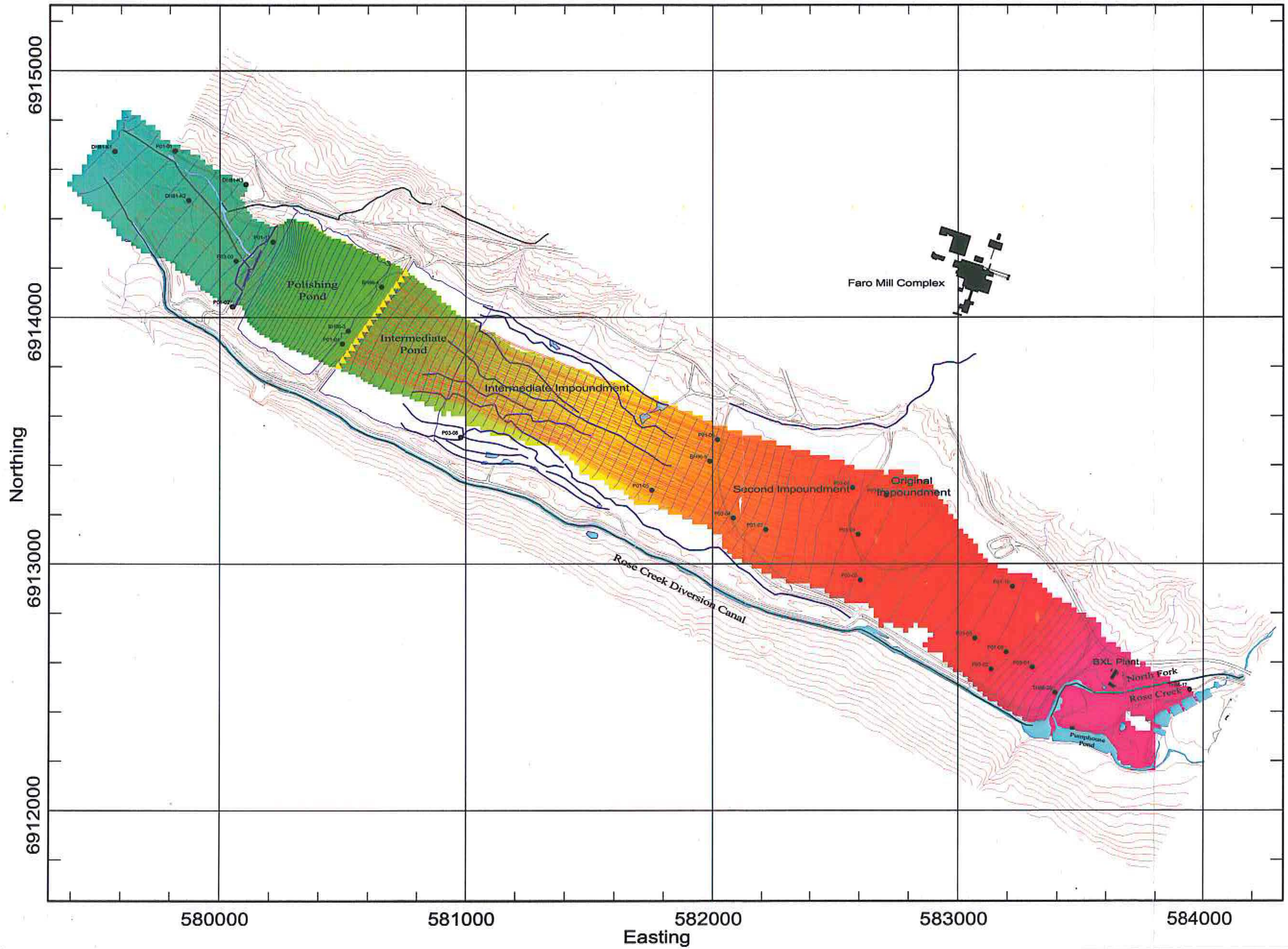

LEGEND:
- Groundwater Monitoring Locations
- Extraction wells - 16
- Particle Tracks
- Model Rivers
- Model Drains

Scenario 6 - Modeled Heads in Layer 3 (Upper FG)

1010 1020 1030 1040 1050 1060 1070

NOTES:
- Original drawing produced in colour
- 16 wells pumping at 1.4 L/s each from Layers 3 (upper sand & gravel aquifer, FG)
- Model run - T_16.MDF

