Closure Planning Project Management

Submitted by Deloitte & Touche Inc.
in its capacity as Interim Receiver of

Anvil Range Mining Corporation

December 2004

Produced with the assistance of:

SRK Consulting Inc.

Anvil Range Mine Complex

Closure Planning Technical Workshop Report

Organized by the

Type II Mines Project Office

on February 16-19 2004

December 2004

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1 Introduction

A workshop was held on February 16-19, 2004, to review the results of technical investigations completed in 2003, and to develop scopes for 2004 technical investigations related to planning the closure of the Anvil Range Mine Complex located near Faro, Yukon. The Type II Mines Project Office and Deloitte & Touche Inc. organized the workshop. (Deloitte & Touche Inc. was appointed Interim Receiver of Anvil Range by an order of the Ontario Court on April 21, 1998.)

The workshop was held at the Marriott Pinnacle Hotel in Vancouver, British Columbia. Participants are listed below.

Anvil Range Mining Corp.	Dana Haggar
Technical Consultants	Ron Nicholson (Stantec)
Technical Consultant	Jim Cassie (BGC)
Technical Consultant	John Brodie (Brodie Consulting Ltd.)
Technical Consultant	Malcolm Foy (LGL Limited)
Technical Consultant	Milos Stepanek (Geo-Engineering Ltd.)
Technical Consultant	Eric Denholm (GLL)
Technical Consultant	Wim Veldman (Hydroconsult)
Technical Consultant	John Chapman (SRK)
Technical Consultant	Daryl Hockley (SRK)
Technical Consultant	Cam Scott (SRK)
Technical Consultant	Peter Healey (SRK)
Technical Consultant	Maritz Rykaart (SRK)
Technical Consultant	Steve Day (SRK)
Technical Consultant	Gail Atkinson (Carleton University)
Technical Consultant	Peter Byrne (University of British Columbia)
Technical Consultant	John Cunning (Golder Associates)
Technical Consultant	Barry Evans (Northwest Hydraulics)
Technical Consultant	Rod Smith (Water Management Consultants)
Deloitte & Touche Inc.	Valerie Chort
Deloitte & Touche Inc.	Joe Solly
Deloitte & Touche Inc.	Wes Treleaven
Dept. of Fisheries and Oceans	Sandra Orban
DIAND	Michael Nahir (HQ)
DIAND	Bill Mitchell
Environment Canada	Vic Enns
Environment Canada	Eric Soprovich
Ross River Dena Council*	Victor Mitander
Ross River Dena Council*	Kathleen Suza
Selkirk First Nation	Darin Isaac
Access Consulting	Dan Cornett
Type II Mines Office	Marg Crombie (YTG)

Type II Mines Office	Leslie Gomm (YTG)
Type II Mines Office	Bud McAlpine (DIAND)
Type II Mines Office	Dave Sherstone (DIAND)
Yukon Government	Tony Polyck
Yukon Government	Bob Truelson

* on behalf of the Kaska Dena Nation

2 Workshop Objectives and Agenda

2.1 Overview of Workshop Objectives

The workshop began on the afternoon of February 16, 2004. Daryl Hockey of SRK provided the overview of the workshop objectives.

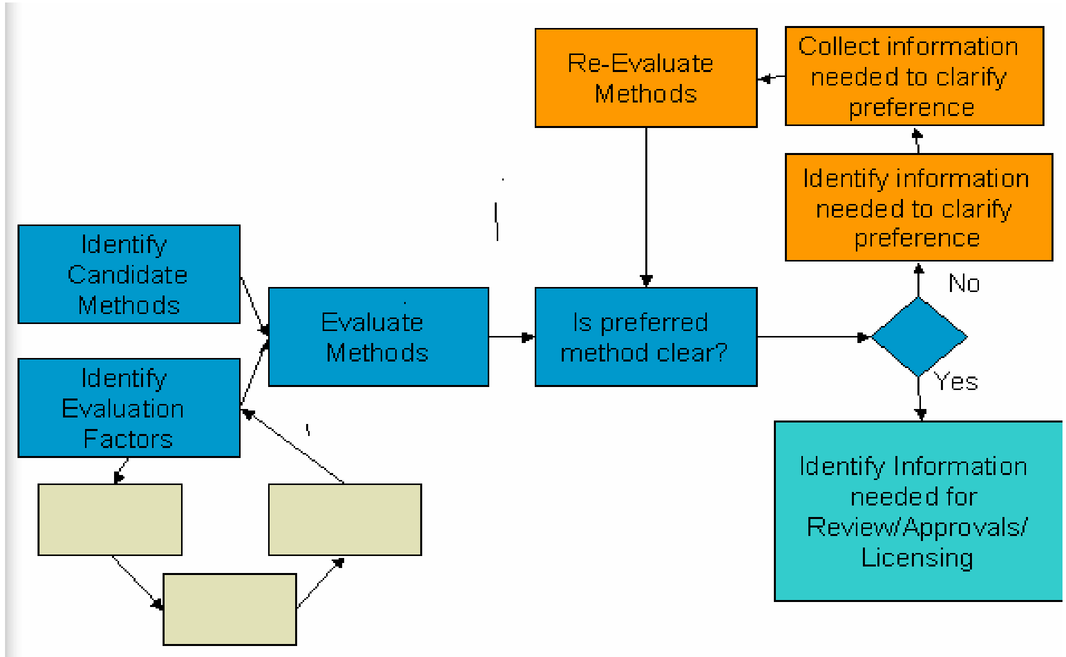
Daryl presented selected figures from the June 2003 workshop (shown on the next page), to remind participants that the technical work involved in closure planning is part of a much larger effort that also includes consultation to define closure objectives (or “evaluation factors” as names in the figure), and an extensive series of reviews and approvals. The role of the technical team assembled for this workshop is to ensure that stakeholders will have the information needed to make decisions about how to best achieve their objectives. Specifically, the technical team needs to collect basic scientific and engineering information, and assemble it into “methods” and “alternatives”. The technical team should not try to select preferred methods or alternatives, but rather should try to define a range of options for stakeholders to review.

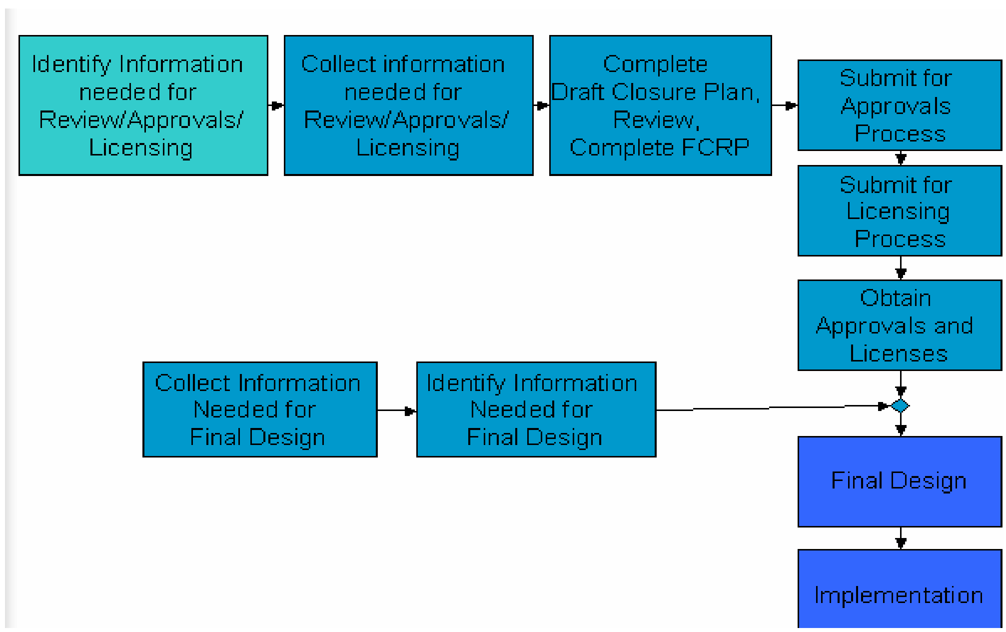
Daryl briefly reviewed the schedule for the technical work. The current draft Water Licence requires that a final Closure and Reclamation Plan be submitted by December 31, 2006. Allowing a full year for internal review and approvals, a complete draft of the plan will be needed by December 2005. Allowing six months for preparation of the draft plan means that the major decisions about closure will need to be made in mid-2005. Therefore, the technical team will need to have all of its information assembled and available to stakeholders in early 2005. The 2004 field season represents the last opportunity to gather that information. Any studies in the 2005 field season will be limited to further definition and design of only the closure methods selected by the decision makers.

2.2 Roles and Responsibilities

Dave Sherstone then followed with introductory comments on behalf of the Type II Mines Project Office. Dave reiterated that the focus of this workshop was on the basic technical work, rather than closure objectives. Closure objectives or “evaluation factors” will be defined in a separate process involving the three levels of government and other stakeholders, rather than technical specialists.

Federal, Territorial and First Nations governments, have agreed to a protocol for involvement in the final closure and reclamation planning, and will be taking the lead in defining closure objectives for the Anvil Range site. Dave provided copies of the protocol to the workshop attendees and walked through the major points. A copy of the protocol is included in Appendix A. Dave noted that the role of the three governments will strengthen as the closure process continues.


Re-Evaluate Methods
Collect information needed to clarify preference
Identify information needed to clarify preference
Identify Candidate Methods
Evaluate Methods
Is preferred method clear?
No
Yes
Identify Evaluation Factors
Identify Information needed for Review/Approvals/ Licensing


Identify Information needed for Review/Approvals/ Licensing
Collect information needed for Review/Approvals/ Licensing
Complete Draft Closure Plan, Review, Complete FCRP
Submit for Approvals Process
Submit for Licensing Process
Obtain Approvals and Licenses
Collect Information Needed for Final Design
Identify Information Needed for Final Design
Final Design
Implementation

Dave emphasized the urgency of the technical investigations, which need to feed into the closure planning process within a timeline that fits with available funding. As identified in the speech from the throne, there is federal funding for the cleanup of contaminated sites for the next five years, but no commitment following that. The Anvil Range site competes with all other Federal contaminated sites for funding and therefore there is a need to maintain momentum in the closure planning process. The current draft Water Licence reflects this urgency in its requirement that a Final Closure and Reclamation Plan be file by December 31, 2006. The objective for this workshop is to address the technical issues relating to this challenge.

Dave clarified the overall management of the site. The Type II Mines Project Office is currently taking the lead on developing a Final Closure and Reclamation Plan, and this workshop will contribute to that effort. The Type II Mines Project Office is also responsible for consultation, but that would not be part of the workshop discussions. Currently, day-to-day management of the site and care and maintenance are the responsibility of the Interim Receiver. All of these roles may evolve as the project proceeds.

2.3 Workshop Agenda

Following the introduction, the agenda for the workshop was reviewed. The remainder of the first afternoon and the morning of the second day were focused on presentation of results from the 2003 studies. The afternoon of the second day included break-out sessions to review the water quality, hydrology and geotechnical investigations. The third day commenced with presentation of the 2003 studies on particular closure methods, and then proceeded to break-out sessions to review the major alternatives in more detail. The morning of the last day was devoted to identifying information needs and designing investigations that could fill those needs by the end of 2004.

The detailed agenda was as follows.

Day 1 Afternoon

Introductory Comments
- *Workshop Overview and Objectives*
- *Update on Type II Mines Office and the Status of First Nations Consultation*

Presentation of 2003 Scientific and Basic Engineering Studies
- *Presentation 1 – ARD Monitoring & Lab Studies (S. Day)*
- *Presentation 2 – Dump Water Balances (D. Hockley)*
- *Presentation 3 – Dump Water Quality Predictions (J. Chapman)*
- *Presentation 4 – Pit Lake Water Quality and Treatment Methods (J. Chapman)*
- *Presentation 5 – Water Treatment Cost Assumptions (J. Chapman)*
- *Presentation 6 – Grum Seepage Requirements (P. Healey)*
- *Presentation 7 – Terrestrial Risk Data (E. Denholm)*
- *Presentation 8 – CCME-based Water Quality Objectives (E. Denholm)*

Day 2 Morning

Presentation of 2003 Scientific and Basic Engineering Studies (Cont'd)

Presentation 9 – Tailings Groundwater Studies (E. Denholm)
Presentation 10 – Requirements for Groundwater Collection (E. Denholm)
Presentation 11 – Earthquake Hazard Studies (G. Atkinson)
Presentation 12 – Tailings Physical Properties (J. Cunning)
Presentation 13 – Foundation Liquefaction Study (P. Byrne)
Presentation 14 – Seismic Stability Assessment (J. Cunning)
Presentation 15 – Faro and Vangorda Creek Hydrology (B. Evans)

Day 2 Afternoon

Groups to review 2003 Scientific and Basic Engineering Studies

- Group 1 - Review of Water Quality Studies
  - *ARD Monitoring & Lab Studies*
  - *Dump Water Balances*
  - *Dump Water Quality Predictions*
  - *Pit Lake Water Quality and Treatment Methods*
  - *Grum Seepage Requirements*
- Group 2 - Review of Hydrology Studies
  - *Faro and Vangorda Creek Hydrology*
  - *Tailings Groundwater Studies*
  - *Requirements for Groundwater Collection*
  - *Terrestrial Effects and Site Specific Water Quality Objectives*
- Group 3 - Review of Geotechnical Studies
  - *Earthquake Hazard Studies*
  - *Tailings Physical Properties*
  - *Foundation Liquefaction Study*
  - *Seismic Stability Assessment*

Feedback from Groups

Day 3 Morning

Presentation of 2003 Closure Method Studies

Presentation 16a, 16b & 16c – Rose Creek Diversion Options (B. Evans & J. Cassie)
Presentation 17a and 17b – Tailings Relocation Methods (J. Brodie & C. Scott)
Presentation 18a and 18b – Waste Rock and Tailings Cover Methods (M. Rykaart)
Presentation 19 – Plug Dam Investigation and Design (J. Cassie)

Day 3 Afternoon

Groups to Review Major Alternatives

Group 1 – Relocation of the Rose Creek Tailings to Faro Pit
Group 2 – Stabilization of the Tailings in the Rose Creek Impoundment
Group 3 – Closure and Reclamation of the Faro, Grum & Vangorda Mine Areas

Feedback from Groups

Day 4 Morning

Review of Gaps in Technical Information
Identification and Scoping of Technical Studies for 2004

3 Review of Year 2003 Studies

3.1 Basic Scientific & Engineering Studies

3.1.1 Presentations

The basic scientific and engineering studies completed in 2003 were presented by the principal investigators, or, in a few cases, by project managers familiar with the work. Copies of the presentations are included in Appendix B.

For each of the 2003 studies, a draft report was available prior to the workshop, and final reports have been issued or are expected to be available in the summer of 2004. To avoid confusion, readers are referred to those sources for further information on each study.

After each presentation, clarification questions were asked and answered. Workshop participants were requested to make note of more involved questions for discussion in the subsequent group sessions. The more involved questions were collected by the facilitator.

3.1.2 Group Reviews

On Tuesday afternoon, the workshop participants were divided into three groups to further evaluate the 2003 studies. Each of the three groups was assigned a specific category of studies to discuss: one group reviewed the studies related to water quality; another reviewed the hydrology studies; and the third reviewed the geotechnical studies. Specialists in each area were asked to join the appropriate group and other participants were free to choose which group they joined. The questions collected after the presentations were provided to the groups to stimulate discussion. After the group sessions each group provided a summary of their reviews.

3.1.2.1 Feedback from Water Quality Group

The water quality group reviewed the following studies:

- ARD Monitoring & Lab Studies
- Dump Water Balances
- Dump Water Quality Predictions
- Pit Lake Water Quality and Treatment Methods
- Grum Seepage Requirements

Key points from the reviews are summarized below.

<u>ARD Monitoring and Lab Studies</u>

The waste rock geochemistry database collected over the last two years, and supplemented by previous studies, is very strong. No further waste rock sample collection or testing is needed. Continued seep sampling and monitoring of installed temperature and oxygen probes are recommended. Two issues for further consideration are the identification of non-PAG rock for construction, and characterization of the haul road.

Dump Water Balances

This project is still underway. There is still uncertainty around infiltration and losses to groundwater. The instrumentation installed in 2003 is excellent and should provide the data needed to improve estimates of infiltration. Other water balance components should also be monitored where possible, for example on Vangorda Dump. It is hard to evaluate the predictive model without at least one year of input data.

Dump Water Quality Predictions

This work on dump water quality estimates has not yet produced definitive predictions. The predictive model developed in 2003 is appropriately simple. Use of the model to look at the sensitivity of water quality estimates to input assumptions and to dump closure methods is recommended.

Pit Lake Water Quality and Treatment Methods

The predictive modeling the study of pit lake water quality used conservative assumptions but still showed that long-term contaminant concentrations in flow-through pits will be lower than was expected. These results need to be reviewed carefully, but they indicate that pit water quality could be in the range where *in situ* treatment is feasible. Each pit has its own timeframe, so it may not be necessary to answer all of the questions immediately. For example, it might be possible to implement *in situ* treatment of flow through pits long after the closure of other site components, once the long-term water quality trends are clear.

Grum Seepage Requirements

The 2003 study of Grum Dump seepage provided estimates for costs of collecting Grum Dump seepage by either ditches or wells, but did not (and was not intended to) determine which method will be required. The latter point needs to be addressed.

3.1.2.2 Feedback from Hydrology Group

The hydrology group reviewed the following studies:

- Faro and Vangorda Creek Hydrology
- Tailings Groundwater Studies
- Requirements for Groundwater Collection
- Terrestrial Effects and Site Specific Water Quality Objectives

Key points from the reviews are summarized below.

Faro and Vangorda Creek Hydrology

The most important outcome of the study of Faro and Vangorda Creek hydrology is the estimate of the Probable Maximum Flood (PMF). That estimate relies on two inputs, the estimated Probable Maximum Precipitation (PMP) and the estimated "time to peak flow". The rationale for the PMP calculation needs to be reviewed. Input should be sought from Mr. Hogg, who first applied the PMP method in the Mayo district. Increased confidence in "time to peak flow" estimates will require site measurements. These measurements should be possible through a combination of the new meteorological stations and the site flow monitoring. Short term measurements on other streams might also be needed. The hydrology of lower Vangorda Creek is uncertain because of disagreement between two monitoring stations. The two gauging stations should be inspected. One of the sites should be adopted for long-term flow monitoring.

The potentially beneficial effects of the North Fork Rock Drain on flood attenuation should be assessed. Dave Campbell of Golder Associates designed the rock drain and has already done some of this. A cost-benefit analysis could show whether the drain should be left in place to attenuate floods.

Tailings Groundwater Studies

The additional wells installed in 2003 have improved the understanding of the tailings area groundwater. There are now enough wells to characterize physical processes. However, there is some doubt about whether the well showing high zinc below the tailings (well P01-09) is functioning properly. It appears possible that there has been a leakage along the wall of the well, and that the high concentrations measured in the underlying aquifer are an artifact of that leakage.

The study of geochemical attenuation processes within the tailings and the underlying materials is lagging behind the physical studies. The attenuation processes are evident in the field data, but their long-term effectiveness needs to be characterized by laboratory tests. That information is required before long-term predictions of contaminant concentrations can be made.

Requirements for Groundwater Collection

The study of tailings groundwater collection used numerical modeling to estimate how much contaminated groundwater might need to be collected in future, and derived estimates of capital and operating costs. The simplest system, involving wells located below the toe of the Cross Valley Dam, was considered and shown to be adequate. The results provide a good benchmark for cost comparisons. More elaborate collection systems, involving wells located to collect water from “hot spots” or additional pumping wells upstream, will need to be considered if a decision is made to leave the tailings in place. Definitive estimates of groundwater collection requirements will require a pump test.

Terrestrial Effects and Water Quality Objectives

Both of terrestrial effects studies and the work on water quality objectives were in their early stages. Traditional Knowledge input is needed. Specifically, lists of important species and traditional land and water uses need to be developed and used in the planning of future work.

With respect to water quality objectives, it was pointed out that Curragh had completed a mesocosm study in Blind Creek, and that the results might be useful to the current work. Other species and other metals should be included in future studies.

3.1.2.3 Feedback from Geotechnical Group

Earthquake Hazard

The earthquake hazard assessment significantly improved the understanding of earthquakes in the project area and provides a strong basis for selecting design earthquakes. One outstanding question is whether the design earthquake should be the median or the mean of the records found by the study. The median represents the 50^{th} percentile, while the mean is influenced by extreme high values and therefore would be closer to the 75^{th} or 80^{th} percentile. The choice could have significant effects on the results of further analyses. For example, the tailings dams would probably be predicted to undergo much greater deformation in the mean earthquake than they would in the median event. It was suggested that the choice of mean or median might need to depend on what was being designed, and therefore how much conservatism was needed. The example discussed was tailings covers vs. tailings dams. The effect of earthquakes on covers would only be local deformation, whereas an earthquake induced dam failure could be catastrophic.

Tailings Physical Properties

The 2003 study of tailings physical properties appears to have filled all of the data gaps in this area. Reviewers felt that the new data provide a strong basis for subsequent work.

Foundation Liquefaction Study

The foundation liquefaction study focused on the potential for seismic events to trigger liquefaction of the foundation of the Intermediate Dam. Liquefaction, meaning a sudden loss of stiffness and strength, can lead to significant movement and even breaching of a dam. The risk of liquefaction is normally assessed by determining whether liquefaction can be triggered, whether a flow slide will result, and whether significant deformation will occur. Only the first step was taken in this study. The results indicate that liquefaction could be triggered in the foundation material along the northern shoulder of the Intermediate Dam. However, the data for the assessment are limited. The review group recommended that Becker density tests or shear wave tests be carried out to provide the data needed to confirm whether liquefaction can be triggered and to provide a basis for determining whether a significant dam failure would result.

Seismic Stability Assessment

The seismic stability assessment was intended to assess the potential for liquefaction of the tailings in earthquakes, the likely magnitude of the resulting deformations, and the requirements for dam upgrades. Only the first objective was met, with the conclusion that fine tailings are certainly subject to liquefaction, and the coarse tailings are questionable.

Reviewers pointed out that the next steps were still needed and should include assessing the potential for the liquefaction to result in a flow slide, and assessing whether the resulting deformation would be significant enough to induce dam failures. It was also suggested that the possibility of liquefaction and significant deformation under earthquakes less than the MCE (maximum credible earthquake) should be checked.

3.2 Studies of Closure Methods

On Wednesday morning, the full workshop reconvened to hear presentation of the 2003 studies that dealt with specific closure methods:

- Rose Creek Diversion Canal options, including three presentations by Barry Evans and Jim Cassie:
    - Hydraulic assessment of the diversion canal in its current form
    - Hydrotechnical implications of three closure options, and
    - Geotechnical and cost implication of three closure options;
- Tailings relocation options;
- Tailings and waste rock covers;
- Faro Pit Plug Dam.

Copies of the presentations are included in Appendix B, and readers are again referred to the final study reports for details. Brief summaries of the key points and the questions raised in subsequent discussions are provided below.

3.2.1 Rose Creek Diversion Canal Options

There were three presentation related to the Rose Creek Diversion Canal.

Jim Cassie presented the results of a study of the flow capacity of the channel in its current form. The study, which was carried out by Gerry Ferris of BGC and Gene Yaremko of nhc, concluded that the channel was not capable of carrying the design 1:500 flood of 160 m^3/s, or even the currently estimated 1:500 year flood of 135 m^3/s. On the contrary, flows greater than about 82 m3/s, roughly the 1:100 year event, would overtop the canal dike crest at a low point above the Intermediate Dam. The recommendation was that the crest should be raised by 0.25-0.5 m over a length of about 1000 m. The study also raised concerns about erosion of the channel in floods, and recommended that riprap upgrades be considered.

Barry Evans presented the results of hydrotechnical studies of three options for upgrading the Rose Creek Diversion Canal. The three options were (1) increasing the channel capacity in its current alignment by raising the dyke along the north bank, (2) creating a new channel over the top of the tailings to a spillway at the south abutment of the Intermediate and Cross Valley dams, and (3) removing tailings to create a much larger pond that could attenuate the flood before passing it over an improved spillway along the north abutment. The hydrotechnical studies led to estimates of the channel and pond sizes for each option.

Jim Cassie then presented the geotechnical considerations and cost estimates associated with each of the three options. He included variants of Option (1) where the current channel would be widened to the south, and the drop structures at the west end of the channel would be replaced by a concrete spillway and a by-pass channel for fish. He concluded that the combination of raising the north bank of the channel and adding the concrete spillway and fish bypass would be the only viable configuration of Option (1). The cost of this variant was estimated at $32,100,000, of which about $18,000,000 was associated with the concrete spillway and fish bypass. The cost for Option (2) was estimated at $59,900,000, of which about half would go to earthworks for the channel over the tailings and half would go to the new spillway. The cost of Option (3) was estimated at $32,600,000, but that number did not include the cost of tailings relocation.

There was lengthy discussion about the studies. Some of the key points raised were:

- Concerns associated with raising the north side of the current channel where it passes above the Intermediate Impoundment (under Option 1), especially whether it would be possible to build a properly compacted structure on top of the fine tailings;

- Alternatives to the very costly concrete spillway, specifically whether it would be preferable to extend the channel further down the valley so that any spillway failure would not propagate back to the dams; and

- The role of the North Fork of Rose Creek in the flood estimates, specifically whether the Haul Road would delay the roughly 40% of the flow that originates from the North Fork and thereby reduce the volume of water that would need to be passed through any of the diversion systems.

3.2.2 Tailings Relocation

There were two presentations on methods to relocate the tailings to the Faro Pit. John Brodie first presented a review of recent literature on tailings relocation using the method of hydraulic monitoring. The review concluded that hydraulic monitoring was a widely used method of relocating tailings. There is extensive experience with the method in South Africa and other zones with warm, dry climates, and at least one large scale project from a much colder site in the Chilean Andes. The only northern project that was found in the literature was a tailings re-processing project at the Giant Mine in NWT. That project was unsuccessful, but it was not clear if the difficulties were related to hydraulic monitoring.

