APPENDIX A

Scope of Work for Task 22H(i)

Robertson GeoConsultants Inc.

Suite 640, 580 Hornby St., Vancouver, B.C., V6C 3B6
Phone: (604) 684-8072 · Fax: (604) 684-8073

Memorandum

DATE:	July 26, 2005
TO:	Valerie Chort, Deloitte & Touche
CC:	Members of Review Panel
FROM:	Christoph Wels, Robertson GeoConsultants Inc.
RE:	**Revised Work Plan for Task 22H (i) – Design of GW Interception System for Rose Creek Valley**

As requested, this memorandum proposes a work plan for the execution of two aquifer pump tests in the Rose Creek aquifer (downstream of the Cross Valley Dam) and the subsequent design of a groundwater interception system at this location (Task 22H(i) of the 2005/2006 closure studies for the Anvil Range Mining Complex).

1.0 Introduction

For the purpose of budgeting for 2005-06, the scope for Task 22H was generally defined as follows: "*This task consists of pumping tests at the Cross Valley Dam. The pumping test component will start with an office assessment to estimate the scope and duration of the pump test(s). Pumping and observation wells would be installed and 1 to 2 week pumping tests completed. The objective of testing is to determine (i) feasibility of pumping the north and south side, (ii) influence of pumping on the Cross Valley seepage and (iii) boundary effects of the aquifer system. Results will be analyzed to assess and design a groundwater collection and water treatment system. The results would provide more reliable estimates of the amount of groundwater to be pumped (for water treatment design) as well as design criteria for a pumping system (depth of screening, interval between wells, pumping rates on south and north side of valley).* "

It should be emphasized that Task 22H(a) does not only consist of a field component (pump testing) but also of an analysis component (pump test interpretation and design of a groundwater interception system). Note also that another component of this study on "attenuation testing" has been split (for administrative purposes) into a separate Task 22H(ii). This work plan only focuses on the aspect of "groundwater collection". The proposal for Task 22H(ii) has been provided by SRK under separate cover.

The rationale for this study was described in an RGC memorandum dated May 6, 2005 and entitled "Task 22H(a) – Pump Testing in Rose Creek Valley" (see Appendix A). Briefly, the results of the water and load balance study conducted by Robertson GeoConsultants Inc. (RGC) suggest that current and future tailings seepage is impacting the local groundwater and that groundwater interception may be required in the future to protect Rose Creek[1]. In 2004, Gartner Lee Limited developed a preliminary design for a groundwater interception system in the Rose Creek Valley aquifer[2]. However, this design was based on modeling alone (no detailed pump test data were available at the time). Furthermore, there is concern that the proposed location (along the crest of the Intermediate Dam) may not be the most suitable location for such an interception system (Appendix A).

On June 18, 2005, a conference call was held with various stakeholders, including staff from Type II Mines Group, Faro Mine Closure Planning Office, Environment Canada and Deloitte & Touche, to discuss the scope of work for this project. During this call it was agreed that this study should be carried out in the fiscal year 2005/06 and Robertson GeoConsultants Inc. (RGC) was authorized to develop a detailed work plan for this study (Task 1 of the proposed study). This memorandum summarizes the proposed work plan and provides a detailed cost estimate (including contractor costs) to complete this work.

2.0 Study Objectives

The primary purpose of this study is to design a groundwater interception system for the Rose Creek aquifer using pump tests and a numerical model. The specific study objectives may be summarized as follows:

- Determine hydraulic properties (T and S) of the Rose Creek aquifer;
- Assess boundary conditions (valley sides; pond seepage, leakage from RCDC etc) that may influence the performance of a groundwater interception system;
- Assess the influence of aquifer heterogeneity on capture efficiency;
- Design a groundwater interception system at the pre-feasibility level including,
    - Number & location of pumping wells,
    - Required depth of pumping wells;
    - Individual and total pumping rates

[1] Robertson GeoConsultants Inc., 2005. DRAFT – Water and Load Balance Study for Rose Creek Tailings Storage Facility, Faro Mine, Yukon Territory, DRAFT Report 118001/1 prepared for Deloitte&Touche, May 2005.
[2] Gartner Lee Limited 2004. Anvil Range, 2003 Project 17b: Assess requirements for groundwater collection, prepared for Deloitte & Touche Inc., July 2004.

- Provide a cost estimate for installation of the proposed groundwater interception system (excluding power supply and pumping to treatment plant).

3.0 Scope of Work

The proposed scope of work can be grouped into five major tasks:

- Task 1. Development of Work Plan;
- Task 2. Drilling and Development;
- Task 3. Pumping Tests;
- Task 4: Test Interpretation & Design;
- Task 5: Costing & Reporting.

In the following, we describe the proposed tasks in more detail.

Task 1. Development of Work Plan

Task 1 included a data review and the development of a preliminary flow model of the lower Rose Creek Valley (see Figure 1 for location) to develop criteria for the proposed pump tests (including duration and rate of pumping). Task 1 has been completed and results are briefly summarized below.

Figure 2 shows the domain of the preliminary flow model developed for pump test design. The domain extends from the lower portion of the Intermediate Dam (near P03-08) to about 1300m downstream of the Cross Valley Dam (near flow station RC2). For this preliminary modeling, the sand and gravel aquifer was assumed to be homogeneous (1 layer) and the underlying till and bedrock units were not included. For the base case, a uniform hydraulic conductivity of 2*10-4 m/s was assumed representing the calibrated value for this reach determined in the 2004 modeling (GLL, 2004). A detailed calibration of this local flow model was beyond the scope of this (preliminary) analysis but will be carried out as part of Task 4 (see below).

Figure 1 shows the location of the (proposed) pumping wells and the various monitoring wells (including three proposed monitoring wells). The model was used to simulate a longer-term (14-day) pumping test in PW1 (proposed on the north side, Figure 1)) and a short-term (1-day) pump test in PW2 (proposed for the south side, Figure 1). Table 1 summarizes the simulated drawdown for different pumping scenarios using this preliminary flow model for the longer-term pumping test at PW1. Figure 3 shows the simulated drawdown of the water table after 7 days pumping for pumping scenario 2 (Q=

4000 m3/day). Figure 4 shows the simulated time-drawdown curves at the pumping well (PW1) and the proposed multilevel piezometer (P05-01 at 50m distance) for the five different pumping scenarios. The results of the simulated 1-day pumping test in PW2 (assuming K-2*10-4 m/s) are shown in Figures 5 and 6.

Table 1. Summary of preliminary modeling for PW1 (north side).

Model Run			1	2	3	4	5
GMS File			RCP08_01	RCP08_01b	RCP08_01c	RCP08_03	RCP08_02
Pumping Rate	Q	m3/day	2000	4000	5000	2000	4000
		USgpm	367	734	917	367	734
Hydraulic Conductivity	K	m/s	2*10-4			1*10-4	4*10-4
Simulated drawdown after 7 days	Well ID	Distance					
	PW1	r= 0m	2.64	5.65	7.32	5.02	2.88
	MW1	r= 10m	2.02	4.25	5.43	3.66	2.25
	P05_01	r= 50m	0.88	1.81	2.28	1.35	1.08
	P03-09	r= 158m	0.06	0.07	0.086	0.025	0.08
	P01-11	r= 174m	0.87	1.81	2.27	1.28	1.1
	X17	r= 206m	<0.01	<0.01	0.005	0	0.01
	P01-02	r= 343m	0.042	0.091	0.114	0.034	0.1
	X16	r= 537m	0	0	0	<0.01	<0.01
	X24	r= 649m	0.073	0.146	0.1795	0.059	0.147

The following conclusions can be drawn from these preliminary modeling results:

- The simulated drawdown in the pumping well itself is very sensitive to the pumping rate; a step test will be required prior to pump testing to determine the appropriate pumping rate to be used during the actual test(s);
- The pumping rates will have to be greater than 2,000 m3/day (~400 gpm) to test the entire aquifer (i.e. the south and north side); assuming a range of K values of 1..4*10^{-4} m/s (determined in previous studies for this sand and gravel aquifer) the pumping rates required for a large-scale pumping test will likely be in the order of 2,000-5,000 m3/day (400-1000 USGPM)
- The pump test will likely have to be run for several days to test aquifer boundaries (including the valley sides and seepage from the RCDC and the Polishing Pond) and to produce any measurable reduction in seepage rates downstream of the Cross Valley Dam.

