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Discussion Memo

To:	Faro – Groundwater Group	**Date:**	November 3, 2005
cc:		**From:**	Quinn Jordan-Knox
Subject:	Preliminary ETA Results	**Project #:**	1CD003.073

This memo summarizes preliminary 2005 results of the Emergency Tailings Area (ETA) investigation. Analyses and interpretation of results are based upon draft working copies of maps and calculations. The purpose of this memo is to familiarize the Faro-Groundwater Group with the current groundwater conceptual model and preliminary loading results. This working document is for discussion purposes only and does not present final results.

The primary objectives of the 2005 work program were to:

- Conduct 24 hr pumping test to refine hydrogeologic setting and parameters at ETA;
- Assess contaminant loading in the ETA area and downstream environment;
- Assess alternative collection system locations;
- Provide design for ETA area collection system or recommendations for Faro Canyon collection system

Figure 1 shows the locations of monitoring wells and surface water monitoring points.

Table 1 shows the completion details for the 2005 ETA monitoring wells. Previously installed wells in 2004 are also shown for comparison.

Table 1. ETA Monitoring Well Summary

2005SRK Monitoring Wells	Easting	Northing	Total Depth (m)	Stick-up Elevation (m.a.s.l.)	Screen Interval (m.b.g.s.)
ETA05-01	582953	6913851	9.1	1105.13	4.3-7.3
ETA05-02	582993	6913849	7.6	1105.06	5.0-7.5
ETA05-03	582975	6913808	9.0	1103.98	7.0-8.8
ETA05-04	583045	6913858	9.0	1105.4	6.7-9.0
ETA05-05	582977	6913856	7.5	1105.44	2.0-5.2
SRK05-ETA-BR1	582972	6913846	13.0	1105.21	9-12
SRK05-ETA-BR2	582987	6913825	23.6	1103.75	14.6-18.9
2004 SRK Monitoring Wells					
SRK-04-04	582,977	6,913,837	11.9	1104.80	7.6 – 11.6
SRK04-3A	582,977	6,913,824	13.4	1104.55	10.4 – 11.9
SRK04-3B	582,977	6,913,824	13.4	1104.63	5.5 – 7.0

Figures 2, 3, and 4 are location map and cross-sections through the ETA with preliminary generalized stratigraphy.

ETA Stratigraphy

General stratigraphy can be summarized as follows:

- Phyllytic bedrock underlies ETA sediments with a maximum depth to bedrock of approximately 12m where intercepted.

- *Uncertainty exists as to the bedrock topography across ETA many holes did not intersect bedrock. At this time it is not known if a paleochannel(s) is incised in the bedrock.* However, bedrock is interpreted to rise in elevation parallel to topography towards the valley edges of the ETA and to the north-east.

- A thin (<1m) weathered zone likely exists at the bedrock surface, but thickness' uncertain over area.

- Alluvium is comprised of 1.7 to 6m thick coarse sands and gravels overlies bedrock in most of the ETA. *This alluvial unit is considered the primary aquifer.*

- Some drill logs (ETA-05-03 and 05-04) indicate presence of Till but distribution of this unit is discontinuous.

- Alluvium is interpreted to thin towards the access road and up-valley past P96-8AB and may extend downvalley within an incised paleochannel (not shown in A-A' section).

- Tailings overly alluvium in all drill logs and becomes thinnner up-valley to the north-east (tails not present in 96-8AB) and towards side- walls. *It is uncertain whether the tailings confine the alluvial aquifer.*

- Tailings are up to approximately 6.5m thick in the south-west near the access road.

Hydraulic Testing

A 24-hr pumping test was conducted on SRK-04-4 at a rate of 2.83 l/s (45 U.S.gpm). Drawdown response to pumping and recovery were monitored in the pumping well and 11 monitoring wells.

- Water-level drawdown and recovery were analyzed using Theis, Theis with Jacob Correction (Unconfined), and Hantush (leakage)
- Some wells show reduced drawdown than would be predicted by Theis, potentially indicating leakage from tailings or dewatering (unconfined conditions)
- Bedrock monitoring well (BR2) shows delayed (10 mins) and lower drawdown compared to BR1 completed in alluvium similar distance from pumping well
- Questions exist regarding the capture of groundwater discharging at seepage face. Visual observations suggest no change in seepage rate during test while drawdown suggests flow should have been significantly affected.

The preliminary calculated average transmissivity (T) for the alluvial aquifer is 50 m^2/d. The calculated T values from the different tests ranged from 23 to 147 m^2/d. Estimated hydraulic conductivity (K) is approximately 10 m/d (1.2xE^{-4} m/s), assuming an average aquifer thickness of 5 m.