Cam Scott presented a comparison of three methods of tailings relocation: dredging, hydraulic monitoring and mechanical (i.e. with trucks). The presentation included conceptual plans and cost estimates developed by specialists in each method. The hydraulic monitoring costs appeared to be the lowest, but the specialist in that method had not yet visited the site. It was expected that the cost estimate for hydraulic monitoring would increase once site specific costs and complexities were included.

In discussion of the various methods, it was concluded that the mechanical approach would not be applicable to all of the tailings, because the surface in the wet areas would not support the trucks. Hydraulic monitoring and dredging were both seen as realistic options for either partial or total relocation of the tailings. But further work would be needed to demonstrate feasibility of the monitoring and develop realistic cost estimates.

The possibility of metal recovery from the tailings was raised. This issue had been investigated in 1996 studies, which concluded that metal recovery would not be economical even with an operating mill. In the current situation, without an operating mill, the economics would only be worse. However, some participants felt that this option should be looked at again as a means to recover some of the relocation costs.

The question of whether the tailings would need to be neutralized prior to being placed in the pit was discussed but not resolved. Some participants believed that the tailings could be placed in the pit as is, because any contamination would be trapped within the pit.

Others thought that addition of lime to the tailings to treat acidity would be required, and/or would be more economic than treating the resulting contamination of the pit water.

Several items were identified as being necessary add-ons to any tailings relocation plan. These included removal of the earthen components of the tailings dams, removing any contaminated soil below the tailings, re-establishing the stream channel and fish habitat, and dealing with any residual groundwater contamination.

3.2.3 Soil Covers Waste Rock and Tailings

Maritz Rykaart presented the results the 2003 studies of soil covers. The study included a review of cover types and functions, inspection of previous cover trials on the Faro tailings and at the Vangorda waste rock dump, a summary of available materials for soil covers, laboratory and *in situ* testing of those materials, a review of constructability issues and re-sloping requirements, and scoping level numerical modeling of possible soil covers. The study concluded that soil covers can be constructed to function as infiltration barriers on the waste rock. Construction of a low infiltration cover on the tailings would be a challenge due to material limitations, access constraints and settlement.

Many questions were asked about the numerical modeling. It was pointed out that the modeling was at a scoping level only, *i.e.* intended only to illustrate the behaviour of various cover profiles and not to provide realistic estimates of infiltration. Realistic estimates of infiltration can only be obtained through field testing.

The function of a tailings cover was discussed. The effect of a cover on long term groundwater contamination and groundwater treatment requirements was thought to be minimal. However, construction of covers for dust control and to prevent tailings uptake by animals would be feasible. The use of waste rock as part of the tailings cover would require that a reasonably inert source of waste rock be found.

Questions about the waste rock covers included the long-term effects of freezing and thawing, the requirements for revegetation, and the need for a two-dimensional numerical model to examine the effects of covers on slopes.

Costs for cover construction were examined in a number of questions. One of the 2003 projects was to have included obtaining contractor quotes for cover material excavation, loading, hauling, deposition, spreading and compaction. Unfortunately, the local Yukon contractors had not responded to requests. Therefore cost estimates were based on experience elsewhere.

3.2.4 Plug Dam

Jim Cassie presented an investigation of the “Plug Dam” that would be needed along the low point of the Faro pit wall if tailings are to be stored there. The dam would need to be raised to an elevation 1176 m, and would require a grout curtain reaching down to elevation 1137 m. However, additional field investigation, including drilling and test grouting, is needed before the design can be further advanced.

Questions were raised about the possibility of outflow along the former alignment of Faro Creek, about the quality of rock along the proposed dam’s west abutment and between the dam and the Zone II Pit, about the possibility of seepage from the dam to the Zone II pit, and whether the proposed dam would need a spillway. It was agreed that these questions should be considered in the next phase of investigation and design.

4 Major Closure Alternatives

On Wednesday afternoon, three groups were formed and each group was assigned the task of examining a particular set of closure methods. One group looked at relocation of the tailings, and another at stabilization of the tailings in their current location. The third group examined a range of closure methods applicable to the mine areas.

Each group was requested to think in terms of a complete combination of methods needed to implement its alternative or alternatives. To keep the exercise focused, groups were requested to first work through the key decisions that would be needed to come up with conceptual plans, and then to develop rough construction sequences and schedules. Each group was also asked to keep track of any remaining uncertainties that were identified in the discussions.

4.1 Tailings Relocation

4.1.1 Selection of Methods

The tailings relocation group discussed the possibility of relocating all of the tailings to the Faro Pit. The group found that the currently available information indicated that hydraulic monitoring would be the preferred method to move the bulk of the tailings, with the final tailings cleanup and dam removal by mechanical excavation. However, the group also noted that there were several open questions about the effectiveness and cost of hydraulic monitoring, and therefore that dredging should not be ruled out until further studies were completed.

Adopting hydraulic monitoring as the basis, the group developed a tailings relocation plan that included four phases, as follows.

In the Planning phase, several remaining questions would need to be resolved:

- Volumes available for tailings storage in the pit, including settling tests to determine the expected tailings densities;
- Details of the hydraulic monitoring system and operations, possibly including pilot testing;
- Requirements for water treatment plant upgrades, pipelines and other water management requirements.

The Execution phase would take approximately 10-15 years and would include the following steps:

- Upgrade of the water treatment system;
- Phase 1 construction of water collection systems for X23 and Guardhouse Creek;
- Lowering of water levels in the Faro Pit and possibly the Intermediate Pond
- Initiation of hydraulic monitoring at the upstream end of the Original Impoundment
- Periodic water treatment and discharge of water to maintain the water balance in the hydraulic monitoring – pond – pit system;
- Ongoing data acquisition and optimization of the hydraulic monitoring method;
- Hydraulic monitoring shifts to intermediate dam;
- Concurrent lowering of the Intermediate and Cross Valley dams;

- Concurrent mechanical cleanup of the original and secondary impoundment basins;
- Monitoring finishes;
- Mechanical cleanup of remaining basin channel.

The Post Relocation phase would cover the approximately 5-10 year period required for the site to stabilize, and would include the following activities:

- Removal of water treatment sludge from the Cross Valley Pond;
- Monitoring of surface and ground water quality throughout the former tailings basin;
- Re-vegetation of exposed ground;
- Phase 2 modifications of the X23 and Guardhouse Creek collection systems;
- Maintenance of a small contaminated water pond behind one of the remnant dams, with construction of a spillways and flow channels;
- Ongoing water treatment.

The Final phase would begin when water quality in the former tailings basin stabilized at a level acceptable for direct discharge, and would include

- Breaching of the remnant dam;
- Re-establishment of a natural channel including fish habitat and riparian vegetation.

It was hoped that the group would be able to develop rough cost estimates for the above activities. However, the group reviewed the current estimates of the unit cost for hydraulic monitoring and found them to need further work. The significant uncertainty in this fundamental input made cost comparisons meaningless, and therefore the group did not pursue cost estimates any further.

4.1.2 Other Requirements

The core activity in this alternative would be the tailings relocation itself. However, the group noted that many of the related activities would also require careful consideration.

Tailings Water Management
The contaminated water generated during the tailings relocation would need to be carefully managed. There would need to be a balance between natural inflows to the system, water used for hydraulic monitoring, water transferred to the Faro Pit and water returned from the pit. Excess water would need to be treated and released. The effect on groundwater below the tailings would need to be monitored to ensure that contaminants were not being driven downwards into the aquifer.

Lime Amendment of Tailings
A significant uncertainty is whether it would be necessary to treat the acidity in the tailings as they are transported to the pit. Treatment would allow the tailings to be deposited “clean”, whereas the absence of treatment would mean that the tailings acidity might adversely affect the quality of water in the pit lake and and/or in the pore space of the deposited tailings. The latter may not be a significant concern, depending on whether the tailings form an impermeable seal in the pit bottom.

Surface Water Management

Surface water around the tailings area would also need to be managed. Guardhouse Creek and the seepage from X23 have the potential to contaminate Rose Creek, and therefore would need to be remediated along with the tailings. Initially, it might be adequate to pump the contaminated water to the mill for treatment in the existing system. Over the longer term, a treatment system located downhill of these sources would save on pumping costs.

Dam Removal or Breaching

Timing of the removal or breaching of the dams was discussed. At least one dam would need to be retained throughout the hydraulic monitoring program to store water. However, that dam could be lowered concurrent with the tailings relocation. After the completion of hydraulic monitoring, it might be beneficial to continue to retain one dam or a remnant thereof to store contaminated water from the tailings footprint, or flowing into the valley from X23 or Guardhouse Creek. Once the contamination is cleaned up and/or the contaminated water re-routed to a treatment system, the remnant dam could be breached and its footprint reclaimed.

Plug Dam

The Plug Dam across the low point of the Faro pit wall was discussed. The elevation of the dam would need to be optimized taking into consideration the available storage volume, the predicted tailings density, the possibility of enhancing the tailings density by thickening or other methods, and the long-term plans for managing Faro Creek either through or around the pit lake.

Valley Reclamation and Restoration

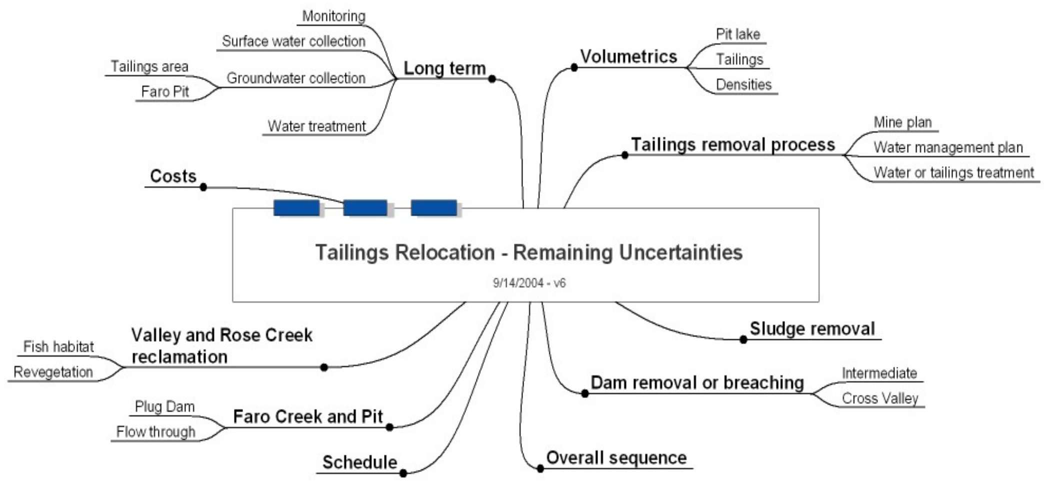
Remediation of the valley bottom, after removal of the tailings, was discussed. It would probably be necessary to excavate below the tailings – soil interface in order to capture all of the contaminated material. Borrow areas below the tailings footprint would also need to be re-graded. Once the excavation is complete, the valley floor could be restored to a natural drainage pattern. It was suggested that the final restoration be delayed to allow several years to flush any residual contamination from the area.

Long Term

The long-term requirements associated with tailings relocation are likely to include monitoring of surface and groundwater, monitoring of groundwater from the tailings in the Faro Pit, and perpetual maintenance of the Plug Dam. There is also a possibility that long-term collection and treatment of contaminated groundwater will be required.

4.1.3 Remaining Uncertainties

After presentation of the group's work to the rest of the workshop participants, the remaining uncertainties associated with tailings location were reviewed. The mind-map on the following page summarizes the results.



4.2 Stabilize Rose Creek Tailings

4.2.1 Selection of Methods

The group discussing stabilization of the tailings in their current location started with the options for the Rose Creek Diversion Channel that were outlined in the 2003 study. As discussed above, three options were presented in that study.

Option 1 consisted of increasing the channel capacity of the Rose Creek Diversion Channel in its current alignment by either cutting into the south bank (1a) or raising the dyke along the north bank (1b), and then adding a concrete spillway at the channel outlet. The group concluded that Option 1b should not be recommended because of the problems associated with raising the dyke where it is founded on tailings, and because of the high costs of constructing and perpetually maintaining a concrete spillway. Option 1a was concluded to be reasonable if the concrete spillway could be replaced by some other outlet mechanism.

Option 2 consisted of covering the tailings and creating a new channel over the top of the cover to a spillway at the north abutment of the Intermediate and Cross Valley dams. The group concluded that this option should not be recommended because of the risk of running a major flood over the tailings, and the lack of a precedent elsewhere.

Option 3 consisted of removing tailings to create a much larger pond that could attenuate the flood before passing it over an improved spillway along the north abutment. This option was not further discussed by the group, because it was considered a relocation option. A fourth option, also involving the relocation of tailings, was briefly considered but then dropped for the same reason.

A fifth option was developed by the group and proposed as a viable alternative. This Option 5 included increasing the capacity of the Rose Creek Diversion Channel to pass a PMF to a point beyond the Intermediate Dam, and then routing a portion of the flood flow through the Cross Valley Pond to the existing spillway on the north side of the valley. The idea of this option was to obtain the major benefit of Option 2, *i.e.* to utilize the north-side spillway, while avoiding the major risk associated with passing flows over the tailings. It was also thought that splitting the hydraulic drop at the end of the Rose

Creek Diversion Channel into two steps, one step into the Cross Valley pond and one step out of the north side spillway, might significantly reduce the cost of the spillway construction and possibly even eliminate the need for concrete.

4.2.2 Other Requirements

The group also discussed the additional activities that would be required, or that could be added to any of the above options.

Stabilization of North Fork Rock Drain
The rock drain that allows the North Fork of Rose Creek to pass under the Grum haul road may have the potential to attenuate floods. It was roughly calculated that the basin behind the haul road could store the estimated 14 million cubic metre volume of the PMF with only a 5 m rise in water level. The attenuation provided by the rock drain would significantly reduce the rate of flow through the Rose Creek Diversion Channel, and therefore lead to significant savings in the cost of the channel upgrade. The volume estimate and the stability of the haul road need to be checked, but the group concluded that this concept is certainly worthy of further consideration.

Seismic Stabilization
The group discussed needs for upgrading of structures to withstand seismic forces. It was concluded that a seismically induced failure of the Rose Creek Diversion Channel itself is unlikely and would have low consequences, as long as future raising of the channel is to the south and not over the tailings to the north. However, all of the dams would need to be upgraded to withstand a Maximum Credible Earthquake. Densification of the tailings beneath the Secondary Dam might also be needed to prevent seismically induced liquefaction.

Groundwater Collection and Treatment
The group concluded that any contaminated groundwater from below the tailings could be collected by a series of wells located below the Intermediate Dam. The collection problem was considered to be relatively simple and technically feasible. The need for and timing of groundwater collection is currently unclear, but could be established through longer term monitoring.

Tailings Cover
The group discussed the construction of soil covers on the tailings surface, and concluded that covers were unlikely to lead to a significant reduction in the potential future cost of groundwater treatment. However, the group recommended that covers still be given serious consideration because of benefits for ecological health, safety, and reclamation.

Surface Water Management
The requirements for surface water management include dealing with water on the tailings as well as water entering the tailings from the north side of the valley. The group concluded that continuing treatment of the Intermediate Pond would certainly be required if the tailings are not covered, and might be required for several years even if the tailings are covered. Two major flows have the potential to enter the tailings area from the north. Provision to capture and treat the seepage from X23 would need to be part of any long-term plan and the existing north wall interceptor system would need to be upgraded.

Preliminary Cost Estimate

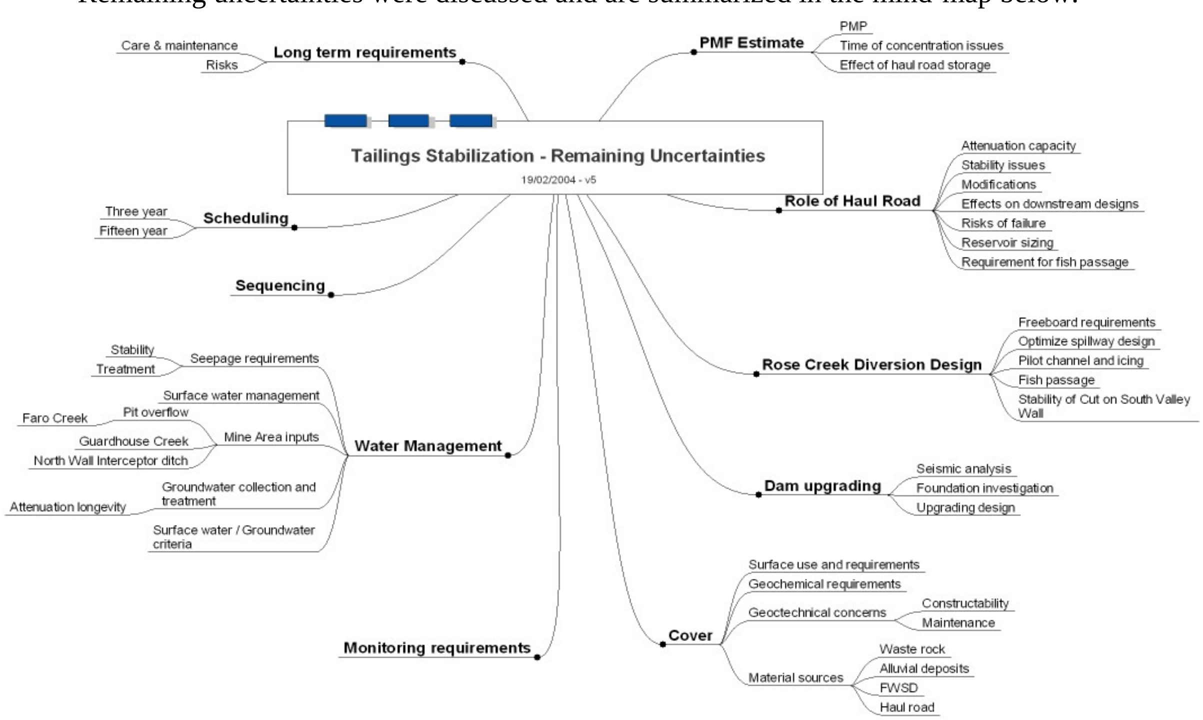
The group prepared a preliminary cost estimate to illustrate the significance of the "other" activities in comparison to the costs of the Rose Creek Diversion Channel options. As the table below shows, the other activities could roughly double the cost of the stabilization alternative. However, the group did not have time to examine the savings that might be possible if some of the other activities are included. A proper trade-off study would be needed to examine those effects.

Preliminary Cost Estimate for Stabilization Alternative ($ million)

Item	*Estimated Cost*
Rose Creek Diversion Channel stabilization (Option 1a)	32
North Fork Rock Drain upgrade	5
Seismic upgrades	
East Secondary Dam	0.5
Main Secondary Dam	1.5
Intermediate Dam	2
Cross Valley Dam	2
Groundwater collection system capital	1
Groundwater treatment plant capital	8
Groundwater collection and treatment operating (NPV)	10
Surface water upgrades	0.5
Cover (1 m rock on 200 ha x $5/m^3)	10
Treatment of Intermediate Pond water	4
Total	76.5

4.2.3 Other Requirements

Remaining uncertainties were discussed and are summarized in the mind-map below.



4.3 Mine Areas

4.3.1 Selection of Methods

Base Case

The group looking at closure of the mine areas started by considering a "base case" where contaminated surface water and seepage would be collected and treated only, without any further remediation of the site. The group used results of the 2003 investigations to develop the preliminary cost estimates for the water treatment systems in each area, as shown below.

Mine Area Base Case Water Treatment Costs ($ million)

	Faro	Grum	Vangorda
Capital Cost	8-11	4-5	2-3
Annual Operating Cost	0.3-0.6	0.2	0.2-0.3
Total Cost (NPV)	17-25	9-10	6-9

Faro Area Options

Two options were considered for the Faro area.

- Option 1 is the base case with relocation of Faro diversion along one of the alignments recommended in the 2003 study
- Option 2 is the base case with relocation or segregation and covering of low grade ore and, where practical, covering waste rock surfaces for revegetation.

Rough cost estimates were developed for these options. The estimates were intended only to serve as a basis for comparing the options to the base case, so many of the costs that would be common to all options were not included.

Comparative Preliminary Costs for Faro Area Options ($ million)

	Base Case	Option 1	Option 2
Cover costs			7
Faro Creek diversion relocation costs		3	3
Backfill and lime amendment costs		-	3
Treatment capital plus operating costs (NPV)	17-25	17-25	12-20
Total	17-25	20-28	25-33

Vangorda Area Options

The group also explored three options for the Vangorda area:

- Option 1 – cover the waste rock and maintain the Vangorda flume
- Option 2 – Cover the waste rock and divert Vangorda Creek to Dixon Creek
- Option 3 – Backfill the pit with lime-amended waste rock, re-establish Vangorda Creek channel over the backfill, and cover the remaining waste rock.

Preliminary cost estimates were developed for these options. The use of a flow-through pit was identified as a possible improvement to Option 1 and Option 2.

Comparative Preliminary Costs for Vangorda Area Options ($ million)

	Base Case	Option 1	Option 2	Option 3
Cover costs	-	6	6	6
Vangorda Creek diversion costs	-	1	3	-
Backfill and lime amendment costs	-	-	-	20
Treatment capital plus operating costs (NPV)	6-9	3-5	3-5	3-5
Total	6-9	9-12	12-17	29-31

Grum Area Options

The primary option for the Grum area was:

- Flow through pit with treatment now to remove current load
- Cover the sulphide cell
- Monitor seepage and groundwater
- Provide a contingency for future groundwater collection and treatment.

The comparative preliminary cost estimates are shown below. The major difference between the base case and the option is that the treatment costs are only a contingency for the option. In other words, the option presents a possibility that no water treatment would be required.

Comparative Preliminary Costs for Grum Area Options ($ million)

	Base Case	Option 1
Cover costs		1
Treatment capital plus operating costs (NPV)	9-10	9-10*
Total	9-10	10-11

*Contingency only

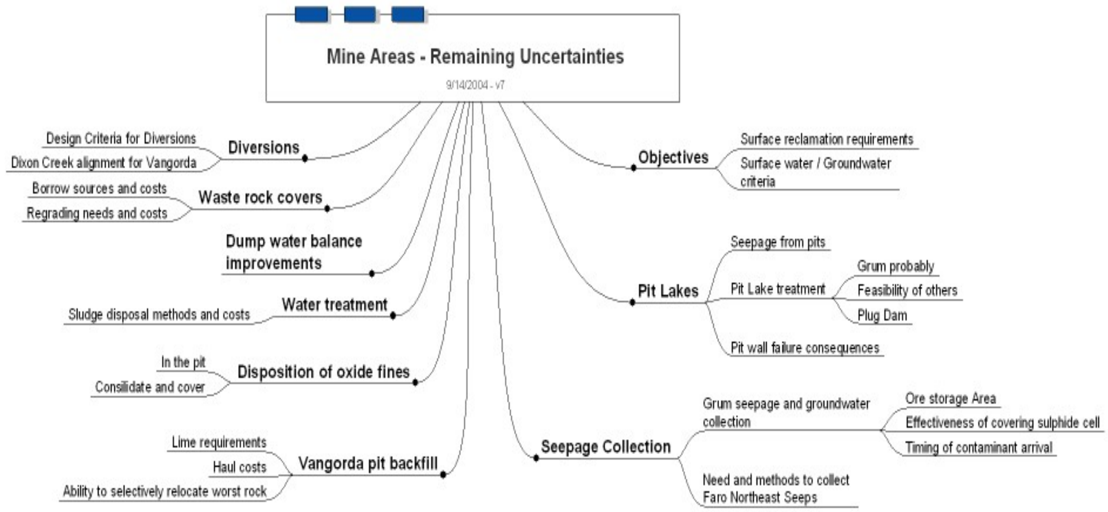
4.3.2 Other Requirements

The group also discussed additional activities that could be required in each area, and came to the following conclusions.

- A minimum cover may be required for reclamation and land use purposes;
- Pit lake treatment is an integral part of some options, but will likely be required to some extent in all cases;
- Site specific water quality objectives for runoff and treated water discharge need to be defined;
- Water treatment will entail requirements for sludge management;
- Ground water may need to be collected and treated;
- Resloping of the waste rock will be needed before covers can be constructed.

4.3.3 Remaining Uncertainties

The discussion of uncertainties pointed out that one of the biggest questions for the Faro mine area is whether the tailings will be placed in the pit. Other uncertainties specific to the mine areas are summarized in the mind-map below.



5 Study Design and Costs

On Thursday morning, the workshop participants were asked to review the key uncertainties identified in the previous day's deliberations, and to design investigations to resolve them. The investigation plans were outlined by three groups covering tailings relocation, tailings stabilization and mine area closure. Each group then reported back to the other participants. Finally, a series of review and compilation tasks, needed to pull together the finding of the technical presentations, was discussed.

The recommended investigations are outlined in the following sections.

5.1 Investigations Related to Tailings Relocation

Volumes

A series of small studies was proposed to better define the volume available for tailings in the Faro Pit. Components of the proposed investigation and rough estimates of costs were:

- Pit soundings – $5,000
- Tailings volume – production – density calculations – $5,000
- Lab testing of tailings settling and final density – $10,000.

Plug Dam

A study to provide the basis for design of the plug dam was proposed. Components and rough costs were:

- Geophysics – old Faro creek channel and plug dam – $50,000
- Review of old SRK logs – cost covered under current study.