SCALES

1:15000 Scale

0 200 400 600

metres

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Groundwater Interception
16 Wells Pumping at 1.4 L/s

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Site Name:	FARO	File Name:	RoseCr03.map

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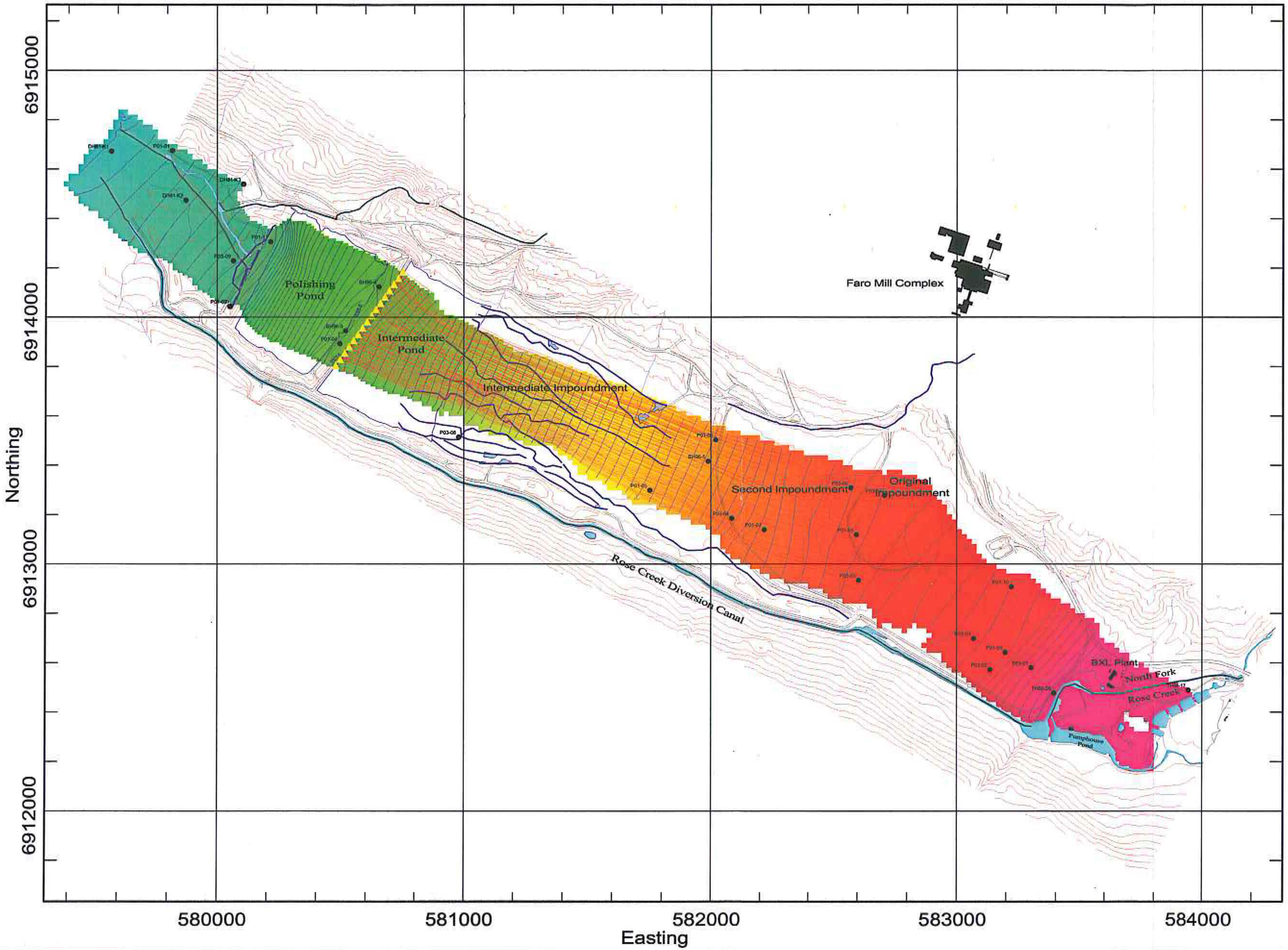
Drawing No. 6



LEGEND:

- Groundwater Monitoring Locations
- Extraction wells - 16
- Particle Tracks
- Model Rivers
- Model Drains