These results compare favourably with the analyses of the 2004 12hr pumping test that estimated a K of approximately 43.2m/d ($5x10^{-4}$m/s).

Water Table Elevations and Groundwater Flow

Contour maps of water table elevations were developed for static and pumping conditions (Figures 5 and 6).

Static groundwater elevations prior to pumping indicate general flow from the north-east to the south-west with converging flow towards the seepage face below the access road. This converging flow may indicate an potential incised paleochannel in the bedrock surface. The gradient along the primary NE to SW flow-path was approximately 0.07 (ETA-05-4 to SRK-04-04).

Water table contours at the end of pumping (24-hr) show converging flow towards the pumping well. The drawdown cone is interpreted to be steeper towards the valley walls and may indicate the influence of valley wall boundaries.

Using the hydraulic conductivity, gradient, and an assumed approximate area of $600m^2$ (120m length x 5m avg. depth), the groundwater flux can be grossly approximated using Q=KiA.

Gradient (i)	Area (m^2)	K(m/s)	Flow Rate (l/s)
0.07	600	1.16E-4	4.9

This groundwater flux of ~5 l/s broadly agrees with the estimate of 6 l/s presented in the 2004 Seepage Collection Design Report. This calculated flux is very sensitive to uncertainty in K, which may vary by an order of magnitude. The estimated flux is roughly twice that of the pumping test rate and ~60% more than the measured flux from the seepage face on October 18th.

Note that the groundwater table appears to be disconnected from the creek in the south-eastern portion of ETA, but may be connected in the vicinity of P96-8A/B. Upward vertical gradients were observed in the two nested wells (P96-8A/B and SRK04-3A/B).

Hydrology Survey and Water Balance

Creek flows prior to and during the pumping test were monitored continuously at upstream (FCS1) and downstream (FCS4) weirs (Figures 7 and 8). Pumping does not appear to have affected measured surface flow rates across the ETA study area. Seepage below the road (FCS3) was visually monitored and was not observed to change during the pumping test. This observation agrees with seepage measurements during the 2004 12-hr pumping test that showed no response.

Figure 8 shows a regular diurnal fluctuation in flows of up to 2 l/s.

Flow rates along Faro Creek were monitored manually on 3 dates in 2005 and shown in Table 2.

A preliminary water balance is shown in Figure 9. Flow-paths are labelled A through H. The increase in creek flows between FCS1 and FCS 2 is interpreted to result from upwelling groundwaters (B).

Table 2 Flow along Faro Creek

Station ID	Location	Flow (L/s)			
		Oct-04	Apr-05	Jul-05	Oct-05
FCS1	WRD seepage in old Faro Creek channel (at X23)	1.3	1.3	1.092	1.15
FCS2	surface seepage discharging below road (below road at culvert)	4.07	0 (frozen and dry)	8.3	3.39
FCS3	subsurface seepage discharging at seepage face below road (at X7)	3.51	4.78	2.37	3.12
FCS4	combined seepage below confluence of X7 and X23 (at mouth of Faro Creek canyon)	10.2	6.6		7.23
FCS5	seepage flow at end of diversion ditch (prior to discharge into Interm. Impoundment)	5.35	4.5		6.38
FCS6	seepage flow appr. Halfway towards Interm. Pond	3.4	~1.0		3.71
FCS7	seepage flow near pond (but u/s of inflow from Guardhouse Creek)	<1.0	0 (frozen and dry)		2.7
GHC	Guardhouse Creek before discharge into Intermediate Impoundment (at road)	8.7	3.0	rain	5

Water Quality

October 2005 water quality results are currently available for some monitoring wells in the ETA and all ETA surface water monitoring points (Tables 2 and 3 and Figure 10). Samples were collected from the pumping well at different times during the test and from a number of wells throughout the year.

Groundwater quality in SRK04-4 improved slightly during the pumping test and was still of very poor quality overall. Shallow groundwater sampled from SRK-04-3B, completed in tailings, showed the highest concentrations of any sample.

FCS-6, FCS-7, and GHC are not shown on the sample location map and are located downstream of the ETA.

Water quality results for FCS3 are broadly similar to deeper groundwaters such as SRK-04-3B and SRK04-4 and of lower concentrations than shallow groundwater sampled from SRK-04-3A. This result suggests that deeper groundwaters comprise a larger proportion of discharging seepage below the road than shallow groundwaters (as suggested in 2004 Preliminary Seepage Collection Design).

Results from P96-8A/B in October 2005 show poor water quality for both deep and shallow monitoring wells, compared to only the shallow well showing poor water quality in May 2005.