Bankable Feasibility Study of Tailings Relocation

A study to provide a feasibility level design of the relocation method was proposed. The initially proposed components and costs were:

- Materials handling / process (water balance and mass balance) – $50,000
- Hydraulic monitoring feasibility or pre-feasibility – $75,000-100,000
- Mechanical excavation complement (characterize footprint, air-photos, old records - $20,000, stripping 2m off top - $5,000) – $25,000 total
- Dam / sludge removal study – $5,000-10,000.

After much discussion, it was concluded that a feasibility level study was not warranted until the decision between tailings relocation and stabilization was clear. A reduced scope of investigation would be appropriate as a first stage.

Pilot Testing

The need for a pilot test of hydraulic monitoring was considered. The conclusion was that a pilot test seemed unnecessary, but that input from contractors would be sought. In the meantime, lab testing of tailings would allow some conclusions about pumping requirements:

- Input from hydraulic monitoring contractor (define pilot test if needed) – $5,000
- Desktop studies – samples to EIMCO – $5,000.

Guardhouse Creek and X 23
A reconnaissance to better define the requirements associated with managing the inflows from the north side of the valley was discussed and a rough cost of $5,000 was estimated.

Lime Addition
An investigation to determine requirements for lime addition to the tailings was proposed. Components and costs were:

- Bench scale tests (enough sample left?) – $15,000
- Examine pit water quality objectives and impacts using a 2-dimensional groundwater model – $15,000.

Restoration of Rose Creek
It was agreed that a rough conceptual design for the restoration of Rose Creek would be a helpful starting point for further discussion. Cost was roughly estimated at $20,000.

5.2 Investigations Related to Rose Creek Tailings Stabilization

PMF Finalization
An investigation to finalize the estimate of the Probable Maximum Flood was proposed, and the cost estimated at about $25,000. Components of the proposed investigation were:

- Define PMP inputs
- Estimate time to peak
- Provide link to weather station and creek gauging stations to improve time to peak estimate.

North Fork Rose Creek – Rock Drain
An investigation of the rock drain to determine its capacity to attenuate peak floods was proposed. Costs were estimated at $25,000 if no drilling is required and $50,000, if drilling is needed. Components were:

- Is PMF flood attenuation possible
- Define benefits to downstream
- Estimate Flow through quality and storage capacity, design current and future
- Estimate stability during flood, potential FDN investigation program for stability (long term)
- Define process for changes to rock drain
- Install upstream pond monitoring for current pond.

Surface Water Management
Studies to further define surface water management requirements were proposed. Components and rough costs were:

- Bathymetry of current Intermediate Pond, maybe Cross Valley Pond as well – $10,000
- Estimate quantity of surface water runoff – $10,000
- Options for Faro Creek input – $10,000-$30,000.

Dam Upgrading
Studies to better define the requirements for seismic upgrading of the tailings dam were proposed, as follows:

- Collect field information using Becker Density Tests or seismic methods at the Intermediate, cross valley and Secondary Dams– $150,000
- Seismic assessment plus scoping of upgrading requirements - $20,000

Groundwater Management
A pump test and design of a tailings area groundwater collection system was proposed, and the cost estimated at $75,000-$150,000.

PMF Design for Rose Creek Diversion Canal
Requirements for advancing the design of the Rose Creek Diversion Channel stabilization program were discussed and the following components and cost estimates proposed:

- Finalize hydrology inputs and complete hydraulic calculations - $10,000
- Examine spillway options (avoid concrete, push further downstream) – $15,000
- Topographic and geotechnical survey of potential extension on south slope for widening of channel – $80,000
- Assess constructability and develop construction schedule - $10,000
- Estimate seepage from channel (geotechnical and water treatment impacts) - $5,000
- Assess method and costs for providing fish passage – $10,000

Tailings Cover – $25,000
A paper study to further examine the options for covering the tailings was proposed. The study would focus on cover designs for limiting contact and enhancing safety, and on practical constraints to construction. The cost was estimated at $25,000.

5.3 Investigations Related to Closure of Mine Areas

Pit Lakes
Further work on the possible *in situ* treatment of the pit lakes was proposed. Components of the proposed program and rough estimates of costs were:

- Feasibility of source management, characterize options – $15,000
- Assess bathymetry and physical configurations – $20,000
- Test treatment effectiveness in limno-corrals and Grum pit – $80,000

Seepage Collection
Investigations were proposed to determine requirements and develop designs for seepage collection systems in the Faro and Grum areas. The Faro program was estimated to cost $45,000 and would include:

- Conceptual design for ditches and/or groundwater collection wells
- Do we need to intercept, seep survey, does it capture all loads going to ground

The Grum program was estimated to cost $20,000 and would include:

- Assessment of seepage below the ore storage area, and whether long-term seepage collection is referable to cleaning up the area
- Groundwater and shallow water sampling along the toe of Grum Dump.

Backfill of Vangorda Pit

A study to assess the possibility of placing waste rock into Vangorda Pit was proposed. The estimated cost was $50,000 and the components of the study were:

- Verification of volume estimates
- Assessment of lime amendment needs, including pore water and seepage quality estimates
- Capping requirements and design
- Flume design
- Monitoring plan.

<u>Oxide and Low Grade Ore Stockpiles</u>
A study to assess the contaminant loadings from the oxide and low grade ore stockpiles was proposed. Components and cost were:

- Sample stockpiles and test samples – $20,000
- Assess the benefits, costs and risk associated with consolidating, re-locating, amending, and/or covering the stockpiles – $15,000

<u>Dixon Creek</u>
An investigation of the possibility or routing Vangorda Creek to Dixon Creek was proposed. The estimated cost was $30,000 and the components were:

- Alignment inspection
- Assessment of feasibility, design criteria, construction costs and long-term maintenance requirements.

<u>Sludge Disposal</u>
A review of options for long-term disposal of water treatment sludges was proposed. The estimated cost was $20,000 and the components were:

- Develop estimates of sludge production rates
- Determine design criteria for on-land or in-pit storage
- Prepare conceptual designs and cost estimates.

<u>Waste Rock Covers</u>
A field study of waste rock covers was proposed. Components and cost were:

- Revegetation study, species selection, soil and nutrient requirements, test plot cells – $20,000
- Construction of field test plots, probably three instrumented cells (use Vangorda and two more, numerical analysis – $200,000

The discussion of this proposal led to a suggestion that the cover test be constructed on an area that is likely to warrant covering under any final plan, such as the Grum sulphide cell, and that the existing Vangorda cover test and revegetation trials be incorporated into the program.

5.4 Review and Compilation Tasks

The review and compilation task identified at the end of the workshop included:

- Assessment of long term risks, maintenance requirements and monitoring requirements
- Identification of requirements for contingency or adaptive management plans
- Development of combined implementation schedules, and identification of critical timing constraints
- Develop of cost estimates and cash flow projections suitable for cost engineering
- Development of a site water and load balance.

It was anticipated that these tasks would be needed to translate the technical studies into the complete alternative descriptions needed by decision-makers.

Appendix A - Partnership Protocol for Development of Remediation Plan for Faro Mine

Endorsed by Oversight Committee - January 29, 2004

A CANADA-YUKON- FIRST NATION PARTNERSHIP PROCESS TO PREPARE A FARO MINE REMEDIATION PLAN (FMRP)

1. Introduction

Canada, Yukon, the Kaska and Selkirk First Nations have indicated their desire to work together on the development of a remediation plan for the Faro site and have agreed on a planning structure that will incorporate all three levels of government. The development of a final remediation plan is a separate activity from the ongoing care and maintenance of the mine site. The affected First Nations participate in the planning and execution of care and maintenance activities through other arrangements with Canada and Yukon, as well as directly with the Interim Receiver.

This paper provides an overview of the objectives and principles that will guide this planning process, the management structure, the overall financial arrangements and interim measures to cover the period until the offices and annual operating budget are in place. The partnership process to complete a final remediation plan, that will be ready for submission for environmental assessment, is expected to take up to three years. This will be followed by the closure plan approval phase (YESAA and regulatory approvals) and an implementation phase. The arrangements for cooperation in these subsequent phases will be developed towards the end of this three year period.

2. Objective

To prepare a Faro Mine Remediation Plan (FMRP) within three years that is suitable for submission for preliminary funding approvals and environmental assessment.

3. Principles

The partnership process outlined in this paper will be guided by the following principles:

i. An open and transparent process will be used through out the work.
ii. Information will be shared.

iii. The process will support community understanding and involvement.
iv. Adequate resources will be made available for meaningful participation by the affected First Nations.
v. The process will respect the First Nations views and aspirations including goals and objectives for the site.
vi. The process will respect the decision making process of all the parties.

4. Work Program

The FMRP Office will be responsible for developing a multi-year program of work to complete the FMRP and annual work plans under the general direction of the Oversight Committee. The program of work should follow a logical sequence of steps and time line to be completed within three years which could include:

- Studies/research - ongoing
- Community involvement/consultation - ongoing
- Development of Closure Objectives - spring 2004
- Development of closure options/alternatives -fall 2004
- Selection of preferred alternative - spring 2005
- Prepare the Final Plan – 2006
- Prepare required documentation for submission to YESAA - 2006

Environmental assessment and licensing is not part of this project but are expected to occur in 2007/08

5. Planning and Management Structure

A multi-government management and planning structure has been agreed to by the parties for the purposes of preparation of a mine remediation plan for the Faro site. The governments of Canada (lead – Indian and Northern Affairs Canada), Yukon (lead – Energy, Mines and Resources), and affected First Nations (Ross River Dena Council, Liard First Nation, Kaska Dena Council, Selkirk First Nation) will all be participants.

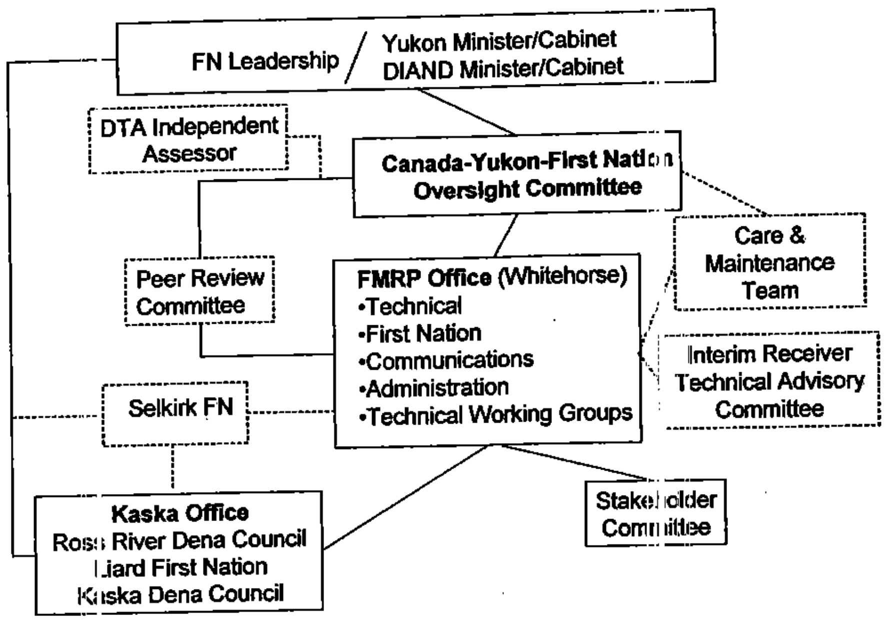
There will be three core components to the structure, namely:

1. a senior level oversight committee
2. a regional based Faro Mine Remediation Project Office
3. a community based First Nations office

In addition to the above core structure, there will be several linkage mechanisms to secure local and community based participation as well as scientific and technical expertise. Linkages will also ensure coordination with the Interim Receiver and associated care and maintenance activities. Lastly, appropriate political direction and decisions will be secured as necessary.

These components are identified in the following chart.

Faro Mine Remediation Planning and Management Structure



The core functions of the various components are outlined below. These roles and responsibilities will become more defined as work plans are developed and funding arrangements approved:

1. Canada-Yukon-First Nation Oversight Committee
   - Canada, to be represented by DIAND; Government of Yukon, to be represented by Energy, Mines and Resources; Selkirk First Nation; Kaska Dena Council, Ross River Dena Council and Liard First Nation, to be represented by a Kaska representative.
   - senior level leadership and direction
   - liaison between Project Office and political leadership level
   - oversee development and approval of annual and multi-year work plans

2. Faro Mine Remediation Project Office
   - lead development of remediation/closure plan
   - direct studies and preparation of closure plan
   - undertake community consultation and provide public information
   - liaise with care and maintenance team and all levels of government

   This office would be located in Whitehorse.

3. Kaska Office

- represents Ross River Dena Council, Liard First Nation and Kaska Dena Council
- coordinate community input to the planning process
- coordinate community education/information sessions/expert forums as required
- participate in development of plan, including technical reviews as required
- manage projects as required by work plans
- other functions as elaborated through work plans as planning structure evolves
- liaise with Pelly Crossing office and FMR project office

The Kaska Office to be located in Ross River will represent Ross River Dena Council, Liard First Nation and Kaska Dena Council. It would be the principal office for First Nation community oriented projects

4. Selkirk First Nation Participation
   - coordinate community input to the planning process
   - coordinate community education/information sessions/expert forums as required
   - participate in development of plan, including technical reviews as required (focus on those aspects which relate to potential downstream water impacts)
   - other functions as elaborated through work plans as planning structure evolves
   - liaise with Kaska and FMR project offices

   The Pelly Crossing office would provide administrative support and liaison function for Selkirk FN participation.

Based upon other mine closure models and Yukon specific circumstances, other mechanisms being considered include:

- a stakeholder committee to include key stakeholders and provide advice to the FMR Project Office
- a peer review committee to include professional and technical expertise and provide independent analysis and advice to both the Oversight Committee and FMR Project Office.

While a separate activity from remediation planning, care and maintenance activities do have linkages to closure. The Oversight Committee will provide guidance on these linkages. The FMR Project Office will also liaise with the Interim Receiver and the Faro Technical Advisory Committee on matters associated with remediation planning.

6.Financial Plan/Budget

A three year financial plan and annual operating budgets will be developed by the Project Office under the guidance of the Oversight Committee and ultimately approved by the governments providing the resources.

To enable the First Nations to participate meaningfully in this work, specific funding arrangements will be set out in the three year work plan and the financial plan and adjusted through the annual work plans and operating budgets. Resources will be included for:

- core capacity requirements for ongoing Kaska and Selkirk First Nation involvement in the process and the planning team, including the Kaska Office in Ross River and office/administrative support for Selkirk First Nation in Pelly Crossing.
- project specific funding i.e. traditional knowledge (TK), workshops/communications and technical advice as agreed to through the annual work planning process.
- Community consultation
- Ross River and Selkirk technical reviews as required
- participation in the Oversight Committee

7. Initial Measures

In order to facilitate early commencement of the planning process and First Nation involvement, the following interim measures will be undertaken:

1. Establish initial (6 months) offices in Whitehorse and Ross River and begin the development of the program of work and associated financial estimates.
2. Establish initial funding arrangements for Kaska and Selkirk FN to participate in:

   i) finalizing the partnership arrangements by mid February

   ii) participation in the Oversight Committee

   iii) participation in specific projects in this initial period

3. Canada,Yukon, Kaska and Selkirk First Nations will consult with the other parties in preparing statements of qualifications and selection of candidates for key project staff positions

Appendix B – 2003 Study Presentations

Presentation 1 – ARD Monitoring & Lab Studies

Presentation 2 – Dump Water Balances

Presentation 3 – Dump Water Quality Predictions

Presentation 4 – Pit Lake Water Quality and Treatment Methods

Presentation 5 – Water Treatment Cost Assumptions

Presentation 6 – Grum Seepage Collection Requirements

Presentation 7 – Terrestrial Risk Data

Presentation 8 – CCME-based Water Quality Objectives

Presentation 9 – Tailings Groundwater Studies

Presentation 10 – Requirements for Groundwater Collection

Presentation 11 – Earthquake Hazard Studies

Presentation 12 – Tailings Physical Properties

Presentation 13 – Foundation Liquefaction Study

Presentation 14 – Seismic Stability Assessment

Presentation 15 – Faro and Vangorda Creek Hydrology

Presentation 16a – Rose Creek Diversion Options – 500-yr Hydrology

Presentation 16b – Rose Creek Diversion Options – PMF Hydrology

Presentation 16c – Rose Creek Diversion Options – Geotechnical

Presentation 17a – Tailings Relocation Methods

Presentation 17b – Tailings Relocation Methods

Presentation 18a – Waste Rock and Tailings Cover Methods

Presentation 18b – Waste Rock and Tailings Cover Costs

Presentation 19 – Plug Dam Investigation and Design

Endorsed by Oversight Committee - January 29, 2004

A CANADA-YUKON- FIRST NATION PARTNERSHIP PROCESS TO PREPARE A FARO MINE REMEDIATION PLAN (FMRP)

1. Introduction

Canada, Yukon, the Kaska and Selkirk First Nations have indicated their desire to work together on the development of a remediation plan for the Faro site and have agreed on a planning structure that will incorporate all three levels of government. The development of a final remediation plan is a separate activity from the ongoing care and maintenance of the mine site. The affected First Nations participate in the planning and execution of care and maintenance activities through other arrangements with Canada and Yukon, as well as directly with the Interim Receiver.

This paper provides an overview of the objectives and principles that will guide this planning process, the management structure, the overall financial arrangements and interim measures to cover the period until the offices and annual operating budget are in place. The partnership process to complete a final remediation plan, that will be ready for submission for environmental assessment, is expected to take up to three years. This will be followed by the closure plan approval phase (YESAA and regulatory approvals) and an implementation phase. The arrangements for cooperation in these subsequent phases will be developed towards the end of this three year period.

2. Objective

To prepare a Faro Mine Remediation Plan (FMRP) within three years that is suitable for submission for preliminary funding approvals and environmental assessment.

3. Principles

The partnership process outlined in this paper will be guided by the following principles:

i. An open and transparent process will be used through out the work.
ii. Information will be shared.

iii. The process will support community understanding and involvement.
iv. Adequate resources will be made available for meaningful participation by the affected First Nations.
v. The process will respect the First Nations views and aspirations including goals and objectives for the site.
vi. The process will respect the decision making process of all the parties.

4. Work Program

The FMRP Office will be responsible for developing a multi-year program of work to complete the FMRP and annual work plans under the general direction of the Oversight Committee. The program of work should follow a logical sequence of steps and time line to be completed within three years which could include:

- Studies/research - ongoing
- Community involvement/consultation - ongoing
- Development of Closure Objectives - spring 2004
- Development of closure options/alternatives -fall 2004
- Selection of preferred alternative - spring 2005
- Prepare the Final Plan – 2006
- Prepare required documentation for submission to YESAA - 2006

Environmental assessment and licensing is not part of this project but are expected to occur in 2007/08

5. Planning and Management Structure

A multi-government management and planning structure has been agreed to by the parties for the purposes of preparation of a mine remediation plan for the Faro site. The governments of Canada (lead – Indian and Northern Affairs Canada), Yukon (lead – Energy, Mines and Resources), and affected First Nations (Ross River Dena Council, Liard First Nation, Kaska Dena Council, Selkirk First Nation) will all be participants.

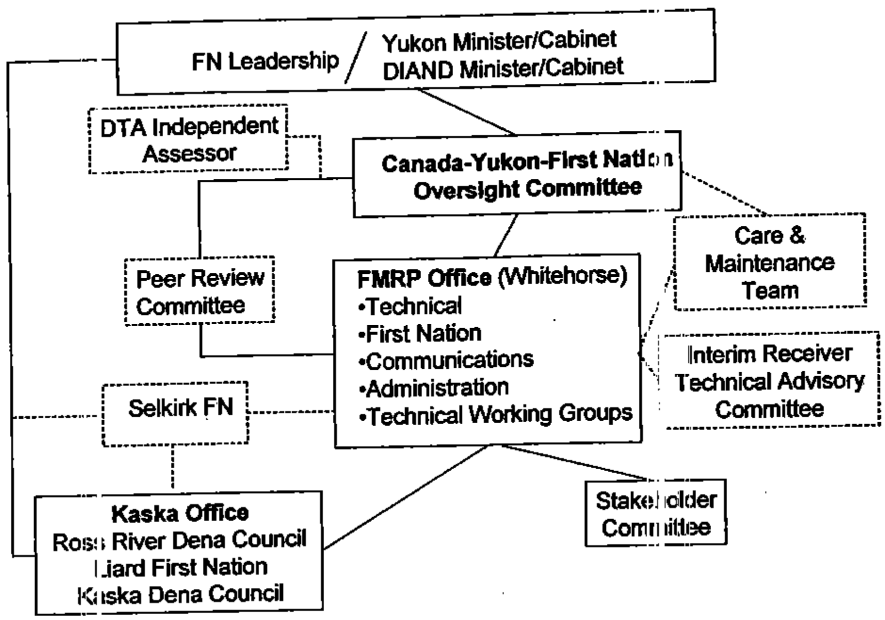
There will be three core components to the structure, namely:

1. a senior level oversight committee
2. a regional based Faro Mine Remediation Project Office
3. a community based First Nations office

In addition to the above core structure, there will be several linkage mechanisms to secure local and community based participation as well as scientific and technical expertise. Linkages will also ensure coordination with the Interim Receiver and associated care and maintenance activities. Lastly, appropriate political direction and decisions will be secured as necessary.

These components are identified in the following chart.

Faro Mine Remediation Planning and Management Structure



The core functions of the various components are outlined below. These roles and responsibilities will become more defined as work plans are developed and funding arrangements approved:

1. Canada-Yukon-First Nation Oversight Committee
   - Canada, to be represented by DIAND; Government of Yukon, to be represented by Energy, Mines and Resources; Selkirk First Nation; Kaska Dena Council, Ross River Dena Council and Liard First Nation, to be represented by a Kaska representative.
   - senior level leadership and direction
   - liaison between Project Office and political leadership level
   - oversee development and approval of annual and multi-year work plans

2. Faro Mine Remediation Project Office
   - lead development of remediation/closure plan
   - direct studies and preparation of closure plan
   - undertake community consultation and provide public information
   - liaise with care and maintenance team and all levels of government

   This office would be located in Whitehorse.

3. Kaska Office

- represents Ross River Dena Council, Liard First Nation and Kaska Dena Council
- coordinate community input to the planning process
- coordinate community education/information sessions/expert forums as required
- participate in development of plan, including technical reviews as required
- manage projects as required by work plans
- other functions as elaborated through work plans as planning structure evolves
- liaise with Pelly Crossing office and FMR project office

The Kaska Office to be located in Ross River will represent Ross River Dena Council, Liard First Nation and Kaska Dena Council. It would be the principal office for First Nation community oriented projects

4. Selkirk First Nation Participation
   - coordinate community input to the planning process
   - coordinate community education/information sessions/expert forums as required
   - participate in development of plan, including technical reviews as required (focus on those aspects which relate to potential downstream water impacts)
   - other functions as elaborated through work plans as planning structure evolves
   - liaise with Kaska and FMR project offices

   The Pelly Crossing office would provide administrative support and liaison function for Selkirk FN participation.

Based upon other mine closure models and Yukon specific circumstances, other mechanisms being considered include:

- a stakeholder committee to include key stakeholders and provide advice to the FMR Project Office
- a peer review committee to include professional and technical expertise and provide independent analysis and advice to both the Oversight Committee and FMR Project Office.

While a separate activity from remediation planning, care and maintenance activities do have linkages to closure. The Oversight Committee will provide guidance on these linkages. The FMR Project Office will also liaise with the Interim Receiver and the Faro Technical Advisory Committee on matters associated with remediation planning.

6. Financial Plan/Budget

A three year financial plan and annual operating budgets will be developed by the Project Office under the guidance of the Oversight Committee and ultimately approved by the governments providing the resources.

To enable the First Nations to participate meaningfully in this work, specific funding arrangements will be set out in the three year work plan and the financial plan and adjusted through the annual work plans and operating budgets. Resources will be included for:

- core capacity requirements for ongoing Kaska and Selkirk First Nation involvement in the process and the planning team, including the Kaska Office in Ross River and office/administrative support for Selkirk First Nation in Pelly Crossing.
- project specific funding i.e. traditional knowledge (TK), workshops/communications and technical advice as agreed to through the annual work planning process.
- Community consultation
- Ross River and Selkirk technical reviews as required
- participation in the Oversight Committee

7. Initial Measures

In order to facilitate early commencement of the planning process and First Nation involvement, the following interim measures will be undertaken:

1. Establish initial (6 months) offices in Whitehorse and Ross River and begin the development of the program of work and associated financial estimates.
2. Establish initial funding arrangements for Kaska and Selkirk FN to participate in:

   i) finalizing the partnership arrangements by mid February

   ii) participation in the Oversight Committee

   iii) participation in specific projects in this initial period

3. Canada,Yukon, Kaska and Selkirk First Nations will consult with the other parties in preparing statements of qualifications and selection of candidates for key project staff positions

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Task 13 – Continue ARD Monitoring and Lab Studies (Waste Rock)

Project Team

- SRK
  - Stephen Day, Kelly Sexsmith, John Chapman
- Access Consulting
- Canadian Environmental and Metallurgical
- Gartner Lee
- Midnight Sun Drilling
- Mine Site Personnel
- Tom Moon

Objective of Task

- Evaluate current sources of contaminant loading.
- Predict future changes in loading.