Scenario 8 - Modeled Heads in Layer 3 (Upper FG)
Contour Line Start: 1010.0 Step: 0.5 Stop: 1070.0
1010.0 1020.0 1030.0 1040.0 1050.0 1060.0 1070.0

NOTES:

- Original drawing produced in colour
- 16 wells pumping at 3.5 L/s each from Layers 3 & 4 (upper and lower sand & gravel aquifer, FG)
- Model run - MaxCapture1.MDF

SCALES
1:15000 Scale
0 200 400 600
metres

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Aquifer Interception
16 Wells Pumping at 3.5 L/s

Drawn By:	F.K.P.	Reviewed By:	E.J.D.
Version No.:	1	Project No.:	23-576
Date Issued:	4/26/2004	Projection:	UTM z8 NAD27
Site Name:	FARO	File Name:	RoseCr03.map

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Drawing No.
7

4. Pumping Scenario Cost Estimates

First-order capital, operation and maintenance (O&M) cost estimates have been prepared for the various pumping scenarios. Year-round operation of the system has been assumed. Detailed examples of the capital and O&M costs for the end-member scenarios are provided in Appendix A. The concepts presented here in are for conceptual planning purposes and do not represent an engineered design of any level. Assumptions used in this costing are as follows:

4.1 Components and Capital Cost Assumptions

It is envisioned that the groundwater interception system would consist of the following components:

1. A detailed hydrogeological assessment of the proposed interception area, including drilling and pumping test of one test well - $84,000 to $92,000 depending on well depth.
2. A series of 152 mm diameter steel-cased water wells with stainless steel screens. The top 1/3 of the aquifer would be fully screened. Based on current drilling costs, costs of each well are estimated at $23,000 per well. Well costs are estimated at $50,000 per well for Scenarios 7 and 8 where the wells are completed across the entire aquifer thickness—this accounts for deeper wells and significantly longer well screens. Mobilization of the driller would likely be an additional lump sum cost of $7,000.
3. Small production pumps plus riser pipe and installation are estimated at $5,000 per well.
4. Well tie-in back to a collection tank (assumed at the north end of the Intermediate Dam) is estimated at $300/m. This based on typical installation costs for buried, insulated pipe, however in the case of the Intermediate Dam, this would require careful consideration. This cost also includes control/power cable for the well pumps.
5. A collection tank, small heated building and booster pump to the mill - $100,000
6. Electrical hookup for the collection building and pump controls - $30,000. This assumes that three-phase power is available at the Intermediate Dam. Costs for bring that service to the Dam, if required, have not been included but is reported to be on the order of $3 million.
7. 3025 m of insulated water line at $350/m from the Intermediate Dam to the mill.
8. Tie-in of the water line to the water treatment plant - $6,000
9. Engineering and construction supervision – plus 35% of total costs.
10. Contingency – plus 25% of total costs.

Table A1 and A2 in Appendix A provide an example of the capital costs for the two end-member scenarios (Scenarios 1 and 9).

4.2 O&M Cost Assumptions

Operation and maintenance cost assumptions for this groundwater collection system are listed below. It was assumed that there will be year-round operation. Water treatments costs are NOT included in these estimates:

1. Pump selection and operating costs are from the Grundfos WinCAPS Version 7 Pump Selection Catalogue. Well pump assumptions are as follows:
   - Pumps set 33 m below dam crest;
   - Static level of 20 m below dam crest plus 5 m static lift above ground;
   - Dynamic head based on specific capacity of 1.3 L/s/m; and
   - Total piping head loss of 1.8 m (average piping run of 330 m to north end of dam).

   Booster Pump to mill assumptions are as follows:
   - 93 m lift from Intermediate Dam to mill; and
   - 3025 m long, 6" or 8" diameter pipeline to mill for a total head loss of 22 to 37 m.
2. Well rehabilitation will be required once every four years for each well. This is due to anticipated fouling of wells due to poor quality water. The cost of rehabilitation is estimated at $15,000 per well.
3. Pump replacement of once every four year for each well. Pump replacement is estimated at $5,000 per well and is assumed to occur concurrently with the well rehabilitation.
4. System operator of 6 hours per week at $50/hour.
5. Miscellaneous items such as road maintenance, building maintenance and insurance are assumed to total $6,500 per year.

Table A3 and A4 in Appendix A provide an example of the capital costs for the two end-member scenarios (Scenarios 1 and 8).