Based on these results we propose the following pump test design (see Figure 2 for locations):

- Pump Test #1: a 7-day constant discharge pump test (with 1-day recovery monitoring) on the north side (PW1) using a pumping rate of 2,000-5,000 m3/day;
- Pump Test #2: a 1-day constant discharge pump test with (0.5-day recovery monitoring) on the south side using a pumping rate of 2,000-5,000 m3/day;

Pump test #1 will stress a larger reach of the aquifer and will allow an assessment of aquifer properties (including degree of heterogeneity and anisotropy) as well as potential boundary effects. Pump test #2 will be adequate to assess the local hydraulic properties in the southern portion of the valley (near PW2). The use of two pump tests (completed in different parts of the aquifer) will further assist in the assessment of aquifer heterogeneity. The northern side was selected for the more detailed (longer) pump test because the groundwater quality in this area is significantly more impacted today than the south side. Groundwater interception is therefore more likely to be required some time in the future than on the southern side. Furthermore, this area is less affected by leakage from the RCDC, hence the pump test is more likely to stress the aquifer.

The anticipated large pumping rates will require the use of 10" ID well casing to accommodate a high capacity pump. The total volume of groundwater to be extracted during the proposed tests will be significant. For example, as much as 35,000 m3 may be extracted during the proposed 7-day test. Nevertheless, this volume is well within the annual allowable discharge permit for Rose Creek (Dana Haggar, pers. comm.). Observed zinc concentration in seeps and wells in the area are typically <0.1 mg/L, i.e. well below the discharge criterion of 0.5 mg/L (Dana Haggar, pers. comm.). It is therefore assumed that the pumped groundwater can be discharged directly into Rose Creek.

Both pumping wells will be drilled to a depth of 18m, representing approximately 40-60% of the total depth of the alluvium (S&G unit) in this reach of the Rose Creek aquifer. Both pumping wells will be constructed and developed for potential (future) use in a groundwater interception system. This will include the use of continuous slot (Johnson) stainless steel screens and natural development of a gravel pack to maximize well efficiency.

Detailed monitoring of water levels in all existing monitoring wells (screened in various depths of the S&G aquifer and in the underlying till) would be carried out to test the efficiency of these "partially penetrating" wells in capturing groundwater. At present, there is only one multi-level piezometer (P03-09) available for detailed monitoring of pump test response with depth. We therefore propose to install one additional multilevel piezometer on the northern side of the valley downstream of the Cross Valley Pond (see Figure 1 for location). This proposed multilevel piezometer would serve three purposes: (i) allow detailed water level monitoring during the pump tests to assess the adequacy of partial penetration, (ii) allow a delineation of the current vertical extent of groundwater impact on the north side of the valley and (iii) allow future monitoring of groundwater quality in the northern portion of the valley.

Task 2. Drilling and Development

Task 2 includes the following subtasks:

- Preparation and Travel;
- Pump Test Drilling & Installation (Air Rotary);
- Monitoring Well Installation (SONIC)
- Prepare Borehole Logs

The proposed pump test drilling program will be carried out using an air rotary rig and includes two pumping wells and two observation wells. All wells will be drilled with a tricone bit and casing advance. The pumping wells will be drilled to a depth of 18m using 10" casing advance. The well assembly will consist of 8" SS continuous slot (Johnson) screens welded to 8" steel casing. The exact location of the well screen(s) will be determined based on the observed stratigraphy (i.e. based on inspection of cuttings) and return flow rates. Note that the slot size of the well screens will have to be predetermined and shipped to site prior to drilling to avoid costly delays during installation (8" screens are not commonly stocked by drilling contractors).

A review of the historic drill logs in this area suggests the presence of occasional silt layers within the alluvial deposits. Any silt layers or silty S&G layers of significant extent (say >0.5m) will be "cased-off" using blank casing to avoid excessive development time and future silting up of these wells. For costing purposes, it has been assumed that eight 5ft sections (~12m total) and 6m blank casing will be used to complete each pumping well. The pumping wells will be developed by air lifting (using a jetting tool) to develop a natural filter pack around the well screen.

The cost estimate for the air rotary program is based on unit costs provided by Midnight Sun Drilling, Whitehorse. An alternative drilling contractor for this contract would be Anderson Water Wells, Ft St Johns, B.C., who specializes in water well installations and has experience with drilling large diameter wells in unconsolidated formations. This contractor has a higher mobilization costs but lower hourly drilling rates.

Provisions have been made in the budget for the project leader (Dr. Wels) to travel to site to supervise the initial field work, including final selection of well locations and supervision of drilling/installation of the monitoring wells. The remainder of the drilling program will be supervised by a staff hydrogeologist from RGC or SRK.

In the vicinity of each pumping well (~10m distance), a dedicated observation well will be drilled to monitor the drawdown of the water table during pumping and recovery (Figure 2). These observation wells will be drilled using a SONIC drill rig (4" inner barrel with 6" casing) and will be completed using 2" PVC screen and casing. The observation wells will be screened from 5-18m below ground surface. As discussed above, we also propose the installation of a multilevel piezometer on the northern side of the valley (see Figure 1 for proposed location). This borehole would be drilled with the SONIC drill rig (4" inner barrel with 6" casing) and completed using the same method and equipment (to the extent possible) as used for the P03 well series. This will provide consistency and allow integration of this well into the routine monitoring program (if required). The multilevel bundle would consist of 6-7 mini-piezometers screened at different depths in the sand and gravel aquifer and underlying till. For costing purposes, we have assumed that the different ports be sealed using a "bentonite pack" (as used in 2003). If required, consideration could be given to pressure-grout the annulus to further reduce any vertical leakage along the annulus.

Allowance has been made in this budget for developing the multilevel piezometers for 2 days. This should be adequate to allow for water level monitoring in these mini-piezometers. Any additional development and potential future sampling for water quality analyses would have to be covered by a separate project.

The installation of the multilevel piezometer will be supervised by Martin Guilbeault from Gartner Lee Limited with assistance by a staff hydrogeologist (from RGC or SRK) and a field technician.

Task 3. Pump Test

Task 3 includes the following subtasks:

- Preparation and Travel;
- Set-Up and Step Testing;
- Pump Test #1 (7-day CD & recovery);
- Pump Test #2 (24-hr CD & recovery).

The proposed pump test program consists of a 7-day constant discharge (CD) pump test in the northern portion of the Rose Creek Valley (at proposed PW1), and a 24 hr CD pump test in the southern portion (at proposed PW2) (see Figure 1 for proposed locations).