Components of Task

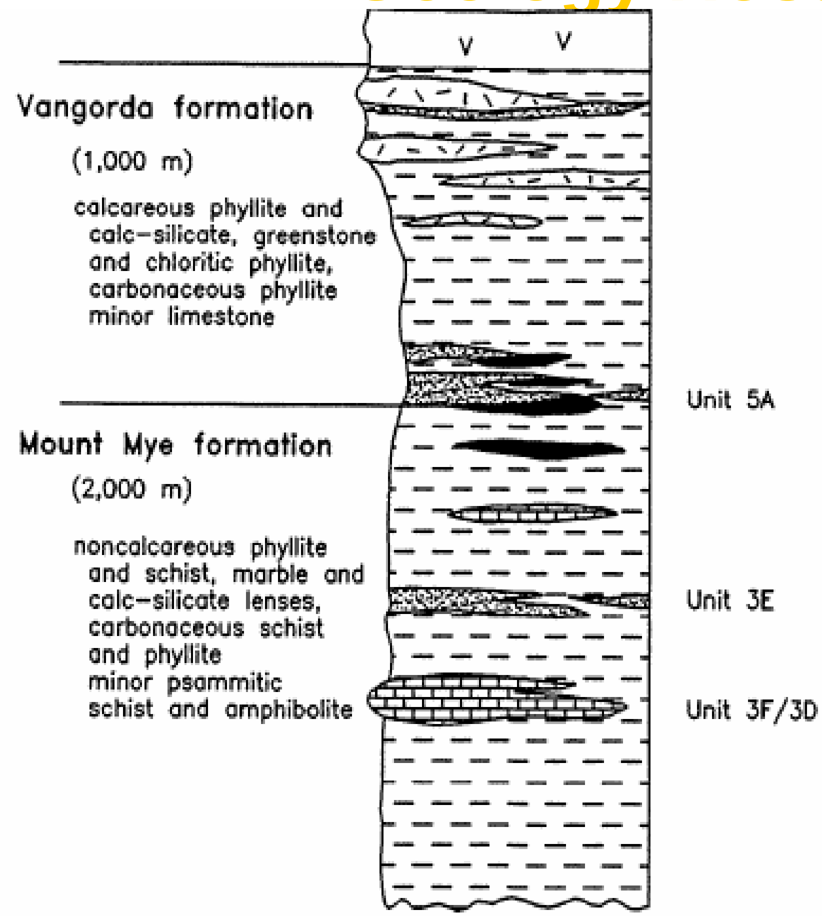
- Compilation of all existing geochemical information and identification of data gaps.
- Initiation of monitoring and data collection on site.
- Laboratory testing.
- Interpretation of database.

Major Database Components

- Inventory of waste rock composition and surface mapping at Faro.
- Waste rock geochemical database including static and kinetic testing (several studies).
- Thermal and gas monitoring of waste rock dumps.
- Seepage monitoring (historical and recent)

Geology Host

- Mineralization is "sulphide rock"
  - Not all sulphide rock is ore
  - Surrounding rock is also partly mineralized.
- Rock "below" ore contains low carbonate.
- Rock above ore contains more carbonate.
- Anvil Batholith ("granite") heated and altered the rock.
- Structurally complex.



Waste Rock Management Practices

- Faro
  - Prior to late 1970's sulphide waste rock was not selectively managed – sulphide pods.
  - 1970's to 1990, sulphide waste rock was placed in at least two "cells".
- Vangorda Plateau
  - Sulphide cell constructed in Grum Pit waste rock dump.
  - Sulphide segregated and placed in upland part of Vangorda Pit waste rock dump.

Critical Differences Between Faro and Vangorda

- Faro
  - Alteration of rocks by Anvil Batholith.
  - Non-management of sulphide waste early on.
  - Proportions of rock types known
- Grum
  - Manageable sulphide waste rock
  - Carbonate-bearing rocks.
  - Proportions of rock types not known.
- Vangorda
  - Sulphide lenses in waste rock.
  - High proportion of sulphide waste rock.
  - Proportions of rock types not known.

Faro Waste Rock Classification

Rock Type	Overall Classification	Acid Onset Time Frame	Metal Leaching
Schist (1D)	Non-acid generating unless mixed with sulphide	Delayed (decades)	-
Alteration Envelope	Acid generating	Immediate	Zn, Cd, Mn, Cu, Fe, Ni.
Sulphide Rock	Potentially acid generating	Immediate	Zn, Cd, Mn, Cu, Fe, Ni.
Calc-Silicate	Acid consuming	-	None
Intrusive	Uncertain	Delayed (decades)	Zn
Till	Components are theoretically potentially acid generating	Delayed (decades)	Zn

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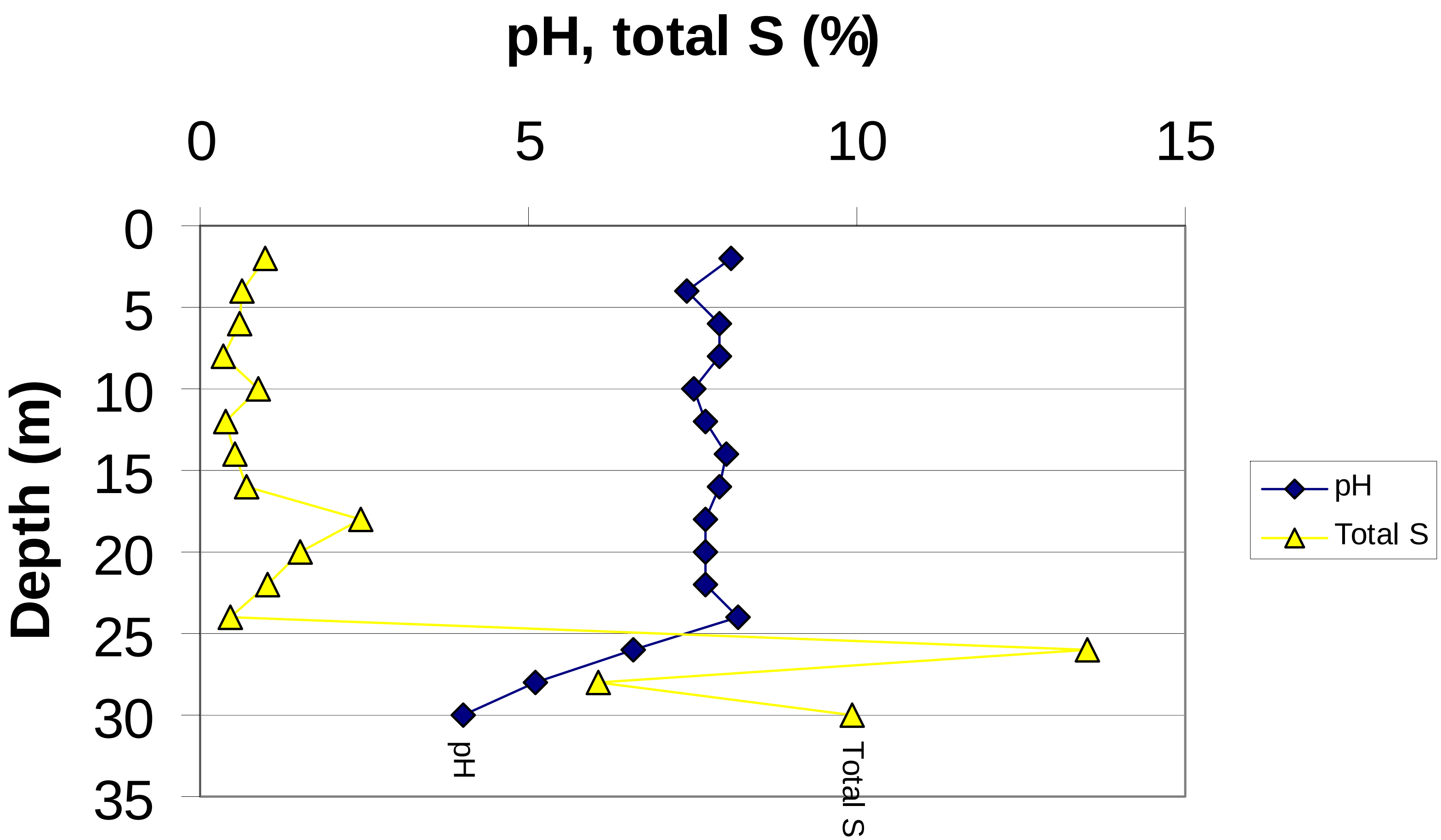
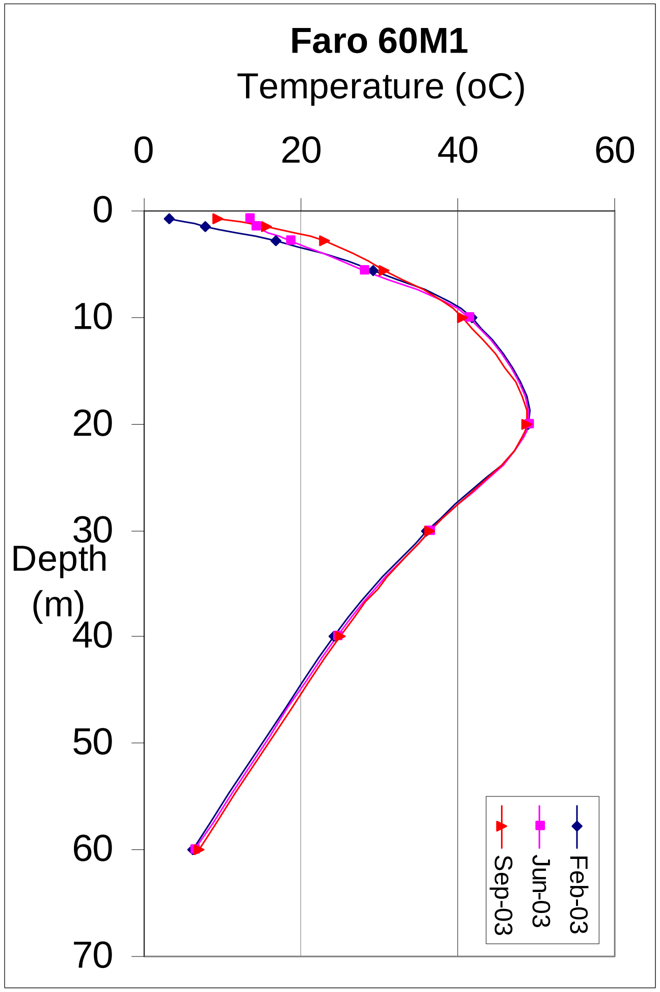
Geochemical Characteristics - Faro



Thermal Characteristics - Faro



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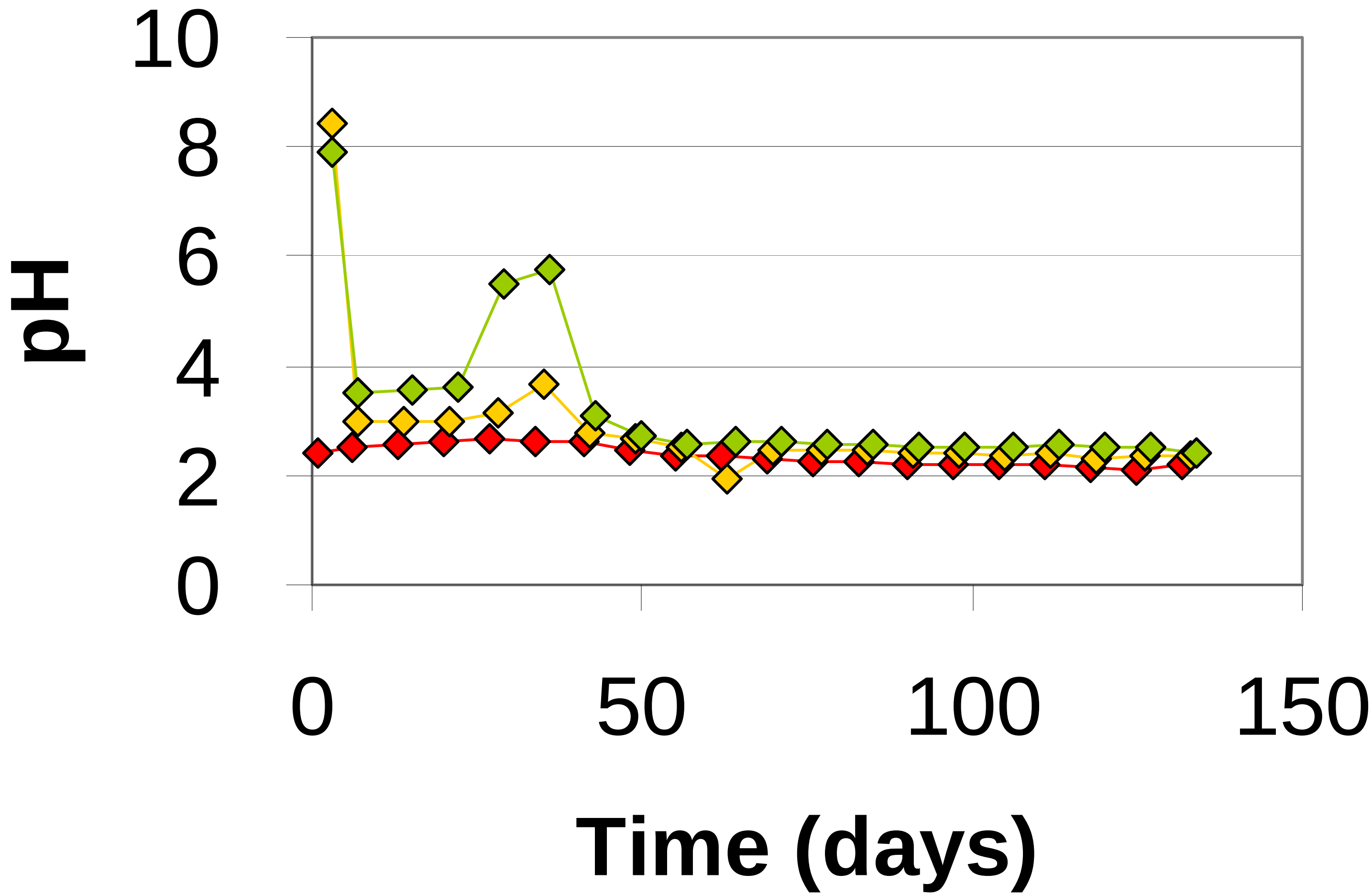
Thermal Characteristics - Faro

- Oxygen entry by thermal convection.
- Profiles used to estimate oxidation rates.

Flowpath Effects near Sulphide Cells



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Faro Seepage Types

- Type 1
  - Non-acidic, relatively dilute, zinc <5 mg/L.
  - Upper NW Dumps.
- Type 2
  - Non-acidic, sulphate near 2000 mg/L, zinc 4 to 595 mg/L.
  - Ore and LGO stockpiles, NE flowing toward pit.
- Type 3
  - Acidic, zinc>40 mg/L.
  - Ore and LGO stockpiles, NE flowing toward pit.

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Vangorda Waste Rock Classification

Rock Type	Overall Classification	Acid Onset Time Frame	Metal Leaching
Non-calcareous Phyllite	Acid consuming unless mixed with sulphide	-	Zn
Sulphide Rock	Potentially acid generating	Immediate to delayed (decades)	Zn, Cd, Mn, Cu, Fe, Ni.
Carbonaceous Phyllite	Potentially acid generating	Delayed (years to decades)	Zn
Calcareous Phyllite	Acid consuming	-	Zn
Chloritic Phyllite	Acid consuming	-	Zn

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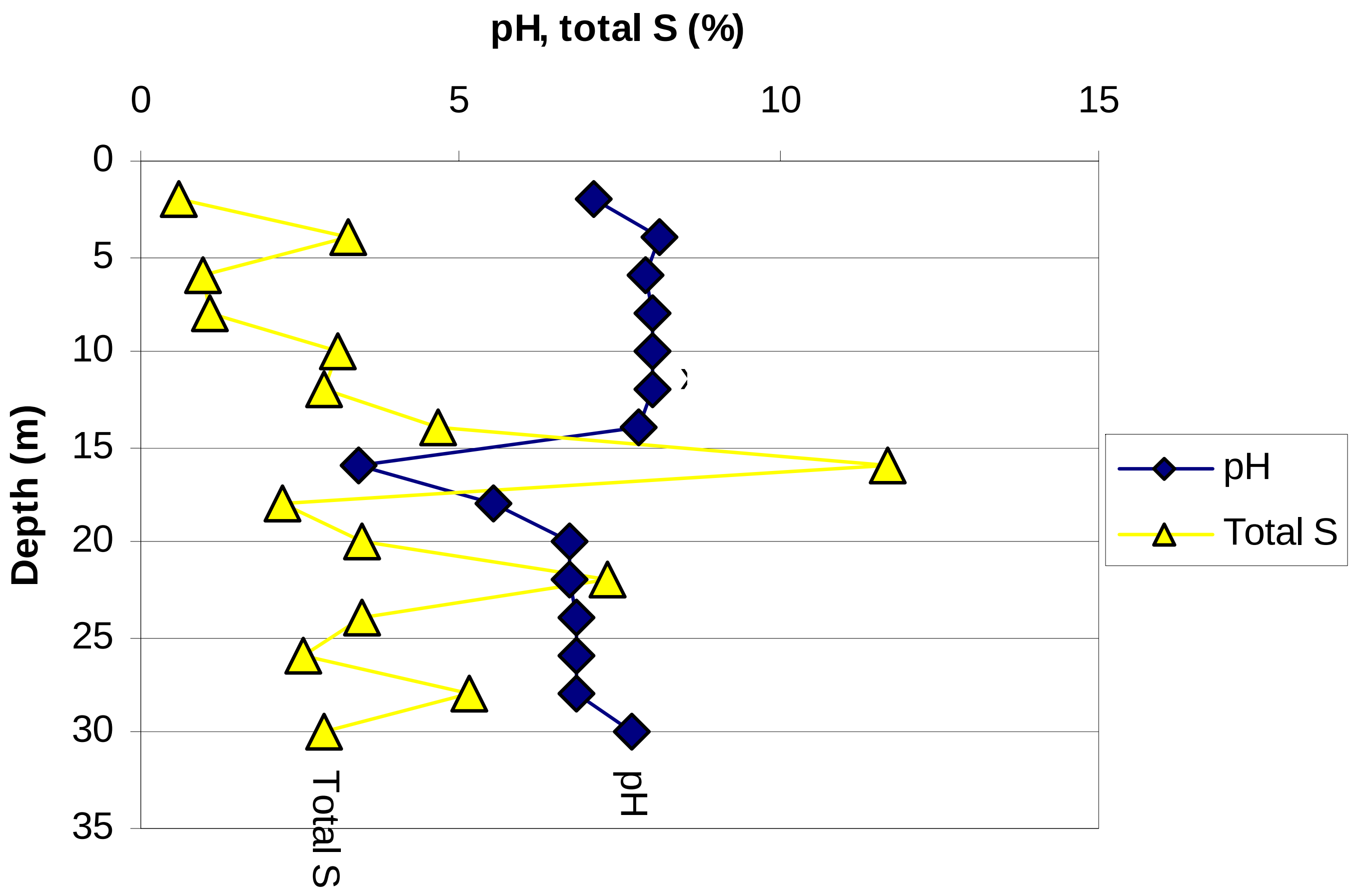
Geochemical Characteristics – Grum Dump



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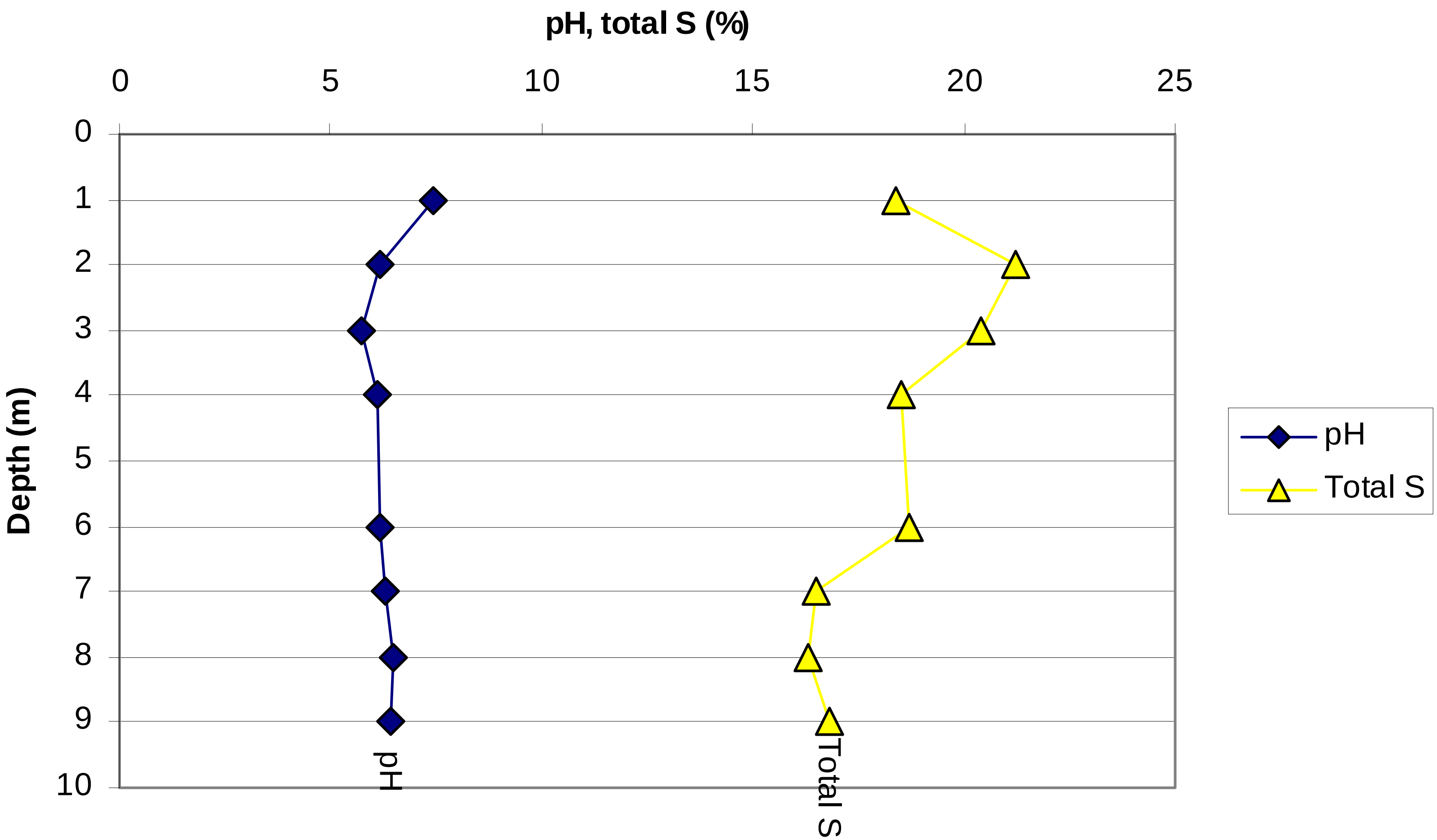
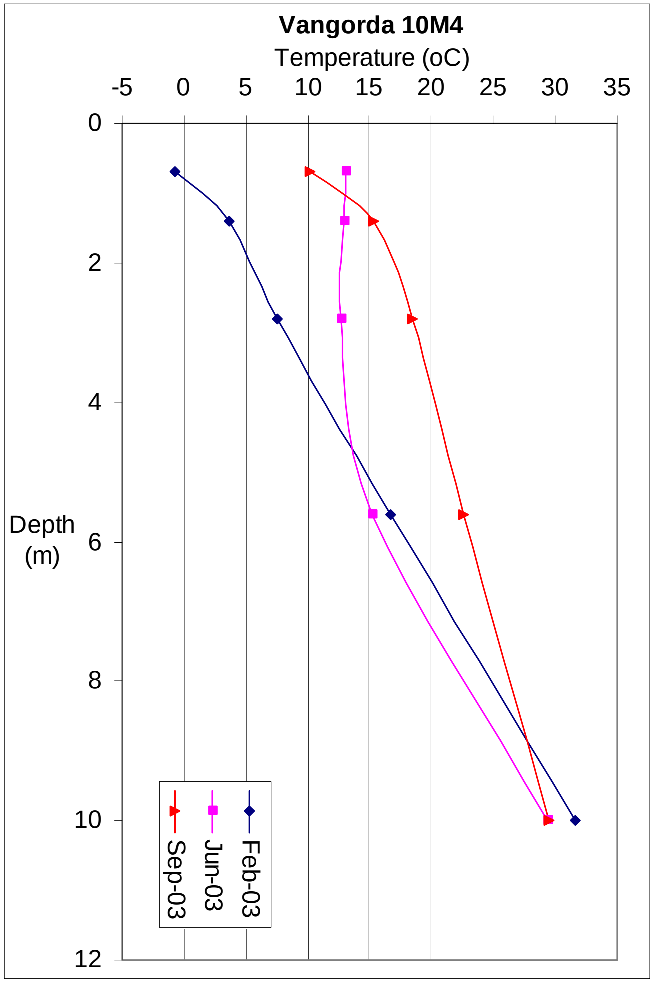
Geochemical Characteristics – Vangorda Dump



Thermal Characteristics – Vangorda Pit dump



Thermal Characteristics – Vangorda Plateau Dumps

- Vangorda Pit dump
  - Oxygen entry by thermal convection.
- Grum Pit sulphide cell
  - No clear evidence of heating
  - Oxygen entry by diffusion.

Vangorda Seepage Types

- Type 1a
  - Non-acidic, low zinc <0.03 mg/L.
- Type 1b
  - Non-acidic, zinc 2 to 5 mg/L.
  - Dowgradient from Grum sulphide cell
- Type 2
  - Similar to Faro Type 2, but higher zinc.
- Type 3
  - Similar to Faro Type 3, but higher zinc.

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Vangorda Plateau Haul Road

- Constructed from segregated non-sulphide waste rock.
- One test pit had sulphide waste rock.
- Schist potentially PAG to marginally PAG.