Table 3. Results of 2005 Monitoring Well Water Quality

ID	Date	Lab pH	Lab Conductivity (µS/cm)	SO4 (mg/L)	Zn (mg/L)	Fe (mg/L)
October 2005 SRK04-04 Pumping Test						
SRK04- 04-1HR	10/2/2005	4.84	8390	8100	461	2380
SRK04- 04-10HR	10/2/2005	5.34	7780	7460	447	2020
SRK04- 04-24HR	10/2/2005	5.39	7610	7460	444	1950
SRK04- 04-36HR	10/2/2005	5.44	7630	7370	438	1950
MOOSE POND Well #2	10/2/2005	7.66	1730	763	0.0094	<0.060
October 2005 Sampling (Pre-Test)						
P96-8A	9/10/2005	6.50	6370	5040	604	0.061
P96-8B	9/10/2005	6.35	6620	4980	368	9.85
May 2005 Sampling						
SRK04- 04-04	5/5/2005	5.23		7080	350	1630
SRK04-03A	5/5/2005	5.87		5480	233	693
SRK04-03B	5/5/2005	3.72		16700	749	6610
P96- 8A	5/3/2005	6.76	197	71.2	1.67	0.064
P96- 8B	5/3/2005	7.01	5540	4520	173	0.22

Table 4 Select Results of 2005 Surface Water Monitoring

ID	Date	Field Conductivity (µS/cm)	SO4 (mg/L)	Zn_D (mg/l)	Fe_D (mg/l)
Faro Creek Stations October 2005 Sampling					
FCS-1	10/18/2005	4230	6200	470	119
FCS-2	10/18/2005	4890	6210	462	45
FCS-3	10/18/2005	5010	6570	219	1090
FCS-4	10/18/2005	4610	4860	309	670
FCS-5	10/19/2005	4350	5780	292	694
FCS-6	10/18/2005	4840	5880	290	681
FCS-7	10/18/2005	5220	5870	297	689
Faro Creek Stations July 2005 Sampling					
FCS-1	4/17/2005	5240	5030.0	278	34.4
FCS-3	4/17/2005	5710	5550.0	291	1090.0
FCS-4	4/17/2005	5190	4170.0	150	604.0
FCS-5	4/17/2005	5180	4870.0	128	473.0
FCS-6	4/17/2005	5140	3750.0	129	502.0
GHC	4/17/2005	1117	416.0	1.2	<0.030

Loading and Conceptual Model

Contaminated groundwater is preliminarily estimated to discharge from the ETA at a rate of ~ 5 l/s. Potential groundwater metal loading from the ETA to the downstream environment can be estimated using this flux and the results from pumping well samples taken at the end of the 24 test (avg groundwater conditions).

Surface water loadings can be grossly estimated from October 2005 measured flows and sampling results (Figure 11 and Tables 5-7).

Table 5 Sulphate Loading Calculations

Station	**Flux** l/s	**[SO_4]** mg/l	**SO4 Load** Tonnes/yr
Groundwater	5	7370	1162
FCS1	1.15	6200	224
FCS2	3.39	6210	663
FCS3	3.12	6570	646
FCS4	7.23	4860	1108

Table 6 Zinc Loading Calculations

Station	**Flux** l/s	**[Zn]** mg/l	**Zn Load** Tonnes/yr
Groundwater	5	438	69
FCS1	1.15	470	17
FCS2	3.39	462	49
FCS3	3.12	222	22
FCS4	7.23	310	71

Table 7 Iron Loading Calculations

Station	**Flux** l/s	**[Fe]** mg/l	**Fe Load** Tonnes/yr
Groundwater	5	1950	307
FCS1	1.15	119	4
FCS2	3.39	44.7	5
FCS3	3.12	1120	110
FCS4	7.23	773	176

Note that the estimated groundwater loads exceed the seepage load (FCS3) and the downstream surface water loads (FCS4) in all cases. This result may indicate that some contaminated groundwater may underflow these stations and consequently that FCS4 may under-report the total load discharging to downstream environments. Alternatively, this result may indicate that the estimated groundwater flux is too high or that the load has not yet reached FCS4. .

Comments for Consideration

- In general, gross-estimated loads are significant compared to those estimated for other areas at Faro.
- Load estimates may indicate groundwater underflow in the Faro canyon at FCS4.
- While some uncertainty exists regarding bedrock topography and weathering, stratigraphy appears to be relatively simple and shallow.
- The pumping test was successfully conducted for 24hrs without encountering significant barriers to recharge, although it may be confined laterally by the bedrock in the canyon walls.
- Preliminary assessment indicates that an ETA collection/pumping system would be feasible but further work required on potential efficiency/performance.