Prior to each pump test, a full water level survey will be carried out in all monitoring wells in the area. In addition, the water level in the Polishing Pond and the Intermediate Dam will be read and the seepage rate at X11, X12 and X13 will be measured. During the CD test, the pumping rate will be monitored throughout the pump test (at 2 hr intervals) and adjusted, if required, to maintain a constant discharge. During the test, the water levels in all monitoring wells will be read at regular intervals (ranging from 10-min to 2-hr intervals depending on distance and observed drawdown). In addition, a data logger will be installed in the pumping well and the observation well nearest the pumping well (i.e. MW1 and MW2, respectively) to provide detailed monitoring of the drawdown and recovery. Finally, the seepage rates at X11, X12 and X13 will be measured approximately every eight hours.

The target drawdown for the 7-day pump test is in the order of 5-10m and for the 1-day pump test in the order of 2-5m. Based on preliminary modeling (see above) the pumping rate is expected to be in the order of 2,000-5,000 m3/day (400-1000 USGPM). At each location, a step test will be carried out prior to the actual CD test to test the equipment and to determine a suitable pumping rate for the CD pump test.

During the pump test, the groundwater pumped out of the pumping well will be monitored for field parameters (temperature, electrical conductivity and pH) at regular intervals (~every 4-8 hrs). In addition, 5-10 samples will be collected throughout the course of each pump test and shipped to a certified laboratory for full chemical analyses (major anions/cations and dissolved metals).

At the end of the CD pump test, a final survey of all monitoring wells in the area will be taken. Then the pump will be shut off and the recovery in the pumping well and monitoring wells will be monitored until 95% recovery has occurred. Again, the recovery in the pumping well and near-by monitoring well (MW1 and MW2, respectively) will be monitored automatically using a data logger. To the extent possible, the recovery in other near-by monitoring wells will be measured manually using a water level tape.

A suitable contractor specializing in pump test support will provide the necessary pumping equipment (submersible pump, genset, discharge piping etc) and will be responsible for operating the equipment and taking water level measurements. A staff hydrogeologist from RGC or SRK will be present during the first two days of each test to supervise the step testing and CD pump test setup and to assist in the initial monitoring. The hydrogeologist will also supervise the monitoring during recovery.

Task 4. Pump Test Interpretation and Design

Task 4 includes the following subtasks:

- Develop Local GW Flow Model;
- Calibrate steady-state GW Flow Model;
- Calibrate transient GW Flow Model;
- Design GW Interception System.

In this task, a local groundwater flow model will be developed to interpret the pump test data and to design a groundwater interception system. The first two sub-tasks will include the development of this local flow model and a calibration assuming "steady-state" conditions. The final model domain will have to be determined based on the results of the pump tests but will likely be similar to the domain used for the preliminary modeling (see Figure 2). The model will include the sand&gravel aquifer (likely subdivided into 2-3 layers), the till layer (1 Layer) and possibly the weathered bedrock (1 layer). The steady-state model will be calibrated using observed groundwater levels and seepage rates (fall 2004 and/or spring 2005 data).

The calibrated steady-state flow model will provide initial estimates of model parameters (Kh, Kz, drain conductance etc) for interpretation of the pump test data. This model will then be run in transient mode (simulating pumping) to interpret the pump test data. The objective of the transient modeling will be to match the observed drawdown (and recovery) for the 7-day pump test. The 1-day pump test may either be interpreted with analytical solutions and/or with the groundwater flow model, depending on the extent of the drawdown achieved during this second test.

Once calibrated, the groundwater flow model will be used to design the groundwater interception system. The following design components will be evaluated as part of the modeling work:

- Location and number of extraction wells;
- Pumping rates for each extraction well;
- Depth of well screen;

In addition, a sensitivity analysis will be carried out to evaluate the benefits of the following options:

- Use of cutoff barriers;
- Use of fully penetrating vs partially penetrating wells;
- Removal of the Polishing Pond;
- Removal of the Rose Creek Diversion.

For each GW interception scenario, the simulated (steady-state) drawdown and interpreted capture zone will be shown in graphical output (maps) and summarized in a table. The capture efficiency will be evaluated using particle tracking (MODPATH).

Based on the results of this modeling work, recommendations will be given for a groundwater interception system to be installed downstream of the X Valley Dam (assuming current flow conditions). The recommended interception system will depend to some extent on the desired capture efficiency. The authors will require input from the review group to determine a suitable capture efficiency for this purpose.

Task 5. Costing & Reporting

Task 5 includes the following subtasks:

- Costing of GW Interception System;
- Preparation of Final Report;
- Project Management.

A cost estimate will be provided for the installation of the recommended GW interception system, including drilling/well installation and pump & controller setup. A costing of the setup of the required power supply and discharge line to the treatment plant are not included in this proposal.

All results of the proposed study, including results of the drilling program, the pump testing program, the model design work and costing will be summarized in a report. The draft report (in pdf format only) will be circulated to D&T and key regulatory stakeholders for review/comment. Comments will be considered in the finalization of the report. The final report will be submitted in electronic version (pdf format on CD-ROM) and 12 hard copies.

Allowance has been made in the budget (under project management) for regular consultation with stakeholders to discuss the progress of the work and to obtain input on the work still to be completed. For costing purposes we have assumed four meetings (via conference call) at the following stages of the project:

- After submission of this work plan (to finalize the scope of work);
- After completion of the drilling program (to finalize the pump testing program);
- After completion of the pump testing and initial model interpretation (to finalize the scope for design modeling);
- After completion of the design modeling work (for final comments prior to report preparation);

For each conference call, a brief progress memorandum will be drafted that summarizes the results of the recently completed tasks.

4.0 Costing

Table 1 shows the cost estimate for the proposed scope of work (including professional hours and charge-out rate by person) by subtask. Table 2 shown below summarizes the estimated total professional fees and disbursements for the five major tasks.

The disbursement cost for the air drilling/installation program ($48,948) is based on unit rates provided by Anderson Well Drilling (now Cora Lynn Drilling) out of Ft St John[3]. The

[3] Midnight Sun Drilling (Whitehorse) provided a slightly lower quote for the work but did not have a suitable rig available for the planned starting time of early August.

disbursement cost for the SONIC drilling/installation program ($26,974) is based on unit rates provided by SDS Drilling (Calgary) and experience during P03 installations.

Table 2. Summary of Cost Estimate for Rose Creek Pump Test Study

ITEM	Description	Professional Fees	Disbursements	TOTAL
1	Development of Work Plan	$16,340	$490	$16,830
2	Drilling & Development	$26,472	$83,366	$109,838
3	Pumping Tests	$14,400	$56,972	$71,372
4	Test Interpretation & Design	$24,832	$745	$25,577
5	Costing & Reporting	$26,880	$1,606	$28,486
	Subtotal	**$108,924**	**$143,180**	**$252,104**
			10% Contingency	**$25,210**
			Grand TOTAL	**$277,314**

The disbursements include 50% of the mobilization costs of the air rotary drill rig as well as 100% mobilization cost of the pump test contractor. A mobilization cost for the SONIC drill rig (to site) is **not** included (assumed to be covered by other field programs).

A total of four trips to site (from Vancouver) and 24 person days on site have been assumed to complete the proposed fieldwork. There may be potential savings in trips and person days on site due to overlap with other on-going work; however those savings are difficult to predict and have therefore not been included in this cost estimate.

A 10% contingency has been assumed for the total budget (including the field program and office work) to cover unforeseen problems/delays during fieldwork and/or additional work requested as part of the review process. It should be stressed that the field program is clearly defined and the contingency money will only be used in case of unanticipated problems. If field problems were to be encountered, Deloitte would be notified immediately. In any case, the contingency money would only be used with the permission of Deloitte. Note that GST has not been included in our cost estimate.