Metal Leaching

- Main elements of concern are:
  - Zn, Cd and Mn under both neutral and acidic conditions.
  - Copper under acidic conditions
- Mineral sources of contaminants:
  - Pyrite – Fe, sulphate, acidity, (Cu, As, Co , Ni)
  - Sphalerite – Zn, Cd, Mn
  - Chalcopyrite - Cu
  - Galena - Pb
  - Carbonate minerals – Mn
  - Sulphosalts – As, Sb, Cu

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Metal Leaching

- Sinks for Metals
  - Fe-hydroxides - Fe
  - Fe-hydroxide sorption – Zn, Cd, Mn, Cu, Ni, Co, As, Sb
  - Carbonates – Zn, Cd, Mn, Cu
  - Sulphates - Lead

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Stages of Seepage Chemistry

1. Dissolution of carbonates (pH>8, low metals and sulphate).
2. Sulphide oxidation accelerates (pH between 7 and 8, increasing Zn and SO_4).
3. Acid rock drainage (pH<4, high SO_4, Zn, Cu).
4. Long term (pH increases, SO_4, Zn, Cu decrease, Pb increases).

Main Conclusions

- Rock type control on WQ established
  - Sulphides - PAG
  - Widespread contamination of schists at Faro by sulphides results in uncertainty.
  - Calc-silicates/calcareous phyllite – acid consuming.
- Rock Mixing
  - Waste rock not intimately mixed.

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Main Conclusions

- Stage of Seepage at Sites
  - Faro (mature, Stage 3)
    - Sulphide rock already acidic
    - Schist may become acid (time frame of decades)
  - Grum (Stage 1 and 2)
    - Sulphide rock not widely acidic.
    - Seepage chemistry expected to worsen as acid water breaksthrough.
  - Vangorda (Stage 2 and 3)
    - Friable sulphides already acidic.
    - Seepage chemistry expected to worsen.

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Dump Water Balances

Project Leader

Richard Janowicz (YTG)

Project Objective

- Develop improved estimates of the amount of water infiltrating into the waste rock dumps at the Faro, Grum and Vangorda sites

Project Scope

- Two stages
  - 2003
    - Install meteorological stations and and develop preliminary water balance estimates
  - 2004
    - Collect data for one full hydrologic year
      - Met stations
      - Snow surveys
      - Weirs for surface runoff
    - Develop improved water balance estimates in 2004

Project Status as of February 2004

- Project team selected
- Meteorological stations procured and installed
- Preliminary water balance estimates complete

Project Team

- Rick Janowicz
  - DIAND/YTG Water Resources since 1982
  - Review hydrology for Yukon mine sites, including Faro
  - 20 publications on northern hydrology
- Dr. Raoul Granger
  - National Hydrology Research Institute
  - Over 70 publications on northern hydrology
  - Snowmelt infiltration into frozen soils
- Rene Hedstrom,
  - National Hydrology Research Institute since 1988

Results to Date

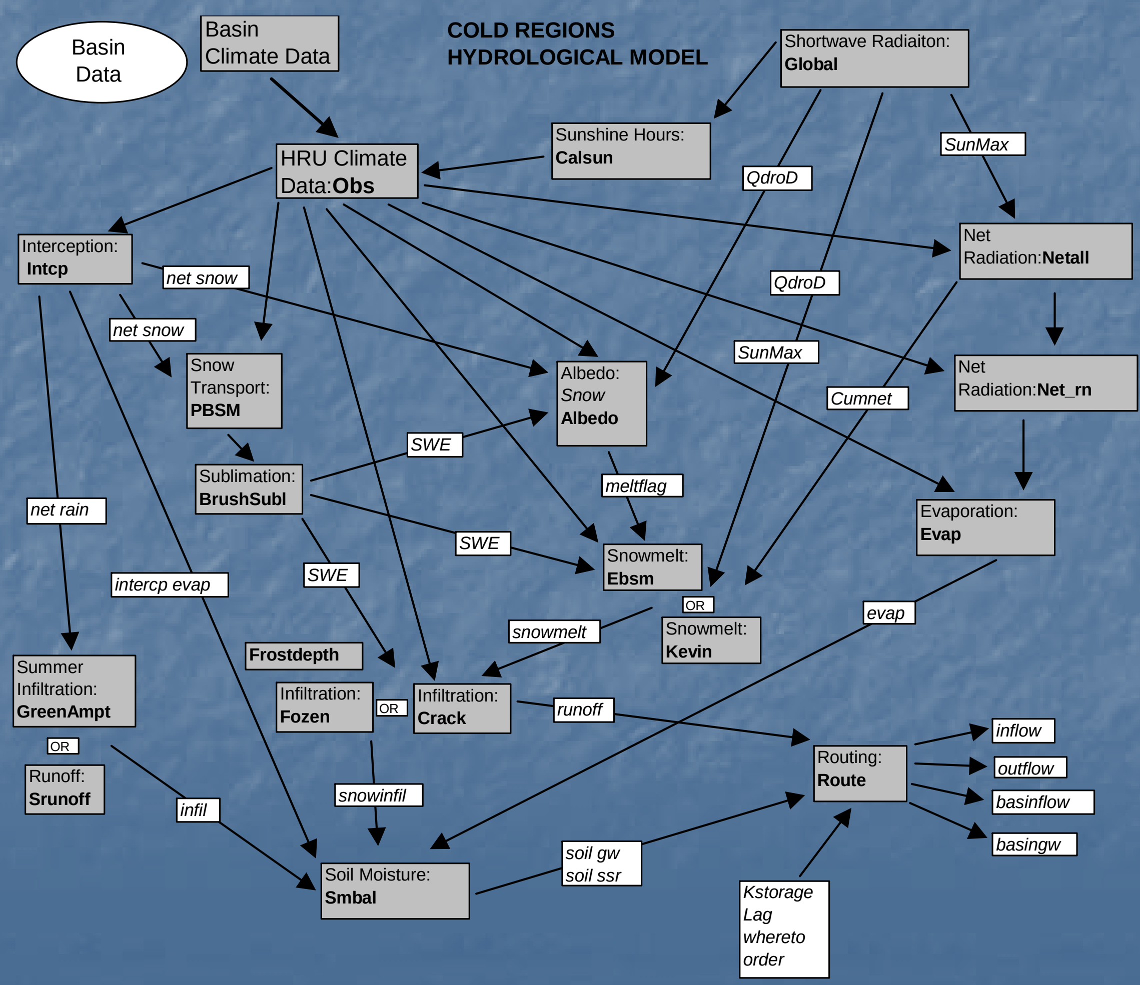
- Meteorological stations established in December

Met Stations

- Instrumentation:
  - air temperature, relative humidity, wind velocity, wind direction, net radiation, solar radiation (direct and diffuse), precipitation
  - soil temperature (3 levels), soil heat flux, and soil moisture
  - snow depth
- Campbell Scientific CR10x data loggers
- 12V DC batteries and solar panels
- Data recorded at 1 hour intervals

Preliminary Water Balance

- Cold Regions Hydrologic Model (CHRM)



Preliminary Water Balance

- Waste dumps divided into six HRU's
  - Flat surfaces
  - Slopes
    - North, East, South, West
  - Bubble dumps

	FLAT	SLOPE (N,S,E,W)	BUBBLE
Slope Angle (deg)	0	40	0
Roughness Ht (m)	0.01	0.05	1.0
Fall Soil Saturation(%)	70	60,15,30,30	15
Albedo	0.21	0.21	0.14

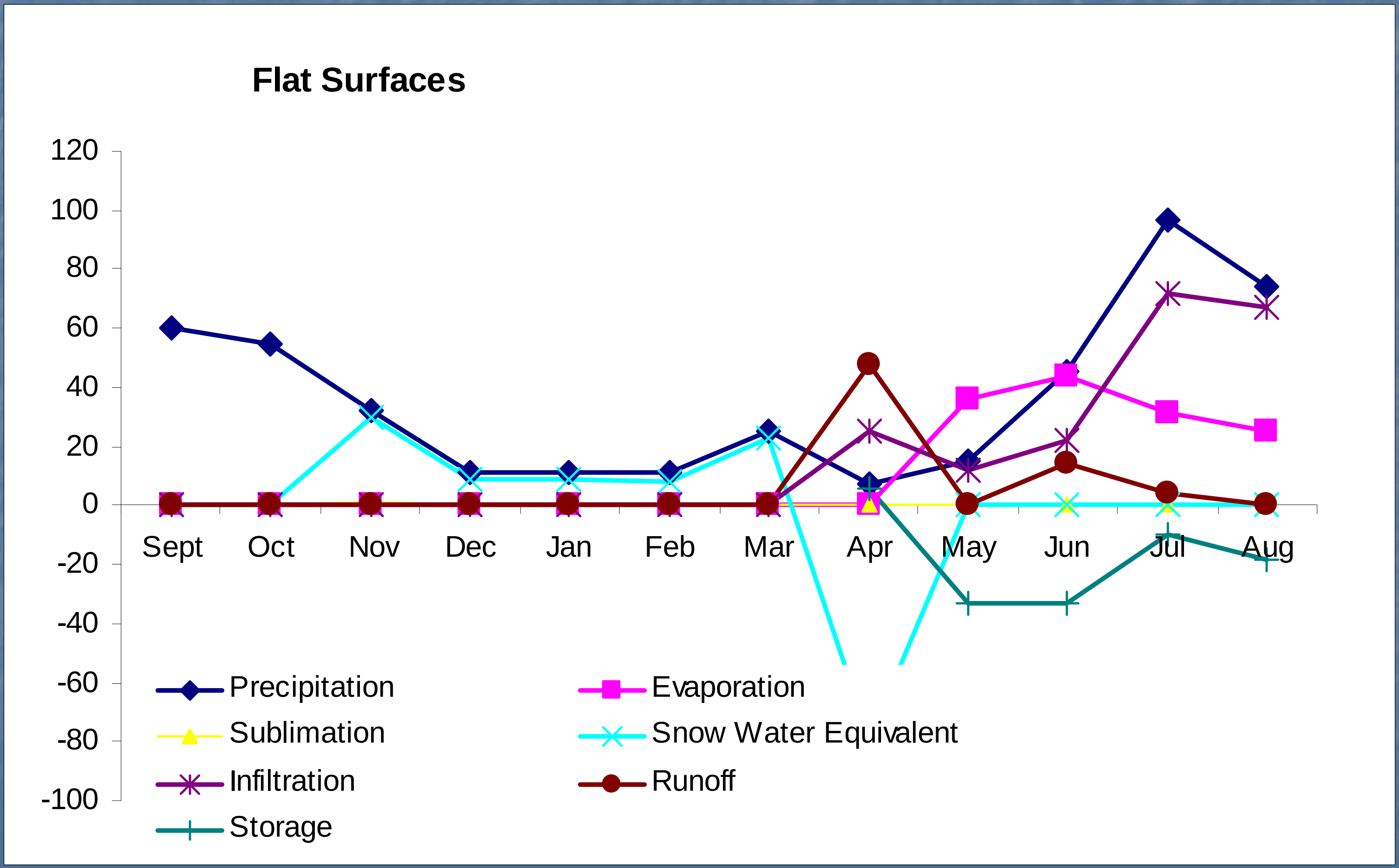
Preliminary Water Balance

- Preliminary estimates based on meteorological input data from:
  - ARMC and Faro Airport
  - Radiation data from Williams Creek

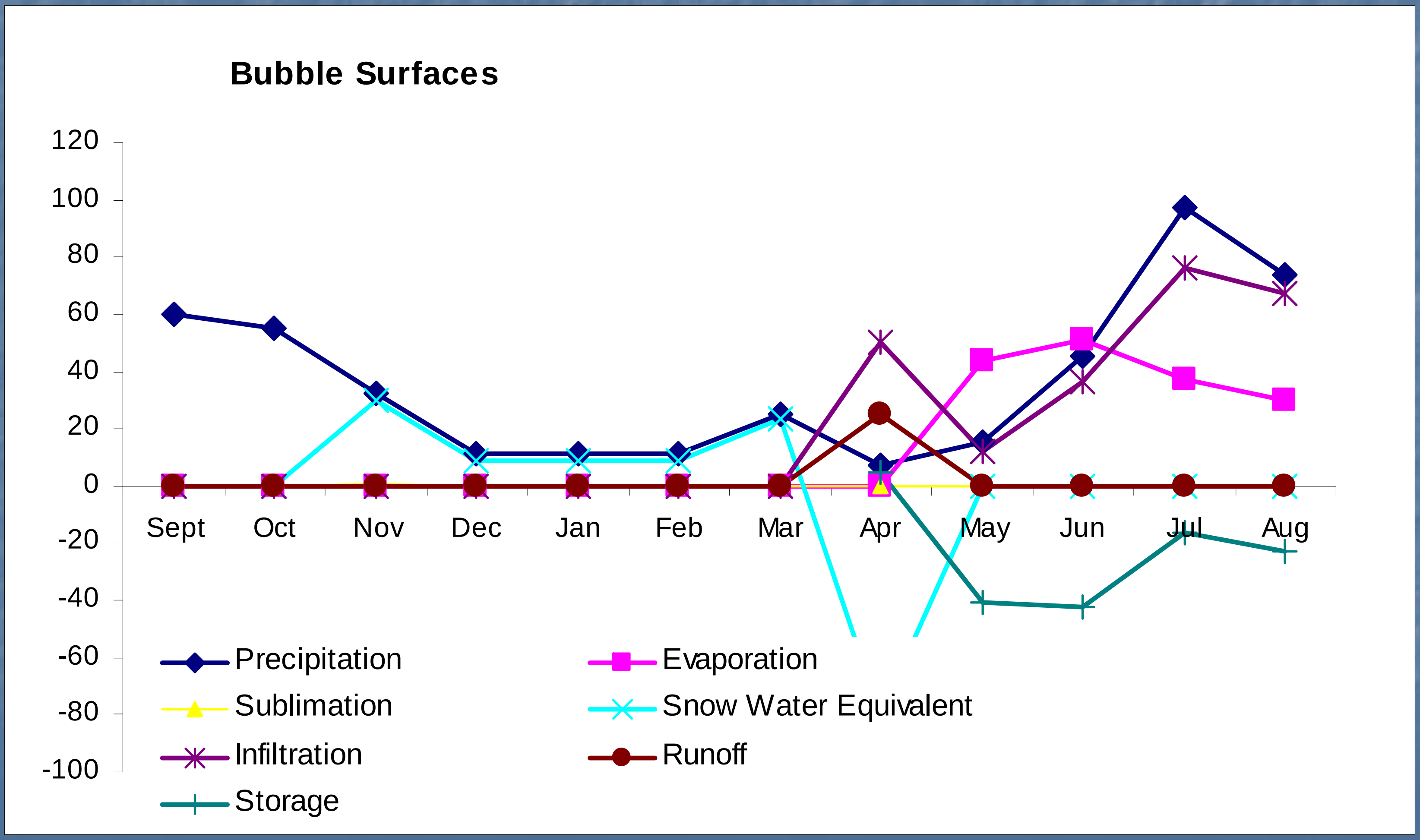
Preliminary Water Balance

- Results to date
  - Preliminary only
  - Wet year only
  - Current results show storage of around 10%
- Infiltration around 45-55% of precipitation
- Surface runoff around 15% of precipitation
- Evaporation around 30-40% of precipitation

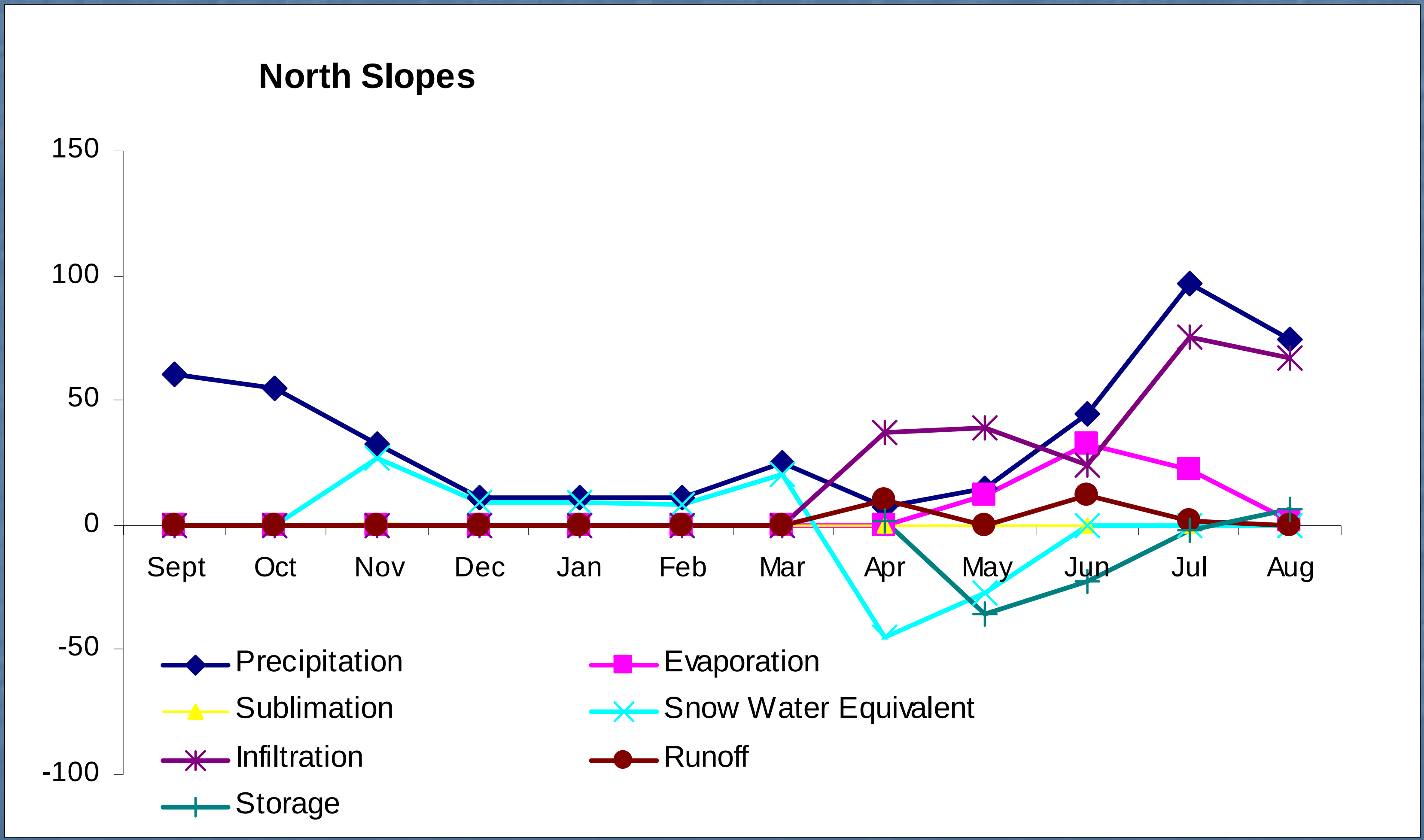
Preliminary Water Balance



Preliminary Water Balance



Preliminary Water Balance



Project Continuation

- Dry year runs underway
- Meeting with SoilCover modellers planned for March 15, 2004
- Snow surveys in April, May
- Weir installations
- Met station data collection
- Revised CRHM runs in December 2004

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Task 14b – Predict Dump Water Quality

Objectives of Task

- Predict concentrations and loadings of contaminants from waste rock.

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Project Team

- SRK
  - John Chapman, Stephen Day, Kelly Sexsmith,, Daryl Hockley

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Approaches

- Regional and Mineral Deposit Type Comparisons
- Empirical Estimates
- Mechanistic Predictions

Waste Rock Geochemistry Conclusions

- Rock type control on WQ established
  - Sulphides - PAG
  - Widespread contamination of schists at Faro by sulphides results in uncertainty.
  - Calc-silicates/calcareous phyllite – acid consuming.
- Rock Mixing
  - Waste rock not intimately mixed.

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Waste Rock Geochemistry Conclusions

- Stage of Seepage at Sites
  - Faro (mature, Stage 3)
    - Sulphide rock already acidic
    - Schist may become acid (time frame of decades)
  - Grum (Stage 1 and 2)
    - Sulphide rock not widely acidic.
    - Seepage chemistry expected to worsen as acid water breaksthrough.
  - Vangorda (Stage 2 and 3)
    - Friable sulphides already acidic.
    - Seepage chemistry expected to worsen.

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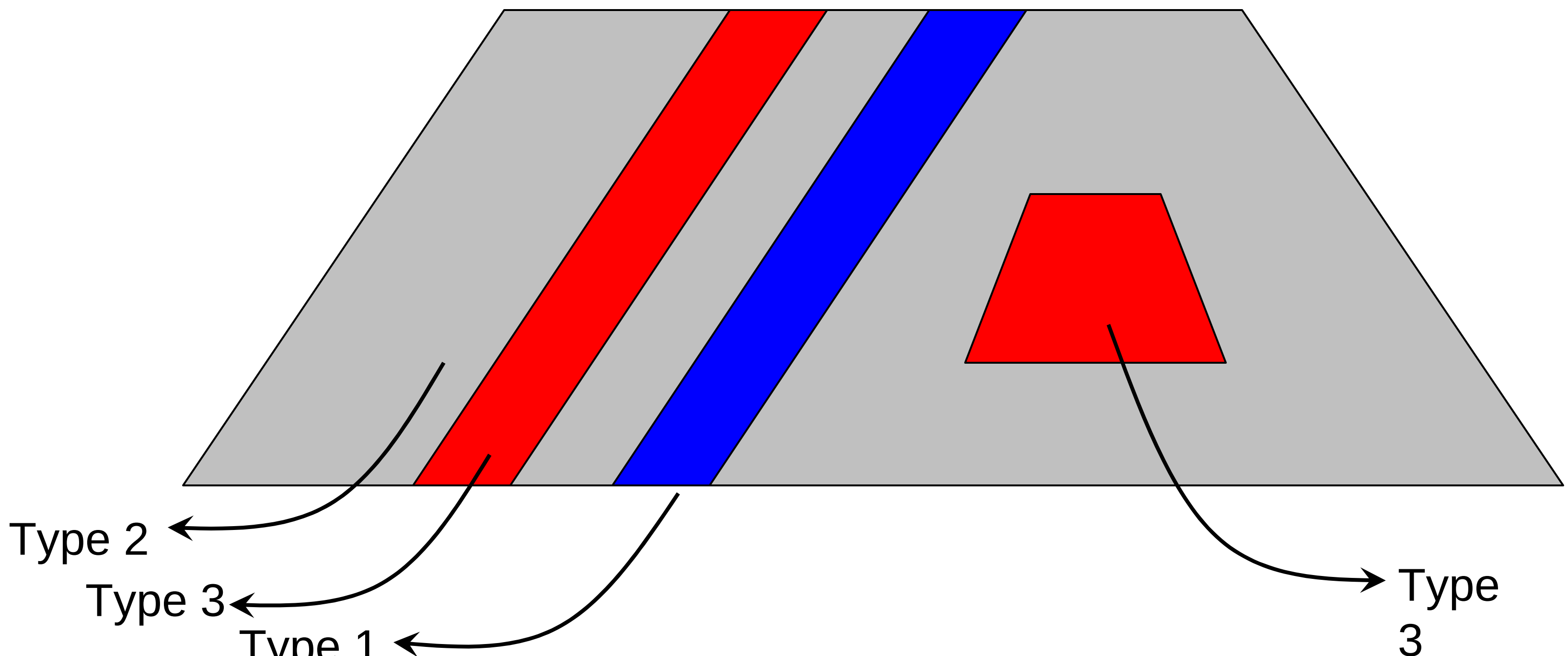
Empirical Estimate Method

- Basic Assumptions
  - Rock generally poorly mixed
  - Sulphide rock older than ~20 years is already generating acid.
  - Carbonate containing rocks do buffer acidity.
  - A component of the low sulphide schists and phyllites will generate acid in the future.