4.3 Summary of Costs for Pumping Scenarios

From the assumptions presented above, capital and O&M costs for the scenarios presented in this report are summarized on Table 4. These costs are for collection and pumping of the water to the mill only and do not include the associated water treatment costs.

Based on these cost estimates, the largest capital cost item for the interception system is the water line back to the mill. This line accounts for approximately half the total system costs. With respect to system operation and maintenance, power costs, especially for the booster pump back to the mill, represent the largest cost, followed by well rehabilitation.

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Table 4. Groundwater Interception System First-Order Cost Estimates

Rose Creek Aquifer, Faro Yukon

Scenario	No. of Wells	Model Layer [1]	Pumping Rate / Well (L/s)	Total Pumping (L/s)	Captial Cost [2]	Total Well Pump Power (kWh)	Booster Pump to Mill Power (kWh)	Total Power Cost (@ $0.13 / kWh)	Total Operating Costs [3]
1	4	3	3	12	$ 2,154,000	63,348	194,159	$ 33,476	$ 87,031
2	4	3	5	20	$ 2,154,000	104,400	317,896	$ 54,898	$ 112,738
3	8	3	1	8	$ 2,242,000	50,808	129,439	$ 23,432	$ 101,319
4	8	3	2	16	$ 2,242,000	105,424	258,878	$ 47,359	$ 130,031
5	8	4	2	16	$ 2,376,000	105,424	258,878	$ 47,359	$ 130,031
6	16	3	1.4	22.4	$ 2,554,000	133,840	351,345	$ 63,074	$ 198,209
7	16	3 & 4	2	32	$ 2,642,000	210,848	473,594	$ 88,977	$ 229,293
8	16	3 & 4	3.5	56	$ 2,642,000	288,144	842,581	$ 146,994	$ 298,913

Notes:

[1] Layer 3 is upper 1/3 of sand & gravel aquifer, Layer 4 is lower 2/3 of aquifer

[2] see Tables A1 & A2 for cost assumptions, does not include power line to Intermediate Dam area.

[3] see Tables A3 & A4 for cost assumptions, includes power costs but does not include treatment costs.

5. Conclusions and Recommendations

5.1 Conclusions

Based on the modeling work completed above, the following conclusions are offered:

1. Six scenarios were run to simulate capture of contaminants originating in the tailings and travelling along the modelled flow path in the upper portion of the aquifer. These scenarios ranged from 4 wells pumping a total of 12 L/s to 16 wells pumping a total of 40L/s. Contaminant capture effectiveness ranged from 81% to 98% capture of particles originating in the tailings respectively.

2. Two scenarios were run to simulate capture of aquifer water from upgradient of the Intermediate Dam (to simulate capture of the entire aquifer flow). These two scenarios considered 16 wells fully screened across the aquifer. Pumping rates used were a total of 32 and 56 L/s. Aquifer water capture effectiveness was 86% and 100% capture of particles originating in the aquifer, respectively.

3. Due to the high pumping rates used in the aquifer capture scenarios, a significant quantity of the water pumped will originate from the polishing pond, resulting in diluted "impacted" groundwater.

5.2 Recommendations

1. With respect to groundwater capture scenarios, the role of the Cross Valley pond should be investigated and modeled. Specifically, scenarios should be run to assess the potential effect of either removing or lowering the Cross Valley pond. This may result in contaminated water reporting to the Cross-Valley pond area without requiring pumped groundwater interception. Alternatively, a lower water level in the Cross Valley Pond may reduce the pumping rates required to provide the desired level of contaminant interception.

2. It is recommended that continued refinement and upgrade of the numerical groundwater flow model be completed. Future upgrades/assessment should include:
   - Upgrade of model surface topography with the new (2003) site mapping data.
   - Review and assessment of the infiltration rate used in the tailing area. This may include either field studies to assess the current infiltration rate and/or application of NHRI's Cold Regions Water Balance model to the tailings area.
   - Model calibration at the south end of the model should be improved to better match observed heads.
   - Bottom topography of the ponds (e.g. bathymetry) should be determined and applied to the model.

3. Lastly, the role of the Cross Valley Pond on the groundwater system is important and should be reviewed closely. All future groundwater level monitoring should include observation of the Cross Valley and Intermediate Pond elevations at the time of sampling.