5.0 Schedule

Task 1 has been completed and the results are contained in this work plan. Task 2 ("Drilling program") will be carried out in early-mid August 2005. The exact dates will have to be coordinated with the drilling contractors and other site activities. Task 3 ("Pump testing") will be carried out in September 2005, i.e. after discharge of treated water from the Polishing Pond has ceased. This work will also have to be coordinated with other pump testing carried out as part of the seepage investigations conducted by SRK.

Task 4 ("Test interpretation & design") will be completed in October-November 2005 and Task 5 ("Costing and reporting") will be completed in December 2005. The final draft report for this study will be submitted on January 31, 2006.

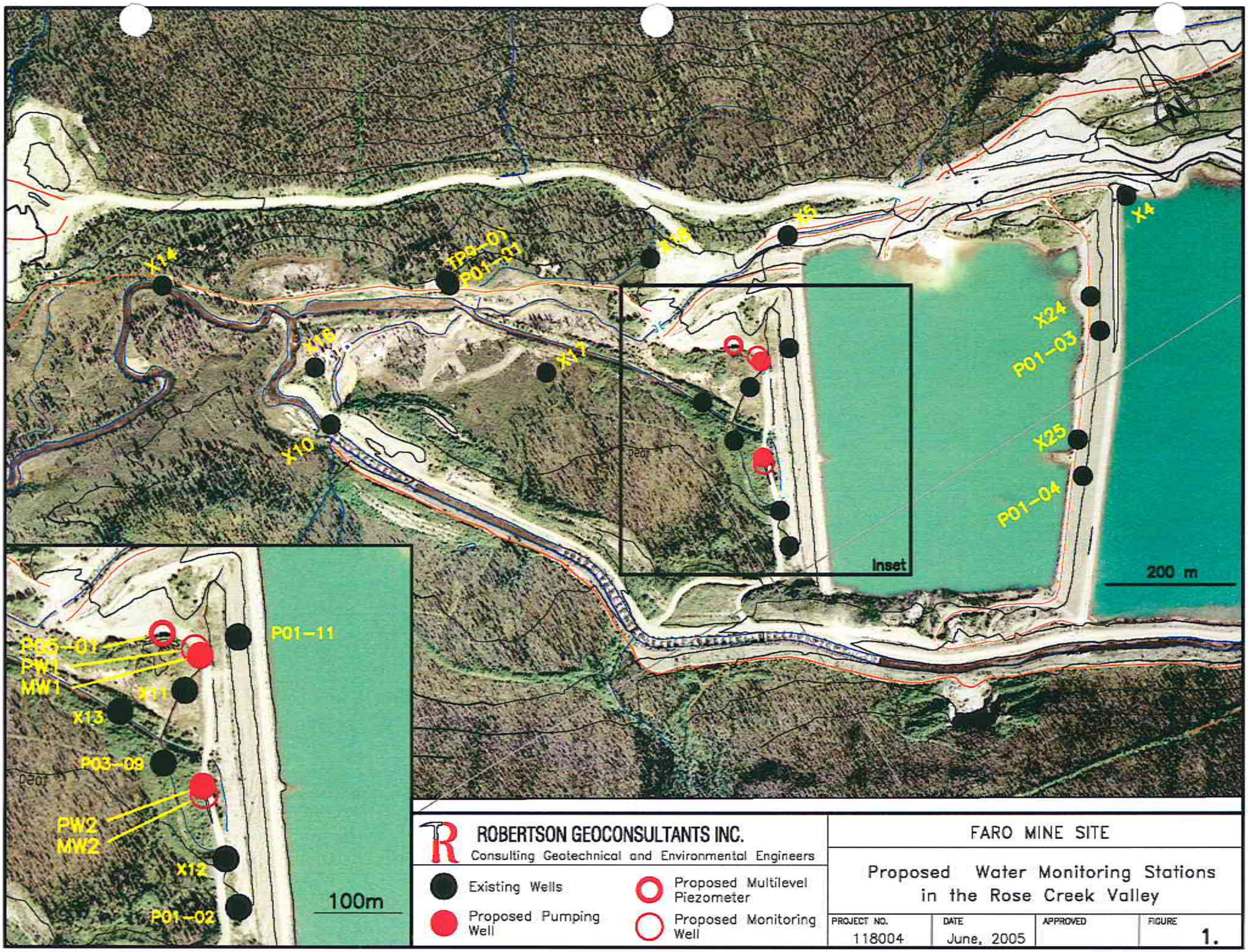
Please contact the undersigned if you have any questions regarding this memorandum.

ROBERTSON GEOCONSULTANTS INC.

Christoph Wels, Ph.D.
Principal Hydrogeologist

Att. Table 1. Detailed Cost estimate
Figures 1-6
Appendix A: RGC memorandum (May 6, 2005)

Figures



ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

FARO MINE SITE			
Proposed Water Monitoring Stations in the Rose Creek Valley			
PROJECT NO. 118004	DATE June, 2005	APPROVED	FIGURE 1.