Assign water chemistry based on rock type

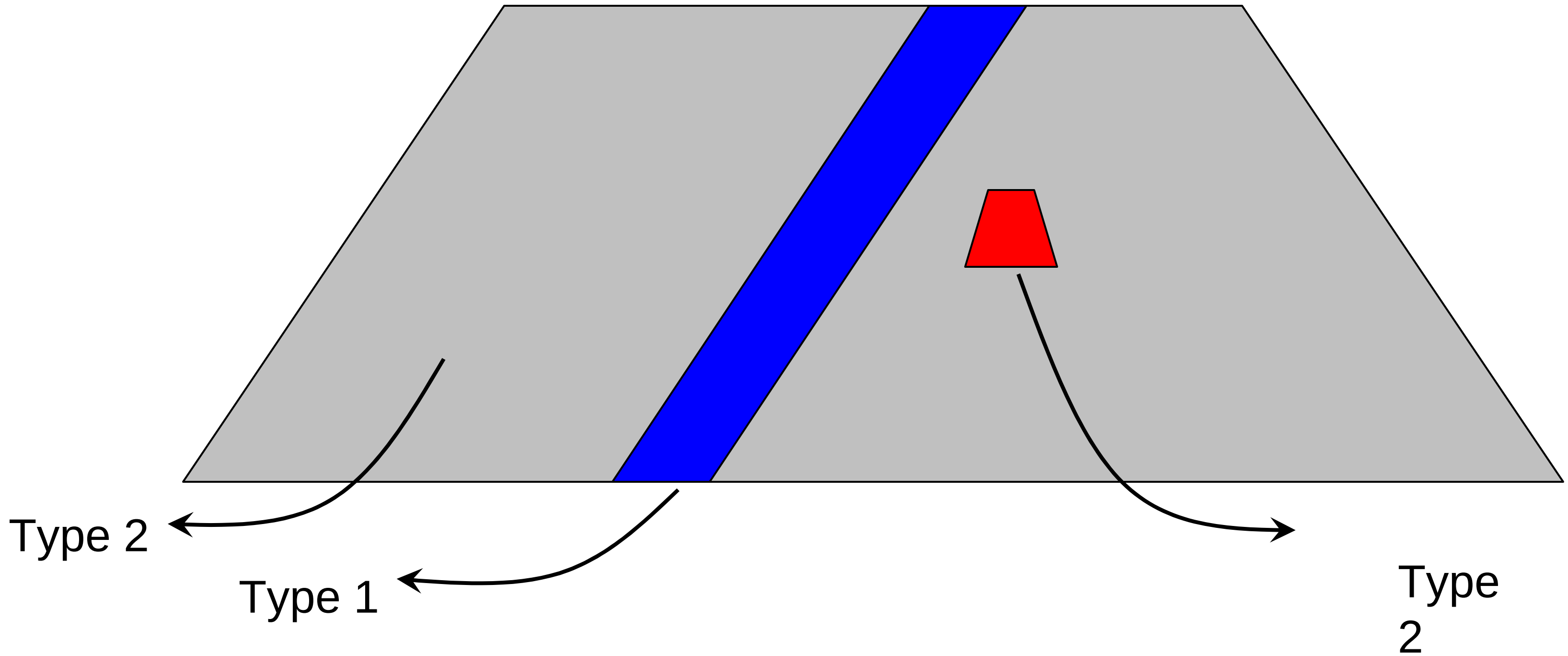
Empirical Estimates

- Faro Waste Rock, high sulphide proportion, poorly mixed



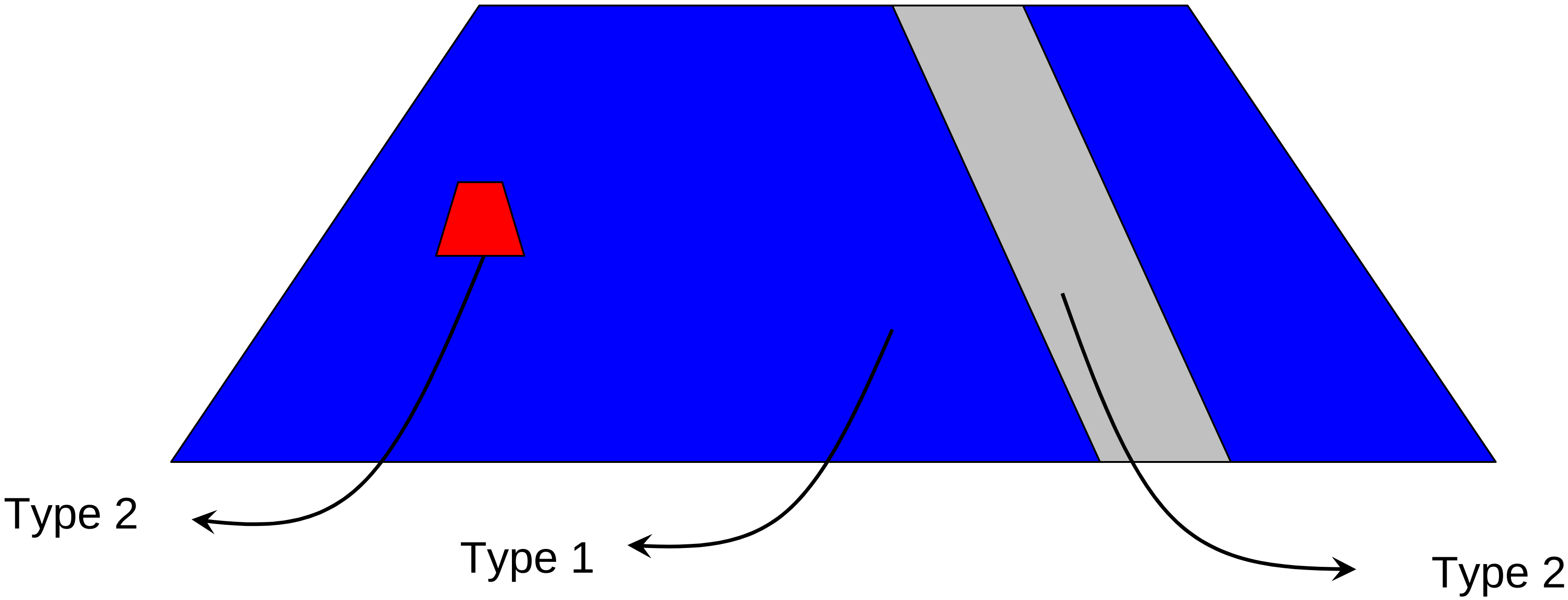
Empirical Estimates

- Faro Waste Rock, low sulphide proportion, mostly schist, poorly mixed



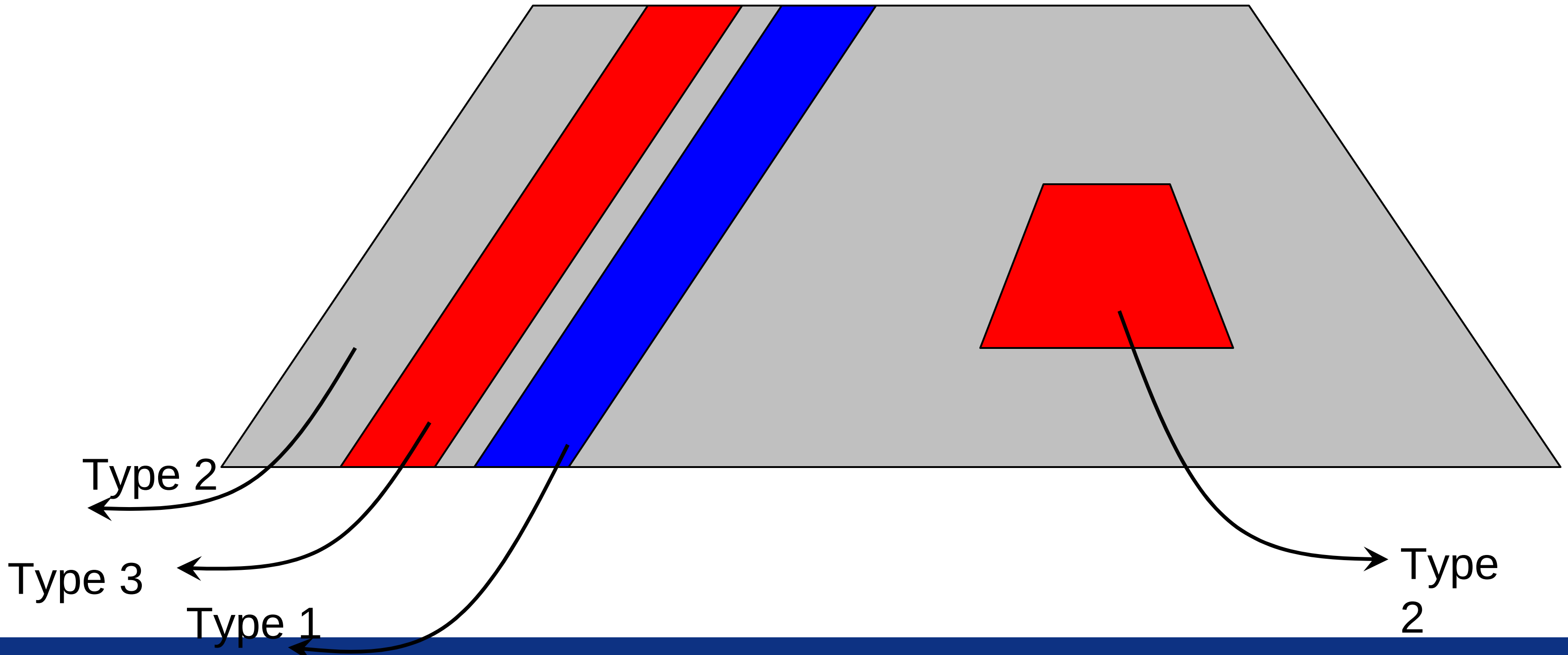
Empirical Estimates

- Faro Waste Rock, low sulphide proportion, mostly calc-silicate



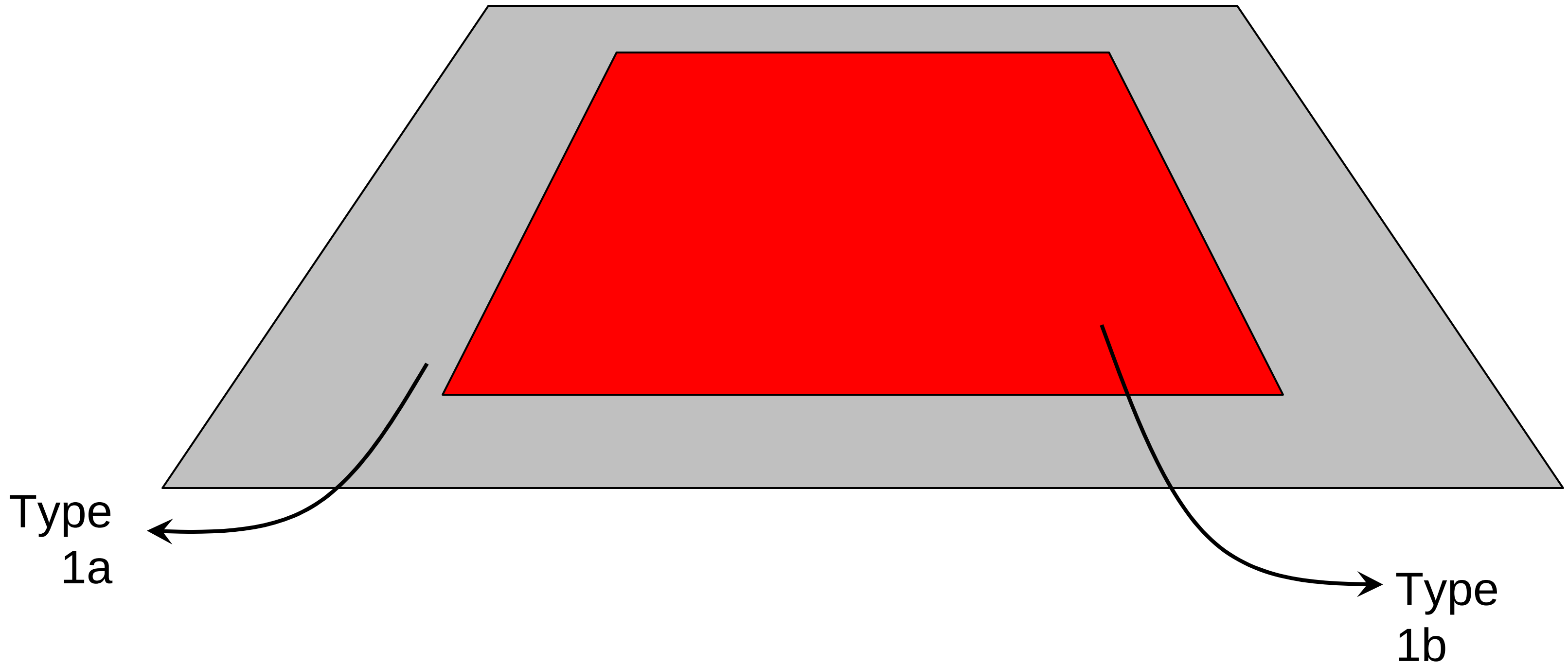
Empirical Estimates

- Vangorda Waste Rock, young, high sulphide proportion, poorly mixed



Empirical Estimates

- Grum Waste Rock, high sulphide proportion in sulphide cell



Water Quality Assignments

- Seepage Measured
  - Use measured value
- Seepage not observed – use Precedence Sequence to assign water quality

1. Age (affects sulphide status)
2. Sulphide proportion (drives water quality)
3. Schist proportion (currently non-acidic)
4. Calc-silicate (acid neutralizing if a large component)

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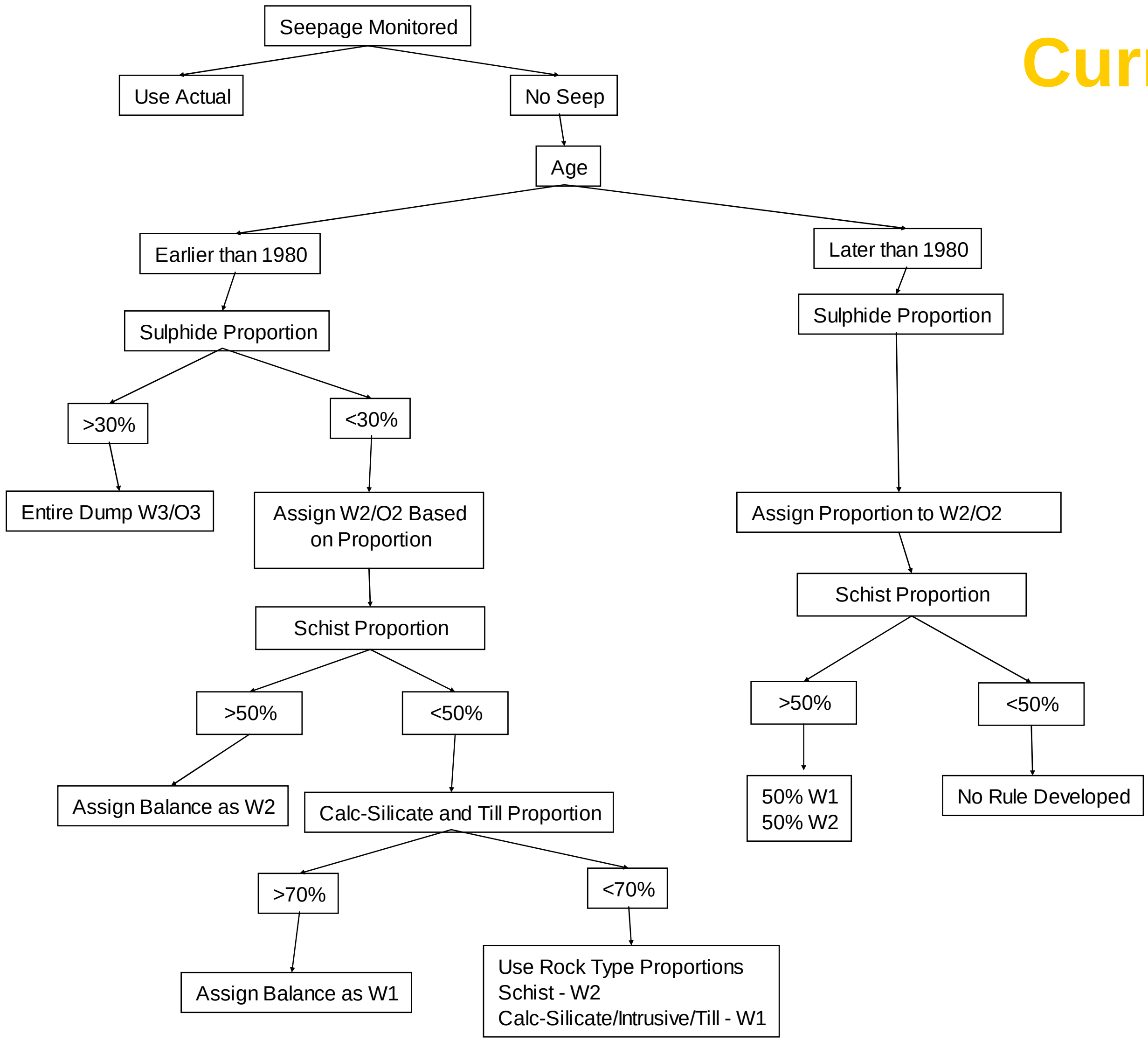
Current



Future Predictions

- Basis
  - All sulphide rock produces acidic water.
  - 50% of schist produces acidic water.
  - If calc-silicate is greater than 60%, no acidic water.

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Inputs

- Infiltration as % of mean annual precipitation.
- Waste dump areas.
- Rock type proportions.
- Seepage types (choice of statistic)

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Faro Results

- Assuming no remedial measures
- Current zinc load
  - 111 tonnes/year
  - 87% from ore and LGO stockpiles (~1% of rock mass).
- Future zinc load
  - 117 tonnes/year
  - 83% from ore and LGO stockpiles.

Vangorda Plateau Results

- Assuming no remedial measures

- Grum
  - Current zinc – 0.2 tonnes/year
  - Future zinc – 61 tonnes/year
- Vangorda
  - Current zinc – 2 tonnes/year
  - Future zinc – 91 tonnes/year

Limitations

- Wide range of possible seepage chemistry.
- Distribution of rock types, particularly for Grum and Vangorda.
- No allowance for attenuation effects.

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Task 16b – Pit Lake Studies

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Objectives of Task

- Establish the intermediate and long term water quality
- Provide basis for developing closure strategies for the Faro, Grum and Vangorda pit lakes

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Task Components

- Grum Pit Lake short term management issues (GLL)
- Potential for pit lake stratification (Dr. G. Lawrence, UBC)
- Review of in-situ pit lake treatment technologies (CANMET)
- Pit lake water quality predictions (SRK)

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Grum Short Term Management GLL

SCOPE

- Determine maximum Water Elevation (for Care and Maintenance period)
- Rate of Filling
- Estimate Operational Treatment Requirements
- Assess Management Plans

Grum Short Term Management GLL

Maximum elevation

- Emergency storage volume for breach of Grum Interceptor Ditch
- Assume seepage may occur at 1216 masl
- 1213 masl (19 m below spill elevation)

Grum Short Term Management GLL

Fill Rate

- Current conditions – 10.5 L/s
- Reach 1213 masl by 2012 to 2014 (9 to 11 years)

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Grum Short Term Management GLL

TREATMENT REQUIREMENTS

- Lime demand from treatability tests (Zn = 12 mg/L)
- 180 tonnes of lime to treat current pond
- Est. Zn 4 mg/L at 1213 masl

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Grum Short Term Management GLL

RECOMMENDED CARE AND MAINTENANCE MANAGEMENT

- In-Situ Treat with lime in 2004
- Continue to monitor:
  - Water Quality
  - Fill Rate

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Pit Lake Water Column Stability (Dr. G. Lawrence, UBC)

Objectives (for all pit lakes)

- Assess water column stability
- Estimate effect of flow through

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Pit Lake Water Column Stability
(Dr. G. Lawrence, UBC)

Definitions

- Stratification (Stable Layers)
  - Thermocline
    - Heating / Cooling
  - Chemocline
    - salinity
- “Meromixis” - permanently stratified

Pit Lake Water Column Stability (Dr. G. Lawrence, UBC)

Current Conditions

- Meromixis ratio $M = St^*/\Delta St$
  - St^* = salinity stratification
  - ΔSt = reduction in salinity stability
  - (exclusion of dissolved solids from ice)
- Assumed ice to be 3.5 to 4 ft

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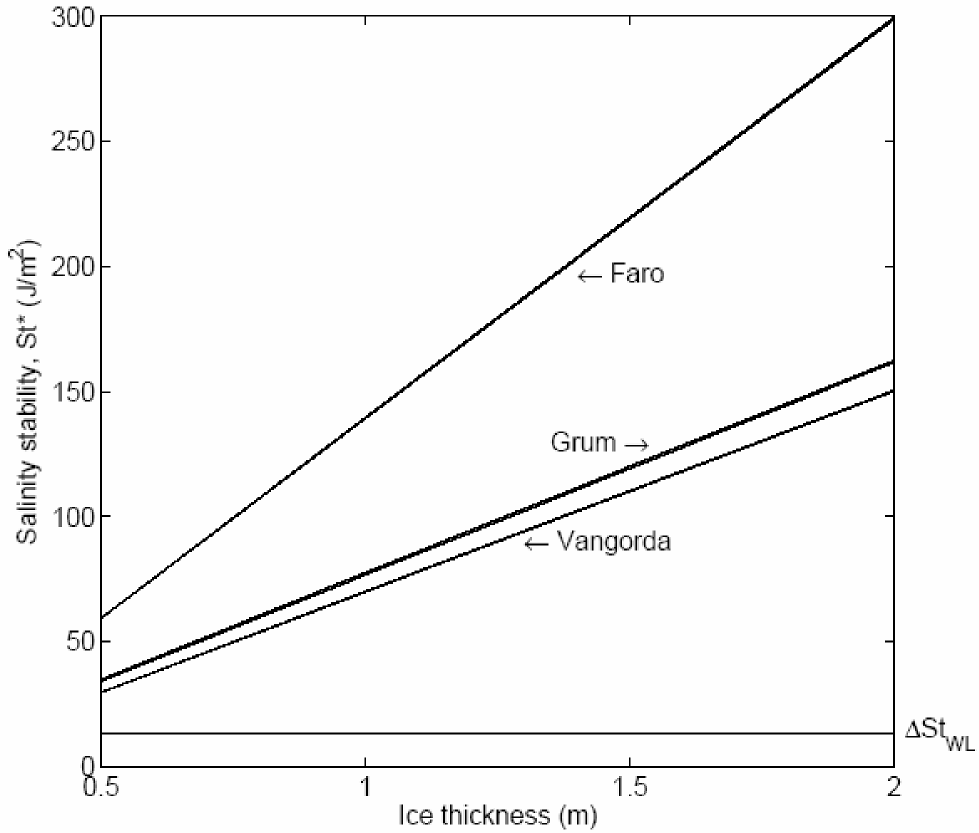

Figure 2. Predicted salinity stability at time of maximum heat content, St^*, for Grum, Faro and Vangorda pits with stream water diverted.

Pit Lake Water Column Stability (Dr. G. Lawrence, UBC)

Flow Through Conditions

- Calculated energy input from stream flow
- Estimated Meromixis Ratio
- Results indicated:
  - energy provided by the stream would be greater than the salinity stability.
  - mixing and displacement would remove salts from the stable layer

Pit Lake Water Column Stability (Dr. G. Lawrence, UBC)

Conclusions (for all pit lakes)

- Current conditions:
  - potential that meromixis may develop
  - additional monitoring of water column profiles through summer and winter required
- Flow through Conditions:
  - completely mixed conditions likely

Pit Lake Water Quality Estimates

Objective

- Estimate future pit lake water quality

Pit Lake Water Quality Estimates

Approach

- Current pit lake water quality
- Pit catchment hydrology
- Pit capacity curve
- Pit lake limnology
- Contaminant sources
- Mass balance calculations

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Pit Lake Water Quality Estimates

Current Water Quality

Parameter	Units	Faro	Grum	Vangorda
pH		6.87 - 7.89	7.49 - 8.08	6.54 - 7.35
Acidity	mg/L	18 - 65	2 - 28	151 - 221
Sulphate	mg/L	486 - 793	424 - 461	1080 - 1280
Iron	mg/L	0.04 - 22	0.06 - 0.17	0.15 - 28
Manganese	mg/L	2.2 - 3.4	0.45 - 0.66	30 - 43
Zinc	mg/L	1.4 - 11	4.4 - 12	91 - 124

Pit Lake Water Quality Estimates

Pit Catchment Hydrology

Component	Units	Faro	Grum	Vangorda
Total catchment	km^2	17.3	1.3	21.66
Surface area of pit lake	km^2	0.6	0.2	0.12
Mean annual runoff	mm	341	270	362
Mean annual precipitation at pit lake	mm	400	450	380

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Pit Lake Water Quality Estimates

Pit Capacity Curves

- Updated for 2003 aerial photography
- 'Meshed' with ICAP for below lake level

Pit Lake Water Quality Estimates

Pit Lake Limnology

- Flow through – completely mixed

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Pit Lake Water Quality Estimates

Contaminant Sources

- Pit wall rocks
- Waste rock within pit lake catchment

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Pit Lake Water Quality Estimates

Pit Wall Rock Sources

- Wall rock mapping
- Estimated surface areas
- Runoff
- Seepage quality according to rock type

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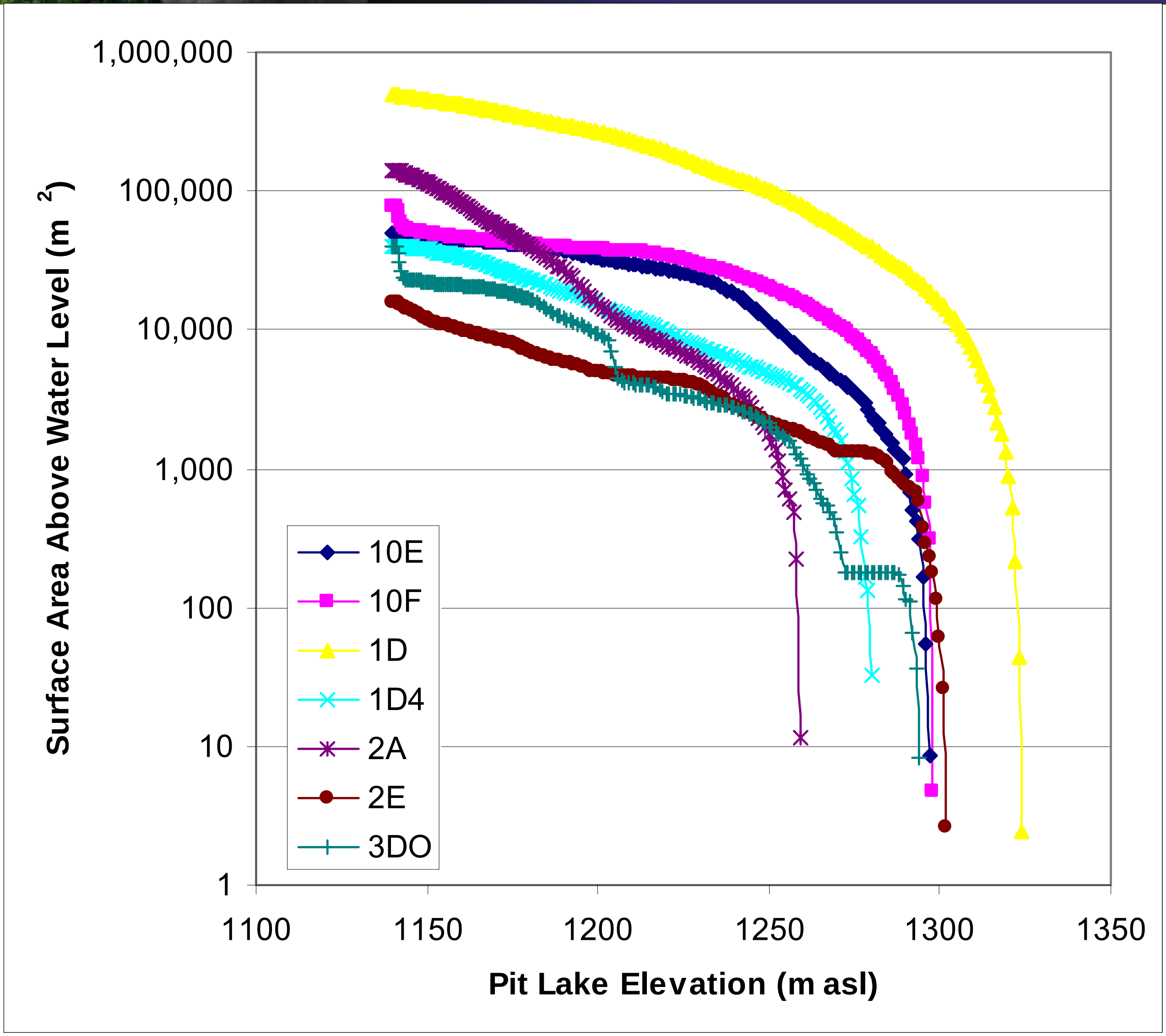
- Faro