Table A1. Groundwater Interception System - Captial Costs

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4 Wells in Rose Creek Aquifer

Item	#	Units	Unit Cost	Total
Hydrogeological Assessment	1	LS	$ 30,000	$ 30,000
Test Well and Pumping Tests	1	LS	$ 54,673	$ 54,673
Production Drilling Mobilization	1	LS	$ 7,000	$ 7,000
Production Wells (4 at 30m)	4	LS	$ 23,253	$ 93,014
Production Pumps	4	LS	$ 2,500	$ 10,000
Riser & Pump Install	4	LS	$ 2,500	$ 10,000
Piping to Collection Tank	330	m	$ 300	$ 99,000
Electrical Hook-up [1]	1	LS	$ 30,000	$ 30,000
Collection tank and booster pump, controls, etc.	1	LS	$ 100,000	$ 100,000
Buried and Insulated Water Line to Mill	3025	m	$ 350	$ 1,058,750
Building Tie-in	1	LS	$ 6,000	$ 6,000

Total	$ 1,498,437
Engineering & Construction Supervision (15%)	224,766
Contigency (25%)	430,801
GRAND TOTAL	**$ 2,154,004**
SAY	$ 2,154,000

Notes:

[1] Assuming 3 phase power avaible at Intermediate Dam

Table A2. Groundwater Interception System - Captial Costs

Gartner Lee

16 Wells in Rose Creek Aquifer (Total Production 56 L/s)

Item	#	Units	Unit Cost	Total
Hydrogeological Assessment	1	LS	$ 45,000	$ 45,000
Test Well and Pumping Tests	1	LS	$ 62,096	$ 62,096
Production Drilling Mobilization	1	LS	$ 7,000	$ 7,000
Production Wells (8 at 50 m)	8	LS	$ 48,746	$ 389,966
Production Pumps	8	LS	$ 2,500	$ 20,000
Riser & Pump Install	8	LS	$ 2,500	$ 20,000
Piping to Collection Tank	330	m	$ 300	$ 99,000
Collection tank and booster pump, controls, etc.	1	LS	$ 100,000	$ 100,000
Electrical Hook-up [1]	1	LS	$ 30,000	$ 30,000
Buried and Insulated Water Line to Mill	3025	m	$ 350	$ 1,058,750
Building Tie-in	1	LS	$ 6,000	$ 6,000

Total	$ 1,837,812
Engineering & Construction Supervision (15%)	275,672
Contigency (25%)	528,371
GRAND TOTAL	**$ 2,641,855**
SAY	$ 2,642,000

Notes:

[1] *Assuming 3 phase power avaible at Intermediate Dam*

Table A3. Groundwater Interception System - Operating Costs

Gartner Lee

Scenario 1 - 4 Wells (Total Production 12 L/s)

Item	#	Units	Unit Cost	Total
Well Pumps	63,348	kwh	$ 0.13	$ 8,235
Booster Pump to Mill	194,159	kwh	$ 0.13	$ 25,241
Well Rehabilitation (1 well per year)	1	LS	$ 14,450	$ 14,450
Pump Replacement (1 every two years)	0.5	LS	$ 5,000	$ 2,500
Operator (6 hr / week @ $50/hr)	312	hr	$ 50	$ 15,600
Access Road Maintenance	1	LS	$ 3,000	$ 3,000
Building Maintenance	1	LS	$ 2,000	$ 2,000
Insurance	1	LS	$ 1,500	$ 1,500

Total	$ 72,526
Contigency (20%)	14,505
GRAND TOTAL	**$ 87,031**
SAY	$ 87,000

Notes:

[1] Does not include water treatment costs

Table A4. Groundwater Interception System - Operating Costs

Gartner Lee

16 Wells in Rose Creek Aquifer (Total Production 56 L/s)

Item	#	Units	Unit Cost		Total	
Well Pumps	288144	kwh	$	0.13	$	37,459
Booster Pump to Mill	842,581	kwh	$	0.13	$	109,536
Well Rehabilitation (4 wells per year)	4	LS	$	15,000	$	60,000
Pump Replacement (4 per year)	4	LS	$	5,000	$	20,000
Operator (6 hr / week @ $50/hr)	312	hr	$	50	$	15,600
Access Road Maintenance	1	LS	$	3,000	$	3,000
Building Maintenance	1	LS	$	2,000	$	2,000
Insurance	1	LS	$	1,500	$	1,500

Total	$	249,094
Contigency (20%)		49,819
GRAND TOTAL	**$**	**298,913**
SAY	$	299,000

Notes:

[1] *Does not include water treatment costs*