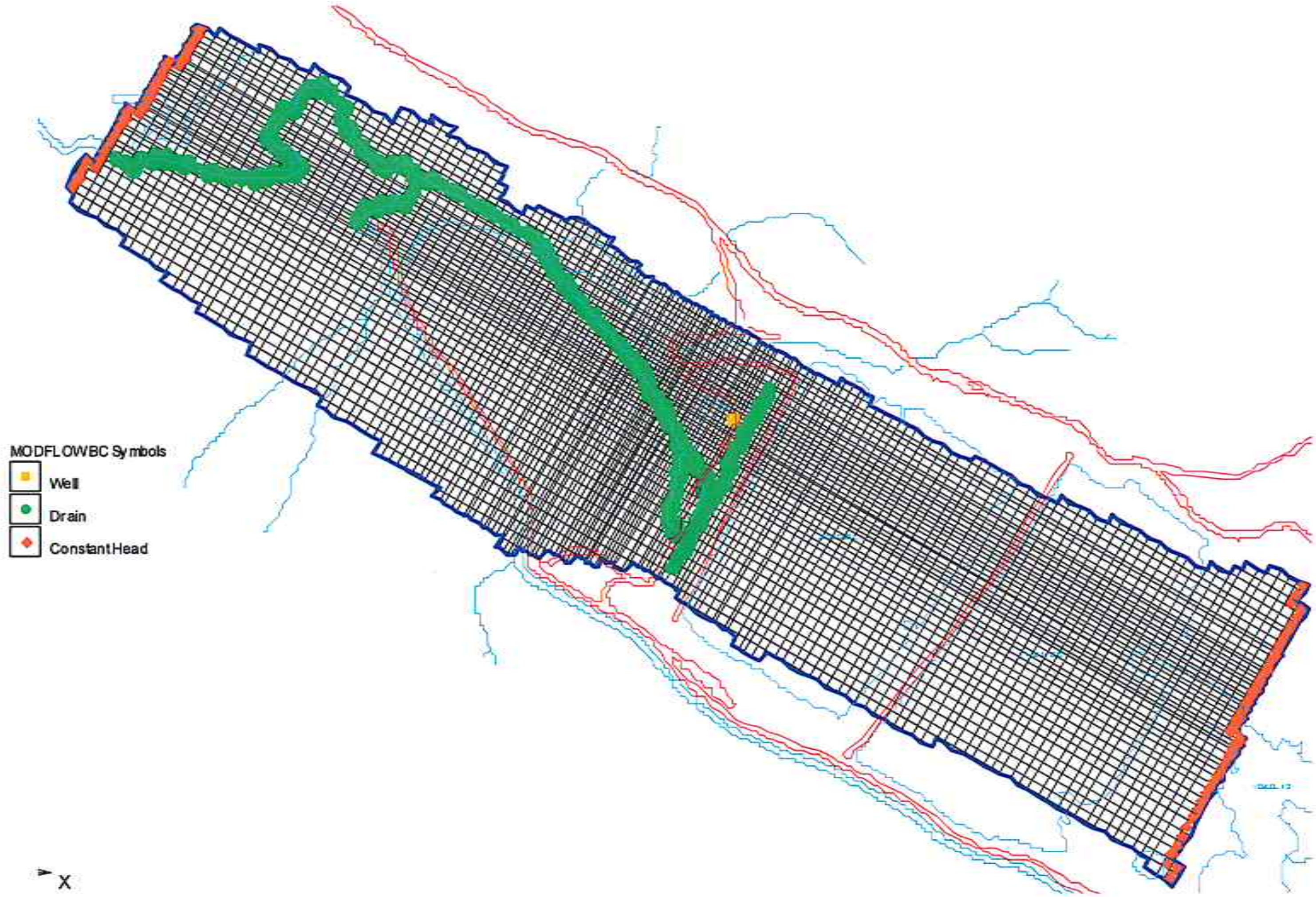


Figure 2. Model domain and boundary conditions for layer 2 (sand and gravel).

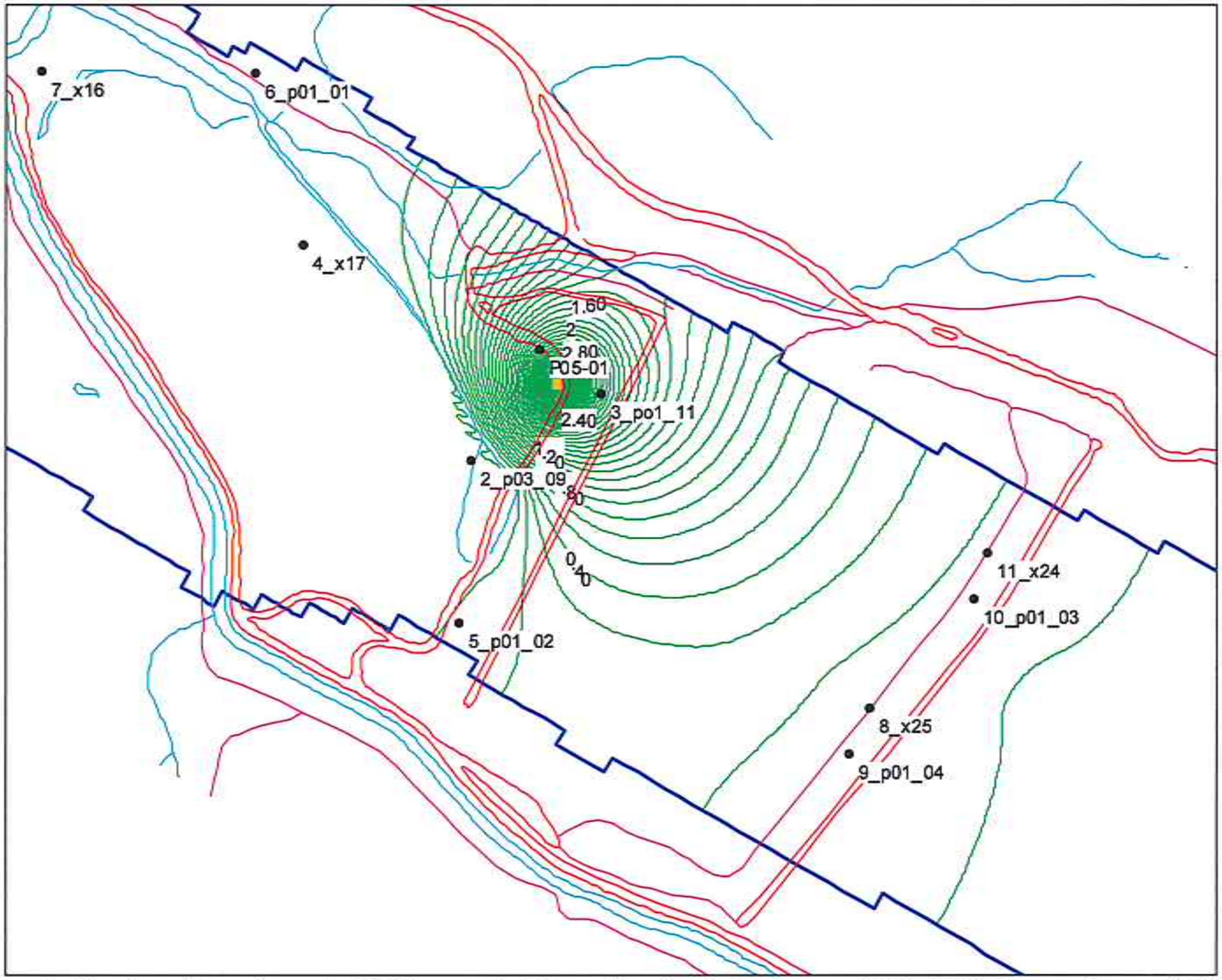
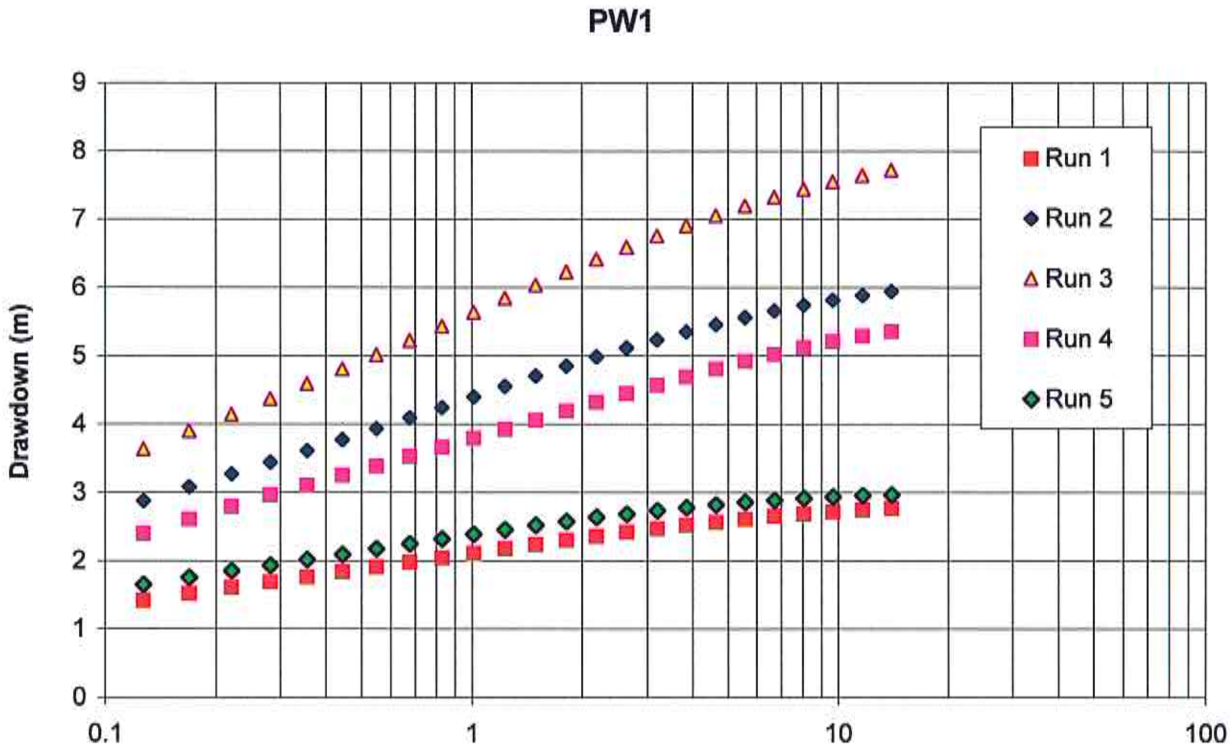


Figure 3. Simulated drawdown for PW1 test after 7 days (2e-4 m/s, Q pump = 4000 m3/d). Contour interval 0.1 m.