Pit Lake Water Quality Estimates

Waste Rock

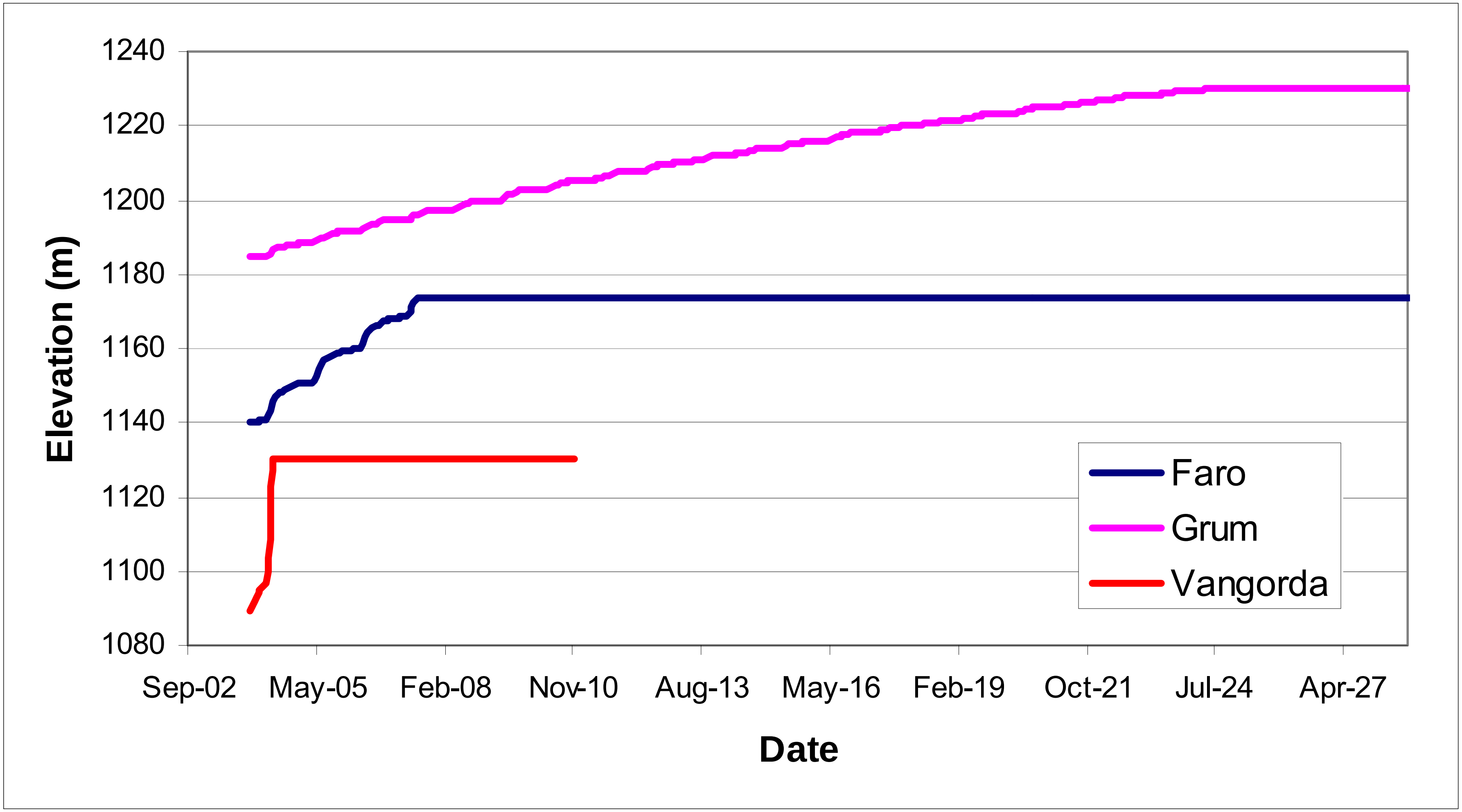
- From waste rock assessment
- Assume surface runoff also at seepage water quality

Pit Lake Water Quality Estimates

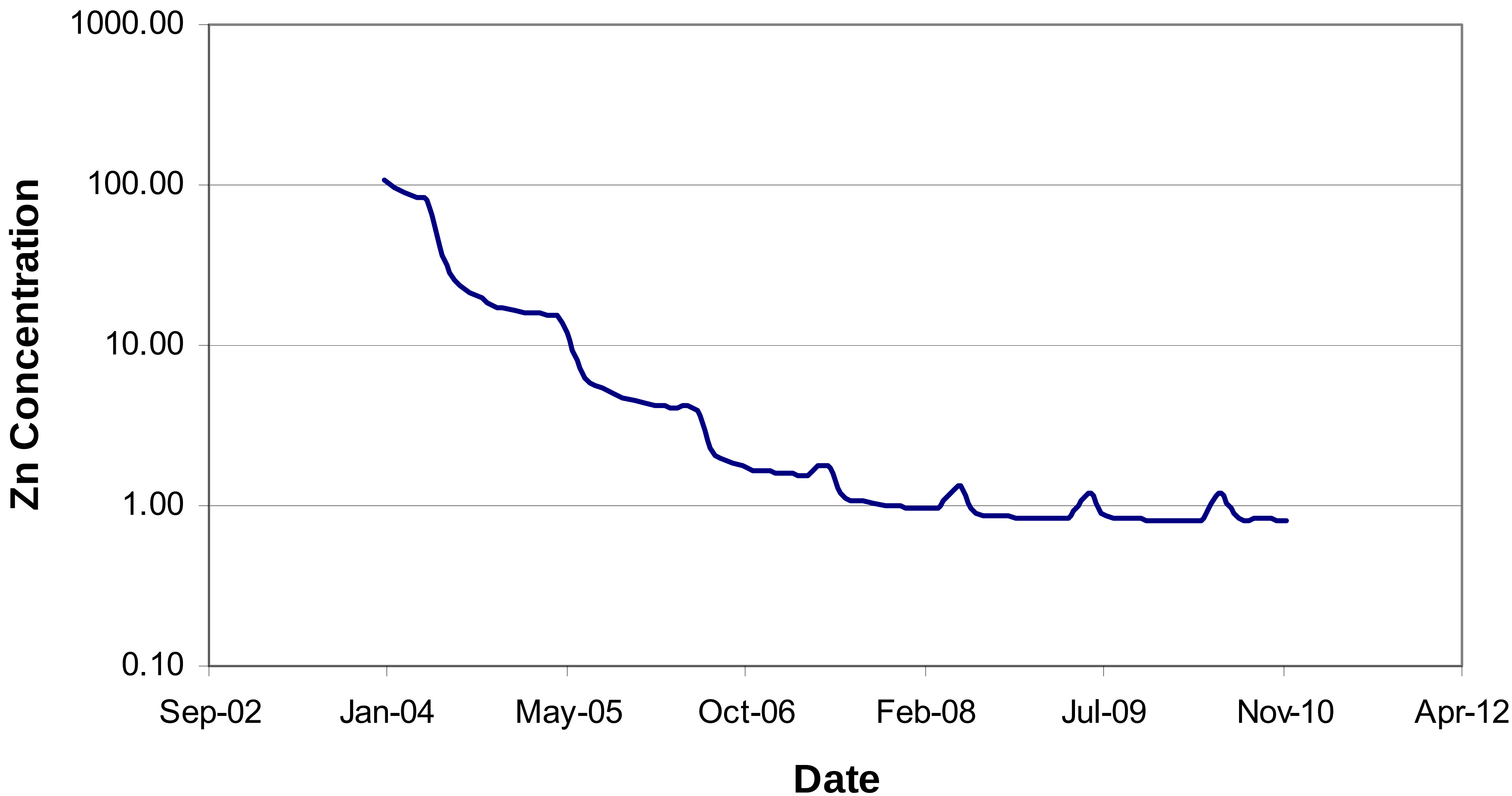
Mass Balance Calculations

- Monthly
- Completely mixed
- Loadings
  - Wall rock
  - Waste rock
- Losses
  - Outflows

Pit Lake Flooding Estimates



Vangorda Pit Lake Water Quality



Pit Lake Treatment Technologies
CANMET

Objectives

- Identify potential treatment technologies
- Assess applicability

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Pit Lake Treatment Technologies
CANMET

Approach

- Literature search
- Addressed:
  - application to *in-situ* treatment
  - status of the technology (commercially available, pilot-scale, laboratory-scale and conceptual stage);
  - effectiveness in removing metals;
  - capital and operating costs; and
  - sustainability of treatment process systems.

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Pit Lake Treatment Technologies CANMET

Technology	Amendment	Example
Bioremediation	fertilizer	Island Copper Mine pit lake
	sugar, alcohol phosphate	Sweetwater pit lake (SRB)
	ethylene glycol	Sulphate Reduction Bacteria (SRB) Systems
Precipitation	lime	Neutra-mill - Anchor Hill Pit Lake
Precipitation/ adsorption	lime	Berkeley pit lake
Adsorption	Kaolin Amorphous Derivative (KAD)	Berkeley pit lake KAD process
	Ferric Oxyhydroxide	McLaughlin south pit lake
Cementation	Se removal	Berkeley pit lake

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Pit Lake Treatment Technologies
CANMET

Process	Amendment	Volume Treated	Cost (Can$)
Bioremediation	fertilizer	3,760,000 m^3/yr	**$0.026/$m^3$**
	sugar, alcohol phosphate	-	$17.17/$m^3$
	n/a	-	$0.46/$m^3$
	ethylene glycol	-	$0.21/m3
Precipitation		1,635 m3/day with 500µg/L As	$0.26/$m^3$
			$4.75/$m^3$
	lime		$0.012/m3
	limestone		$0.003/m3
Precipitation / Adsorption	lime	28,300 m^3/day	Plant: $15.7-$28.8 mil Operational: $0.25/m3
Adsorption		11,355 m^3/day	$264/$m^3$
Cementation			$2.83/$m^3$

Pit Lake Treatment Technologies
CANMET

Conclusions

- Lime treatment – proven performance
- Biological – promising technology - low cost

Pit Lake Treatment Technologies
CANMET

Recommendations

- **Lime** or some other similar form of chemical treatment to raise the pH.
- Amendments with sugar and alcohol to create anoxic conditions under which **SRB** precipitate metals (Note: may not be applicable if meromixis cannot be sustained).
- Nutrient additions as means of creating **algae and phytoplankton** that remove metals such as Zn when they settle to the bottom.

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SUMMARY

Estimated Water Quality at Time of Spill

Parameter	Units	Waste Rock Loads Included			Waste Rock Loads Removed	
		Faro	Grum	Vangorda	Faro	Vangorda
Acidity($CaCO_3$)	mg/L	23	5.2	73	20	73
SO_4	mg/L	409	256	324	396	323
Al	mg/L	0.16	0.072	0.074	0.07	0.071
Cd	mg/L	0.006	0.006	0.022	0.005	0.022
Cu	mg/L	0.023	0.0039	0.022	0.011	0.020
Fe	mg/L	4.1	0.03	4.0	3.6	3.9
Pb	mg/L	0.0062	0.015	0.014	0.0038	0.014
Mn	mg/L	1.6	0.19	9.7	1.6	9.7
Ni	mg/L	0.05	0.11	0.16	0.05	0.16
Zn	mg/L	5.2	2.9	29	4.6	29

SUMMARY

Long Term Water Quality

Parameter	Units	Waste Rock Loads Included			Waste Rock Loads Removed	
		Faro	Grum	Vangorda	Faro	Vangorda
Acidity($CaCO_3$)	mg/L	9	1	2	3	2
SO_4	mg/L	60	152	11	32	10
Al	mg/L	0.27	0.059	0.0064	0.08	0.0038
Cd	mg/L	0.0032	0.0030	0.00076	0.0011	0.00054
Cu	mg/L	0.037	0.0030	0.0036	0.011	0.0018
Fe	mg/L	1.4	0.0089	0.20	0.4	0.15
Pb	mg/L	0.0085	0.015	0.00052	0.0033	0.00044
Mn	mg/L	0.20	0.04	0.31	0.07	0.24
Ni	mg/L	0.013	0.045	0.0082	0.005	0.0077
Zn	mg/L	2.1	0.27	0.87	0.66	0.68

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Conclusions

- Water column stability:
  - Existing conditions may lead to meromixis
  - Flow through conditions unlikely sustain stratification
- Water quality
  - Flow through conditions will lead to lower long term concentrations
  - Removal of waste rock sources (Faro and Vangorda) will further reduce concentrations
- Water treatment technologies
  - Biological promising – low cost
  - Lime proven
- Long term flow through conditions
  - Concentrations may decrease to within limits suitable for biological in-lake treatment

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Task 12c – Revise Water Treatment Cost Assumptions

Objectives of Task

- Update water treatment performance and cost estimates using 2003 data
- Estimate sludge generation

Approach

- Review water quality data for water treated in 2003
- Calculate chemical consumption rates and unit water treatment costs
- Model High Density Sludge (HDS) Treatment for water treated 2003
  - Capital costs
  - Operating costs

Water Treatment Systems

- Vangorda/Grum – purpose designed and built water treatment system
- Faro Mill – mill equipment converted water treatment system
- Down Valley – 'mobile' system (currently located at the Intermediate Impoundment Spillway) – low mixing / short contact

Existing Water Treatment

- Average Water Quality

Parameter	Units	Vangorda/Grum	Faro	Down Valley
Alkalinity	mgCaCO3/L	51	-	
Acidity*	mgCaCO3/L	143	21	58
pH		7.1	7.6	7.4
Al	mg/L	0.02	0.04	0.07
Fe	mg/L	0.67	0.16	6.8
Mn	mg/L	22	2.2	12
Zn	mg/L	66	11	11
SO_4	mg/L	828	520	703
Ca	mg/L	196	129	192
Mg	mg/L	69	50	49

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Existing Water Treatment

- Operating Conditions

Parameter	Units	Faro Mill	Vangorda	Down Valley
Operating Period	days	66	45	54
Downtime	days	0	7	0
Flow Rate	USgpm	5300	2000	1500
Volume Treated	m3	1,906,550	414,230	441,482
Lime consumption	short tons	240	140	220
	mg/L	114	307	452
Power Draw	kWh	800	700	175
Consumed	kWh	1,267,200	638,400	226,800
Genset Fuel	gals/day	n/a	na	200
Labour Shift	hr	12	12	12
Rotation		4x4	4x4	4x4
Operators		4	8	4

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Existing Water Treatment

- Lime Utilization

Parameter	Units	Faro Mill	Vangorda	Down Valley
Volume Treated	m^3	1,906,550	414,230	441,482
Average Acidity	mg $CaCO_3$ eq/L	27.9	142.5	59.8
Equiv. to pH 9.5	mg $CaCO_3$ eq/L	1.6	1.6	1.6
Total Acidity Equivalent	mg $CaCO_3$ eq/L	29.5	144.1	61.4
Lime consumed	short tons	240	140	220
Acidity equivalent	mg $CaCO_3$ eq/L	114	307	452
Lime Utilization	%	25.8	47.0	13.6

Lime Utilization incl. Mg	%	49.1	74.5	16.3

Existing Water Treatment

- Operating Costs

Parameter	Faro Mill	Vangorda	Down Valley
Overall Operating Costs			
Quick Lime	$ 76,800	$ 44,800	$ 70,400
Power	$ 164,736	$ 82,992	$ 29,484
Labour	$ 66,623	$ 90,850	$ 54,510
Total	**$ 308,159**	**$ 218,642**	**$ 154,394**
Unit Operating Costs ($/m^3)			
Quick Lime	0.040	0.108	0.160
Power	0.086	0.200	0.067
Labour	0.035	0.219	0.124
Total	**0.161**	**0.527**	**0.351**

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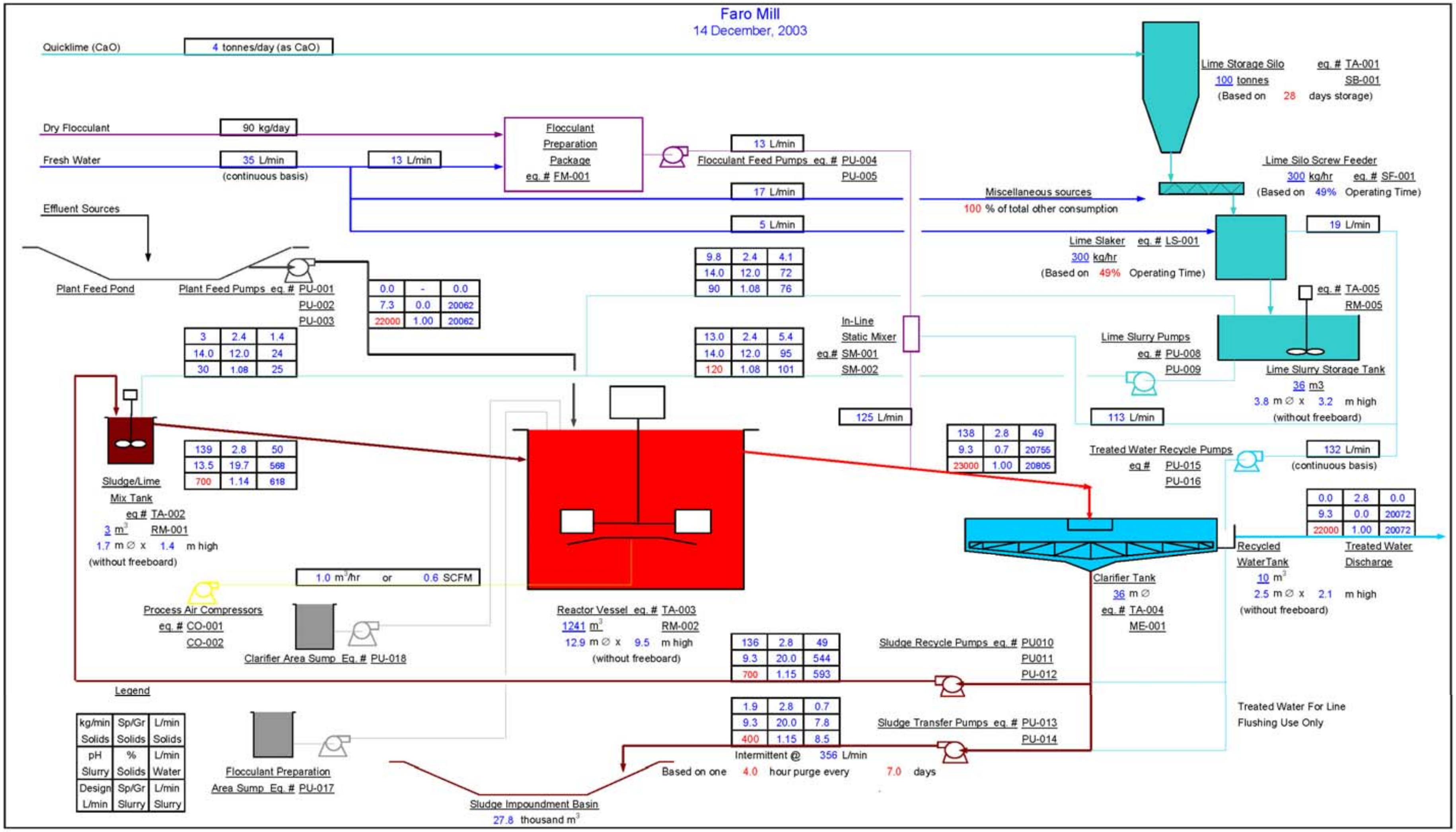
HDS Treatment



kg/min Solids	Sp/Gr Solids	L/min Solids
pH Slurry	% Solids	L/min Water
Design L/min	Sp/Gr Slurry	L/min Slurry

Plant Feed Pumps:

0.0	-	0.0
7.3	0.0	20062
22000	1.00	20062

Plant feed to reactor:

3	2.4	1.4
14.0	12.0	24
30	1.08	25

Lime slurry:

9.8	2.4	4.1
14.0	12.0	72
90	1.08	76

13.0	2.4	5.4
14.0	12.0	95
120	1.08	101

Sludge/Lime Mix Tank to reactor:

139	2.8	50
13.5	19.7	568
700	1.14	618

Reactor to clarifier:

138	2.8	49
9.3	0.7	20755
23000	1.00	20805

Treated water discharge:

0.0	2.8	0.0
9.3	0.0	20072
22000	1.00	20072

Sludge recycle:

136	2.8	49
9.3	20.0	544
700	1.15	593

Sludge transfer:

1.9	2.8	0.7
9.3	20.0	7.8
400	1.15	8.5

HDS Treatment

- Capital and Operating Cost Estimates

HDS System		Vangorda/Grum	Faro Mill	Down Valley
Flow	US gpm	2000	5300	1500
Lime consumption	g/L as CaO	0.197	0.123	0.144
Lime utilization	%	87	87	87
Sludge generation	**kg/m^3**	**0.228**	**0.097**	**0.151**
Capital Cost	**$**	**4,670,000**	**8,790,000**	**3,870,000**
Unit Operating Cost	**$/m^3**	**0.21**	**0.14**	**0.21**

Conclusions

		Vangorda/Grum	Faro Mill	Down Valley
Existing System				
Flow	US gpm	2000	5300	1500
Lime consumption	g/L as CaO	0.172	0.064	0.253
Lime utilization	%	74.5	49.1	16.3
Unit Operating Cost	**$/m^3**	**0.527**	**0.161**	**0.351**
HDS System				
Flow	US gpm	2000	5300	1500
Lime consumption	g/L as CaO	0.197	0.123	0.144
Lime utilization	%	87	87	87
Sludge generation	**kg/m^3**	**0.228**	**0.097**	**0.151**
Capital Cost	**$**	**4,670,000**	**8,790,000**	**3,870,000**
Unit Operating Cost	**$/m^3**	**0.21**	**0.14**	**0.21**

Conclusions

- For different water qualities and flows:
  - Lime demands
  - Sludge generation rates
  - Capital costs
  - Operating Costs
- Inputs to AMD TREAT

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Grum Seepage Collection

Home

Presented by:

Peter Healey

SRK Consulting

Grum Seepage Collection

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Issues:

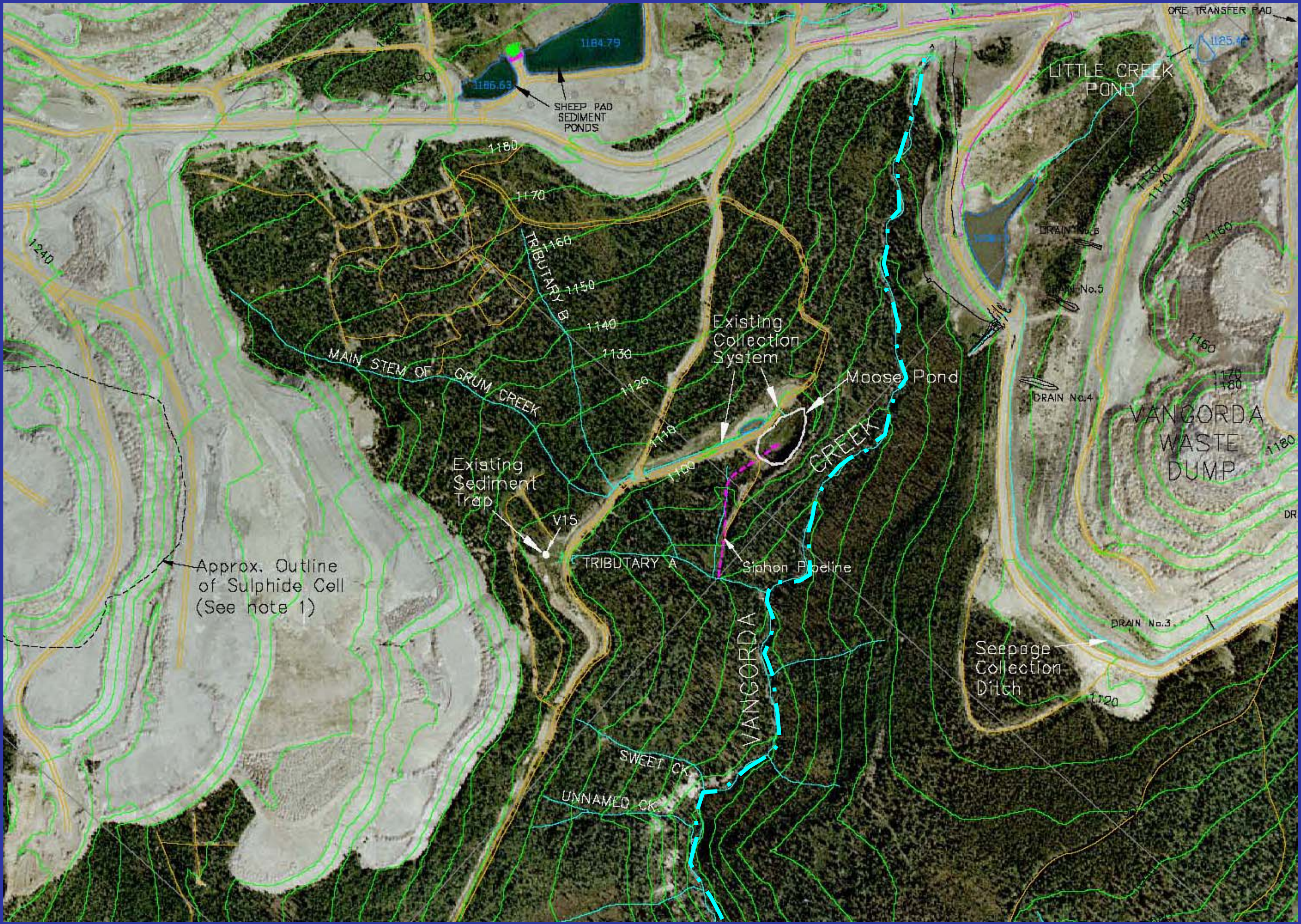
1. What proportion of the contaminant load from Grum dumps needs to be collected to protect Vangorda Creek ??
2. How much of the loading can be captured with collection ditches and or sumps ??
3. If we need to capture more of the loading what options do we have?