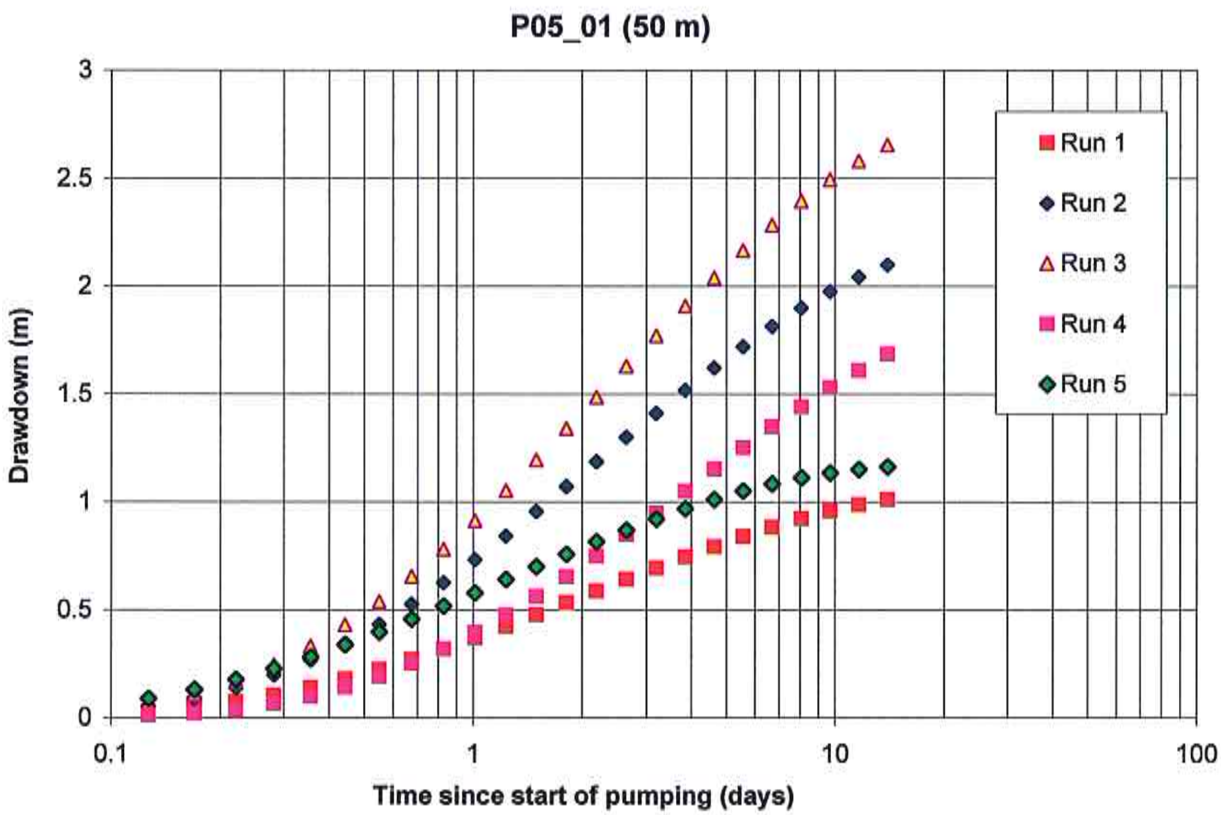


Figure 4. Simulated drawdown for pump testing at PW1 (north side).

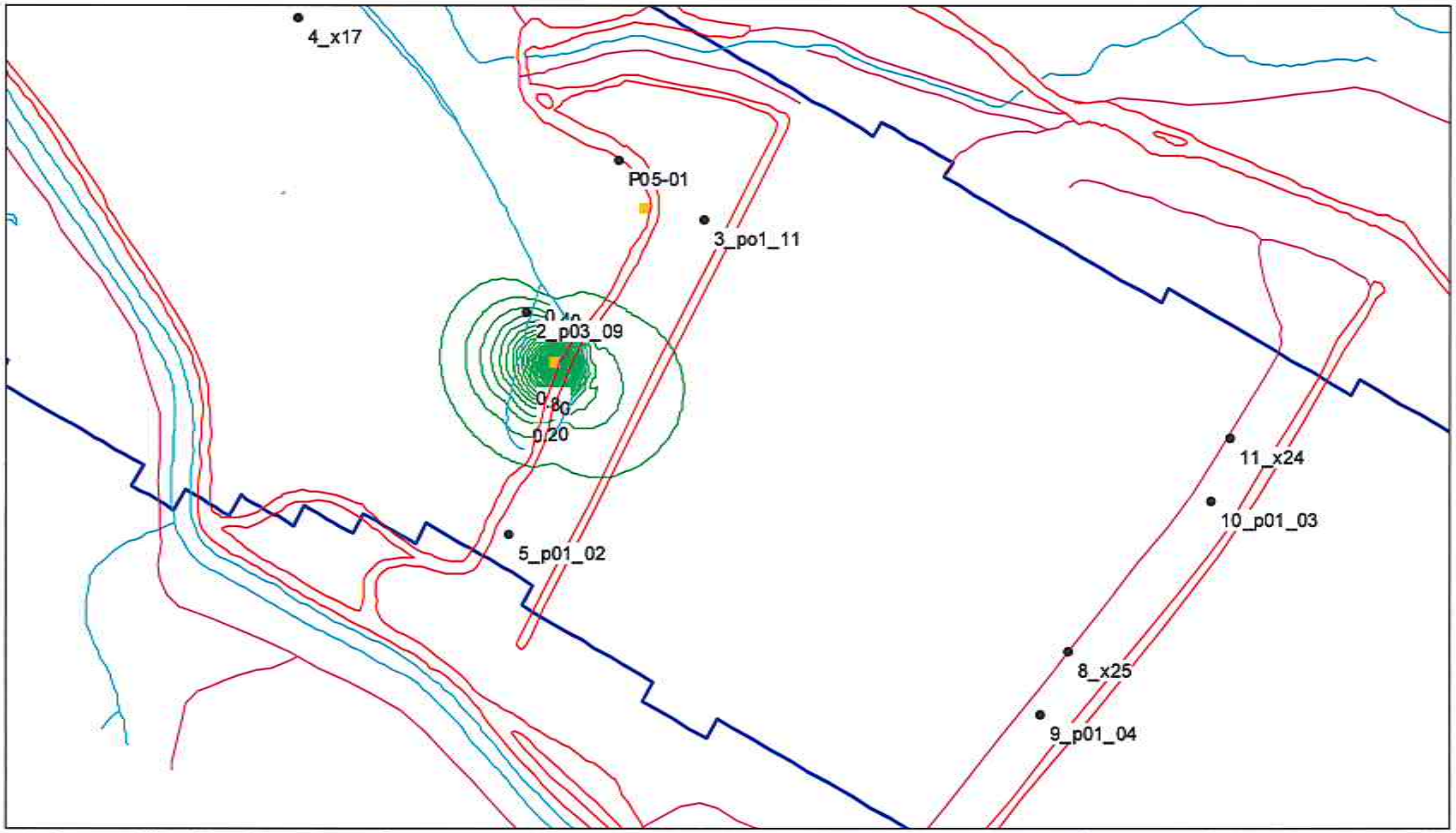


Figure 5. Simulated drawdown for PW2 test after 24 hours (K = 2e-4 m/s, Q pump = 4,000 m3/d). contour interval 0.1 m. Max drawdown 3.61 m at pumping well 2.

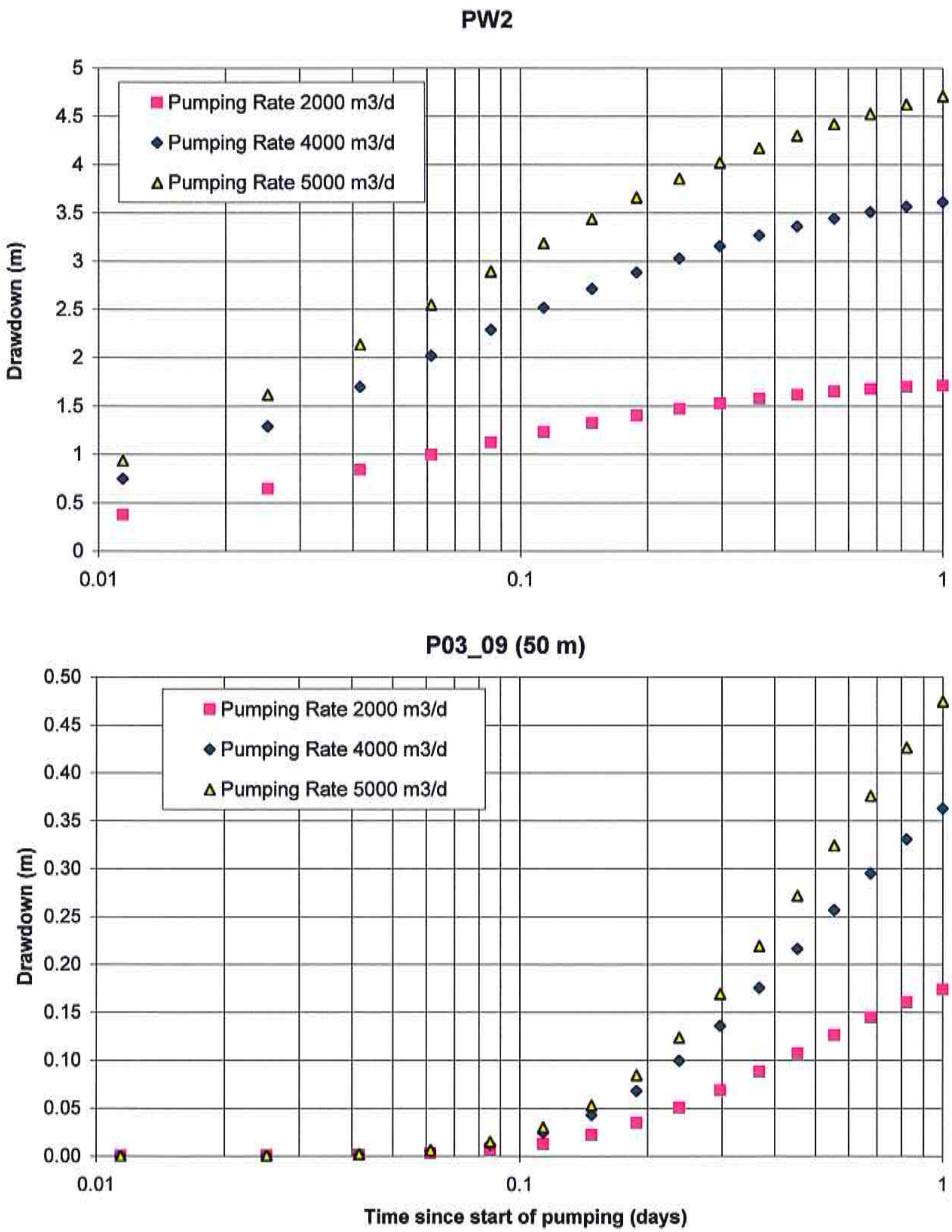


Figure 6. Simulated drawdown for 1-day pump test at PW2 (south side).

Appendix A

Robertson GeoConsultants Inc.

Suite 640, 580 Hornby St., Vancouver, B.C., V6C 3B6
Phone: (604) 684-8072 · Fax: (604) 684-8073

Memorandum for discussion

DATE: May 6th, 2005

TO: Valerie Chort, Deloitte Touche

CC: members of review committee

FROM: Christoph Wels, Robertson GeoConsultants Inc.

RE: Task 22H (a) – Pump Testing in Rose Creek Valley

As requested, this memorandum discusses the advantages and disadvantages of carrying out pump tests in the Rose Creek aquifer during the upcoming 2005 field season. To provide context, the memo also briefly outlines the scope of work and rationale for this study.

Scope of Work

For the purpose of budgeting for 2005-06, the scope for Task 22H (a) was generally defined as follows:

"*This task consists of pumping tests at the Cross Valley Dam. The pumping test component will start with an office assessment to estimate the scope and duration of the pump test(s). Pumping and observation wells would be installed and 1 to 2 week pumping tests completed. The objective of testing is to determine (i) feasibility of pumping the north and south side, (ii) influence of pumping on the Cross Valley seepage and (iii) boundary effects of the aquifer system. Results will be analyzed to assess and design a groundwater collection and water treatment system. The results would provide more reliable estimates of the amount of groundwater to be pumped (for water treatment design) as well as design criteria for a pumping system (depth of screening, interval between wells, pumping rates on south and north side of valley).* "

It should be emphasized that Task 22H(a) does not only consist of a field component (pum testing) but also of an analysis component (pump test interpretation and design of a groundwater interception system. Note also that another component of this study on "attenuation testing" has been split (for administrative purposes) into a separate Task 22H(b). This memo only focuses on the aspect of "groundwater collection".

Rationale for Study

The performance of a pump test in Rose Creek was originally planned for the 2004 field season (original scope of Task 16f) to update a preliminary design of groundwater interception completed by Gartner Lee Limited in 2004[4]. At the time, I argued for a postponement of this field work in order to allow for a detailed review of all available information and the development of a water and load balance (which integrates all available information).

The water and load balance model provided a framework for assessing the potential sources of zinc loading to the aquifer and future zinc concentrations in Rose Creek under different remediation scenarios. The modeling results suggested that zinc concentrations in Rose Creek may rise above applicable standards over the next 10-20 years, regardless of which remediation option is selected for the tailings facility. It is therefore likely that some form of groundwater interception will be required to protect Rose Creek. It should be emphasized that groundwater collection, at least on an interim basis (20-60 years), may be required even if tailings relocation (i.e. full source removal) is selected as the preferred remedial option.

The proposed Task 22H(a) addresses the need to design such a groundwater interception system. In my opinion, the preliminary design of a groundwater interception system provided by GLL in 2004 will require updating for the following reasons:

- Our understanding of the groundwater flow system has improved since completion of this study; for example, seepage from the X-Valley Pond is likely significantly less than assumed in the GLL study and leakage from the Rose Creek Diversion is likely significantly higher than assumed;
- The groundwater flow model was calibrated without the benefit of a detailed pump test (as proposed here); this limited the ability to estimate the groundwater flow rates and hence required pumping rates;
- The GLL study assumed that the fence of wells would be placed along the Intermediate Dam; however, this location may not be the most suitable location for groundwater interception (see below);
- The study assumed that the X-Valley pond would be maintained during pumping; the influence of this assumption on pumping rates was not evaluated;

[4] Gartner Lee Limited 2004. Anvil Range, 2003 Project 17b: Assess requirements for groundwater collection, prepared for Deloitte & Touche Inc., July 2004.

- The predicted pumping rates ranged from 12 L/s (4 shallow wells with an estimated capture efficiency of 47%) to 56 L/s (16 deep wells with an estimated capture efficiency of 100%); these estimates are smaller than groundwater flow estimates obtained during calibration of the water balance model (ranging from 100-180 L/s);

GLL recognized the limitations of their preliminary design work and therefore proposed the implementation of a pump test in the Rose Creek valley and updating of the modeling work. In my opinion, a detailed design of a groundwater interception system (based on pump testing in the Rose Creek aquifer) will be required at some stage prior to implementation. In other words, the main question is not whether to perform the study but whether this work should be carried out during this upcoming field season or whether it would be prudent to postpone it until later. In the following section I will review the "pros" and "cons" for carrying out this program during the 2005 field season.

Pros and Cons for Pump Testing in 2005

Table 1 summarizes the "pros" and "cons" for carrying out Task 22H(a) during the upcoming field season.

Table 1. Advantages and disadvantages of carrying out a pump test in Rose Creek aquifer during 2005 field season.

Advantages ("Pros")	Disadvantages ("Cons")
Reliable estimates of pumping rates and water treatment costs available for closure costing	Location of groundwater interception system has not been decided
Cost savings for field program due to synergies with other planned field programs (drill rigs and field personal)	Hydrogeologic conditions may change between test and implementation
Pump tests will provide field evidence on the degree of capture efficiency that can be achieved	
Results of pump tests can be used to validate/update water and load balance model and model predictions	

The following sections briefly discuss the advantages and disadvantages for moving ahead with the project in the upcoming field season.

Advantages ("Pros")

First, there is a significant discrepancy between estimated groundwater flows in the Rose Creek aquifer (100-180 L/s depending on study reach) and the groundwater flow rates assumed in the GW flow model used for pumping design (20-50 L/s). The proposed pump tests would provide more reliable estimates of groundwater flow in the aquifer and therefore of the required pumping rates. These estimates are perhaps the most time sensitive outcome of the proposed Task 22H(a), because they directly impact on closure costing (a stated requirement for the execution of studies during 2005/06).

Second, the implementation of the proposed pump testing during the field season 2005 would offer (potentially significant) cost savings due to the execution of other parallel field programs. Cost savings may be realized by sharing field equipment (drill rigs, pump test equipment) thus reducing mobilization costs and sharing field personal (drillers, consulting staff) thus resulting in more efficient use of the field time. Those savings may not be available in future years.

Third, the water and load balance model indicated that a very high capture efficiency (>90%) would be required to protect Rose Creek. The existing groundwater flow modeling completed by GLL suggests that 100% capture efficiency can be achieved with 16 wells fully screened across the aquifer. However, this modeling work is based on the assumption of uniform aquifer properties. The proposed pump tests will provide information on the heterogeneity in the aquifer. The results of the pump tests will demonstrate whether a very high capture efficiency is a reasonable expectation for this aquifer.

Finally, the results of the proposed pump tests could be used to validate or, if required, update the water and load balance model and it's model predictions. The water and load balance model represents an integral part of the assessment of different remediation scenarios, and a check on the model assumptions (e.g. groundwater flow rates, pond seepage rates etc.) would provide more confidence in the model findings.

Disadvantages

The primary reason for postponing the proposed pump tests to a future date would be the uncertainty about the actual location of any future groundwater interception system. Clearly, it would be preferable to carry out the pump test at the same location where the system will be ultimately constructed.

The likely options for the location of a future groundwater interception (pumping) system are:

(i) below X Valley Dam;
(ii) below Intermediate Dam; and/or
(iii) upstream of Intermediate Dam (within foot print area of Rose Creek Tailings Facility).

At present, only options (i) and (ii) are available for pump testing. In my opinion, the location downstream of the X Valley Dam is superior for pump testing for several reasons:

- the site is more easily accessible;
- several monitoring wells are available in the area to allow detailed monitoring of the pump test response (including a multi-level piezometer);
- the impact of pumping on toe seepage (from X Valley Dam) and groundwater discharge downgradient can be better assessed (groundwater discharge is easily measured using existing weirs);
- the groundwater flow in the area downstream of X-Valley Dam is only influenced by the Polishing Pond, whereas groundwater flow at the toe of the Intermediate Dam is influenced by both the Intermediate Pond and the Polishing Pond;
- hydraulic conditions at the toe of X-Valley Dam are less likely to change throughout the remediation period than at the toe of Intermediate Dam.

No decision has yet been made about the final location for a groundwater interception system. Hence it is unclear whether the detailed knowledge gained at the X Valley Dam with the proposed pump tests could be used for the final design of a groundwater interception system. However, in my view, the area downstream of the X Valley Dam likely represents the most suitable location for future groundwater interception for much the same reasons as listed above. This is particularly true for the initial period of rehabilitation (until 2020), when the existing dam configuration will still be in place. The results of the proposed pump tests would provide good field data to support (or potentially reject) the option of developing a groundwater interception system immediately downstream of the X Valley Dam.

The second argument for potentially postponing the pump tests is the potential for a significant change in hydrogeological conditions that may potentially compromise the results of the pump test analysis. For example, the Polishing Pond may be removed at some stage (after remedial work), which could influence the groundwater flow regime downstream of the X Valley Dam. Similarly, the final alignment of the Rose Creek Diversion may be changed resulting in changes to the groundwater flow in the aquifer.

Two arguments can be made to counter this concern. First, such changes may not come into effect for many years after start of remediation, still requiring the design and implementation of a GW interception system under (more or less) current conditions. Second, the effect of any future changes in the configuration of the Dams, ponds and diversion channel can be accounted for, at least theoretically. We plan to interpret the pump test results using a local groundwater flow model for the area. The effect of such (potential) future changes in the flow field on pumping rates can be assessed by way of sensitivity analysis.

Recommendations

In my opinion, the potential cost savings for carrying out the pump tests this year and the additional information gained for closure planning (including more reliable estimates of the pumping rates and associated treatment costs) outweigh the arguments for postponing the tests, in particular the uncertainty about the final location of the GW interception system. In fact, the proposed pump testing may even assist in deciding which location is most suitable for interim and/or long-term seepage interception. Based on this analysis, I therefore recommend that the proposed study Task 22H(a) be carried out during the 2005/06 fiscal year. I further recommend that the pump tests be carried out downstream of the X Valley Dam. The results of the pump tests should be interpreted using a local groundwater flow model to allow an assessment of alternative groundwater flow conditions as a result of potential changes in the dam and pond configurations.

Best regards,

ROBERTSON GEOCONSULTANTS INC.

Christoph Wels, Ph.D.
Senior Hydrogeologist