Objectives:

- Further input from Geochemistry and Water balance required to answer Issue 1
- Study focused on Issues 2 and 3
- Provide the basis for design and redesign of closure options
- Compile all available geotechnical and water quality data
- Provide interpretation of the data where applicable
- Present some example designs

Location Map

Site Plan



ORE TRANSFER PAD
1184.79
1186.63
SHEEP PAD
SEDIMENT
PONDS
LITTLE CREEK
POND
TRIBUTARY B
MAIN STEM OF GRUM CREEK
Existing
Collection
System
Moose Pond
DRAIN No.6
DRAIN No.5
DRAIN No.4
DRAIN No.3
VANGORDA
WASTE
DUMP
VANGORDA
CREEK
Existing
Sediment
Trap
V15
TRIBUTARY A
Siphon Pipeline
Approx. Outline
of Sulphide Cell
(See note 1)
Seepage
Collection
Ditch
SWEET CK.
UNNAMED CK.

Grum Dump from Vangorda Dump

Sediment Trap at V15

Outfall from V15 Sediment Trap above V2

Geotechnical Database

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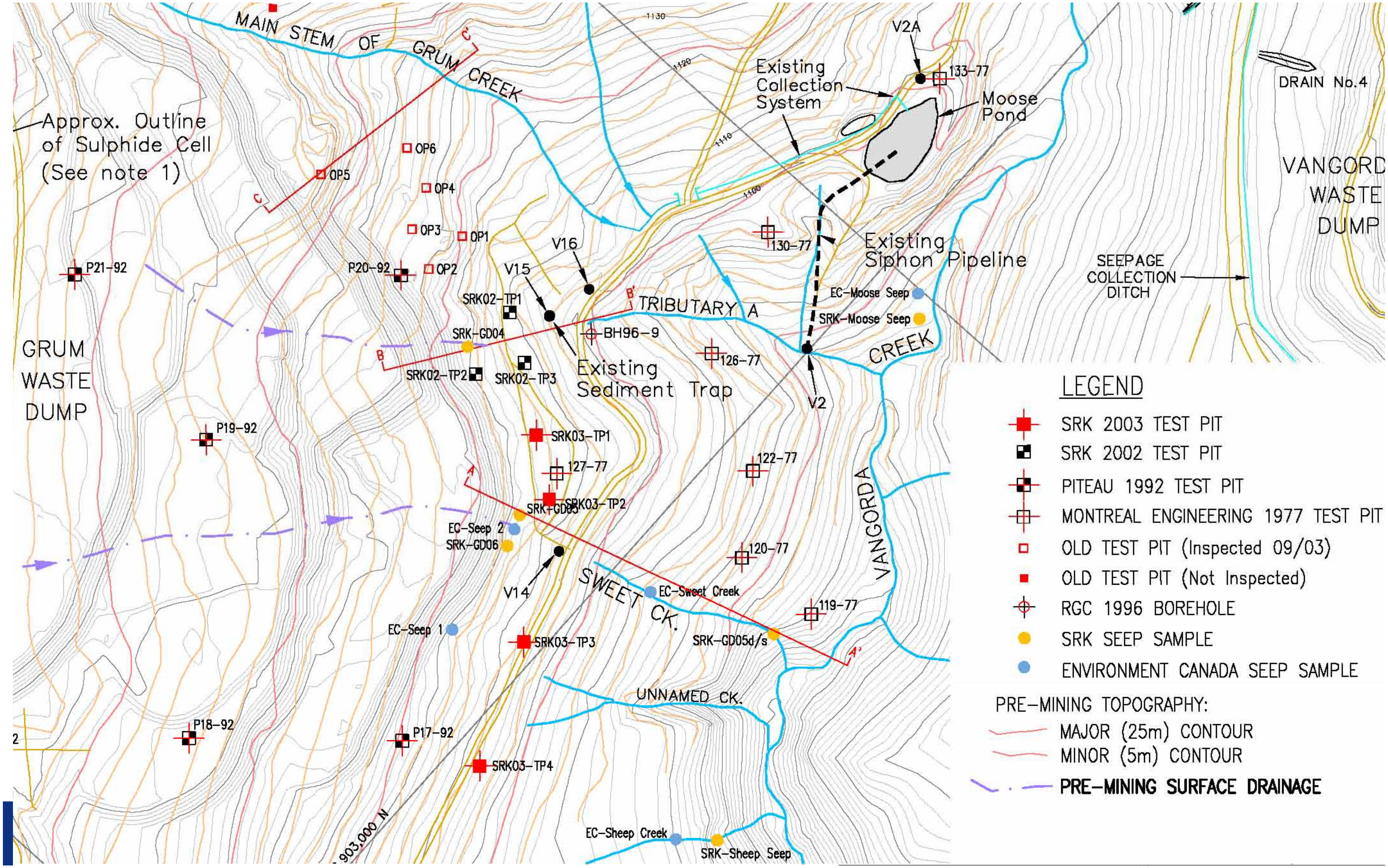

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Soil Conditions

- Along the toe of the dump, the soil is quite variable
- To the west the soil consists of 1 to 2 m of glacial till over fractured bedrock
- To the east, no bedrock was encountered and soil consists of 1 to 2 metres of sand and gravel over a silty till.

Water Quality

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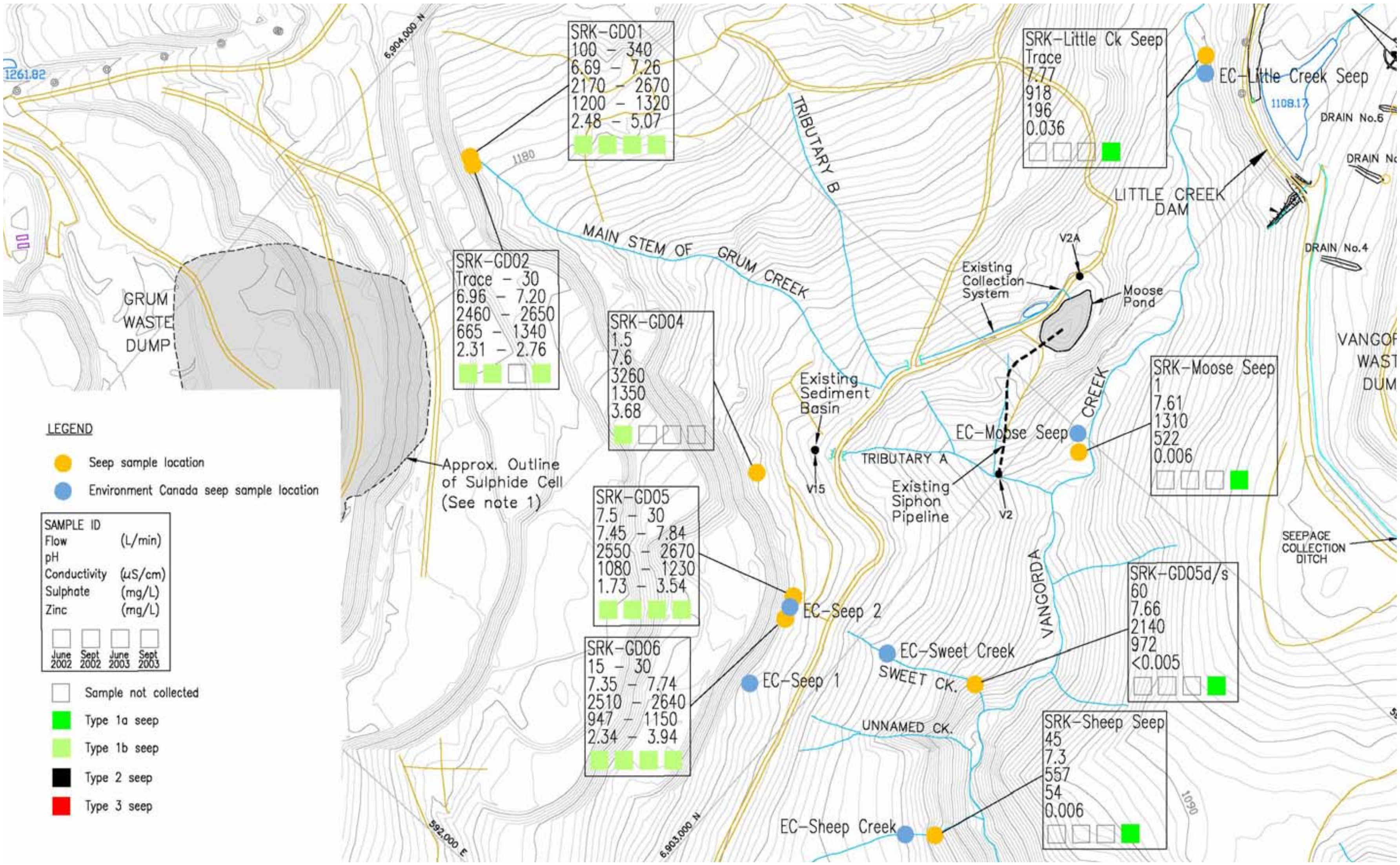


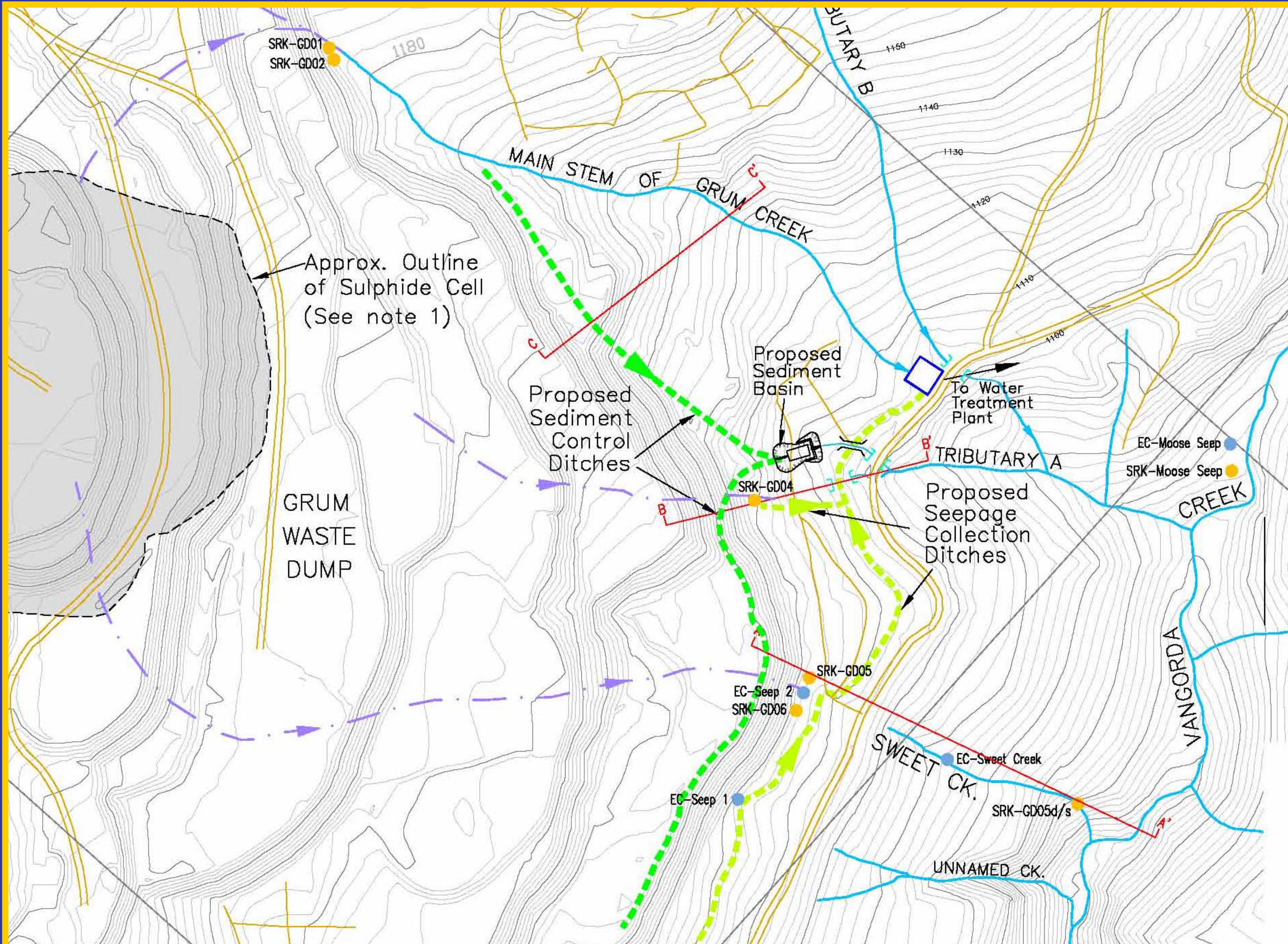
Water Quality

- All Grum seeps are neutral to slightly alkaline
- Zn conc range from 2 to 5 mg/L
- Sulphate conc greater than 500mg/L
- Sulphide waste rock not limited to the sulphide cell

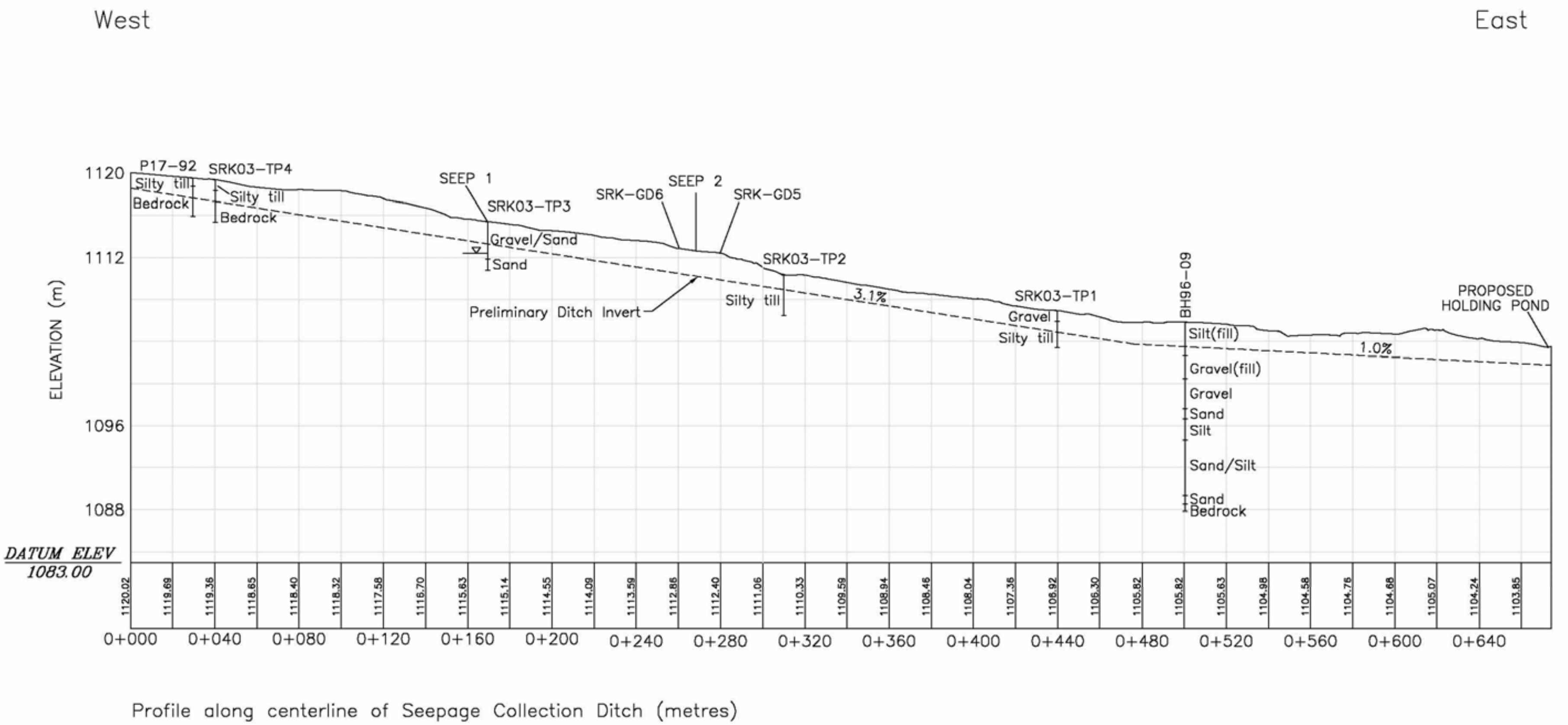
Approach to Closure Methods

- Separate dump runoff/sediment from seepage
- Runoff/sediment load would be collected in an open ditch to a sedimentation pond
- Seepage would be directed to a holding pond and ultimately to a WTP in a separate ditch or sumps/pipelines

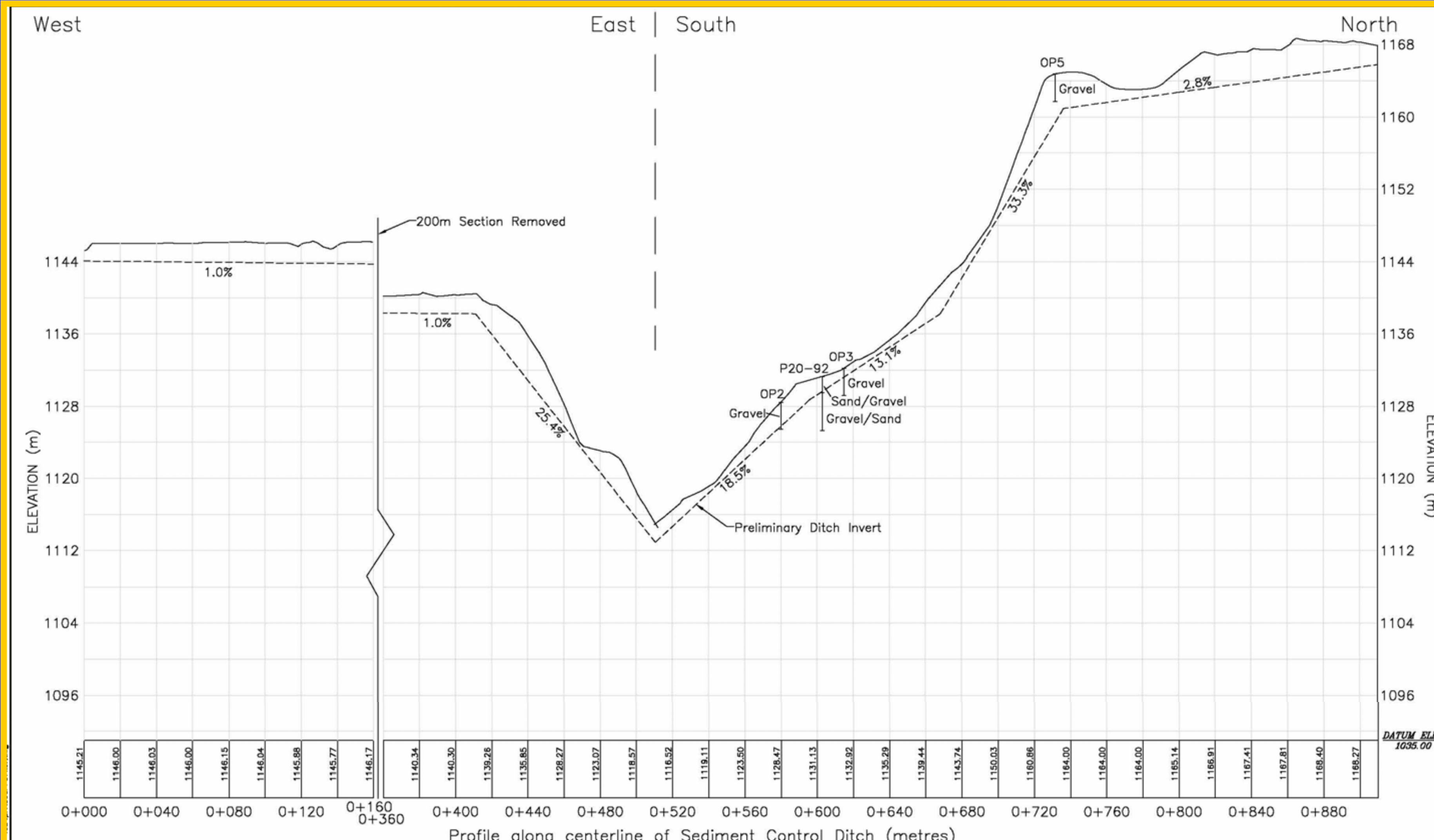
Closure Method Option 1



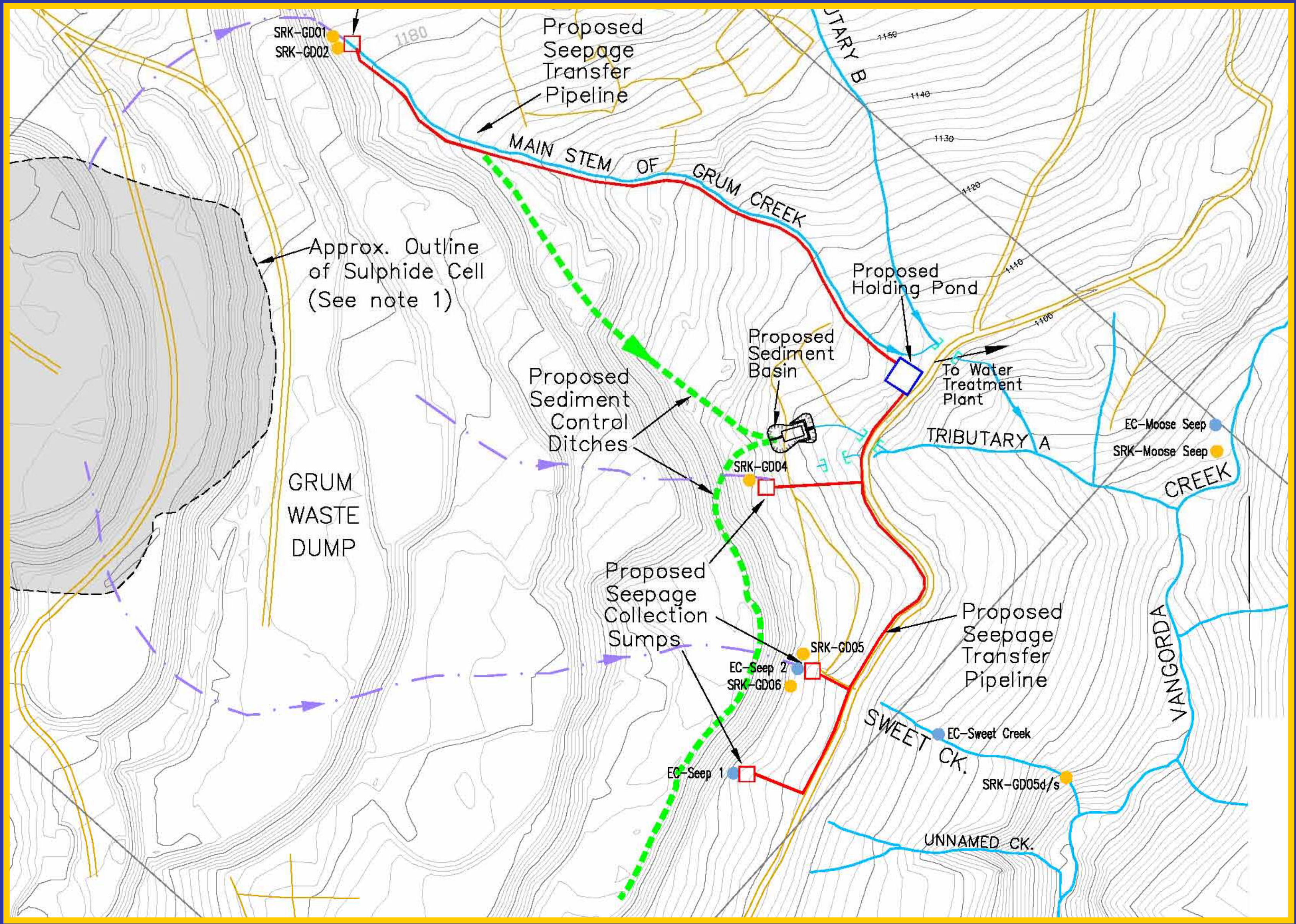
Seepage Collection Ditch Profile



Sediment Control Ditch Profile



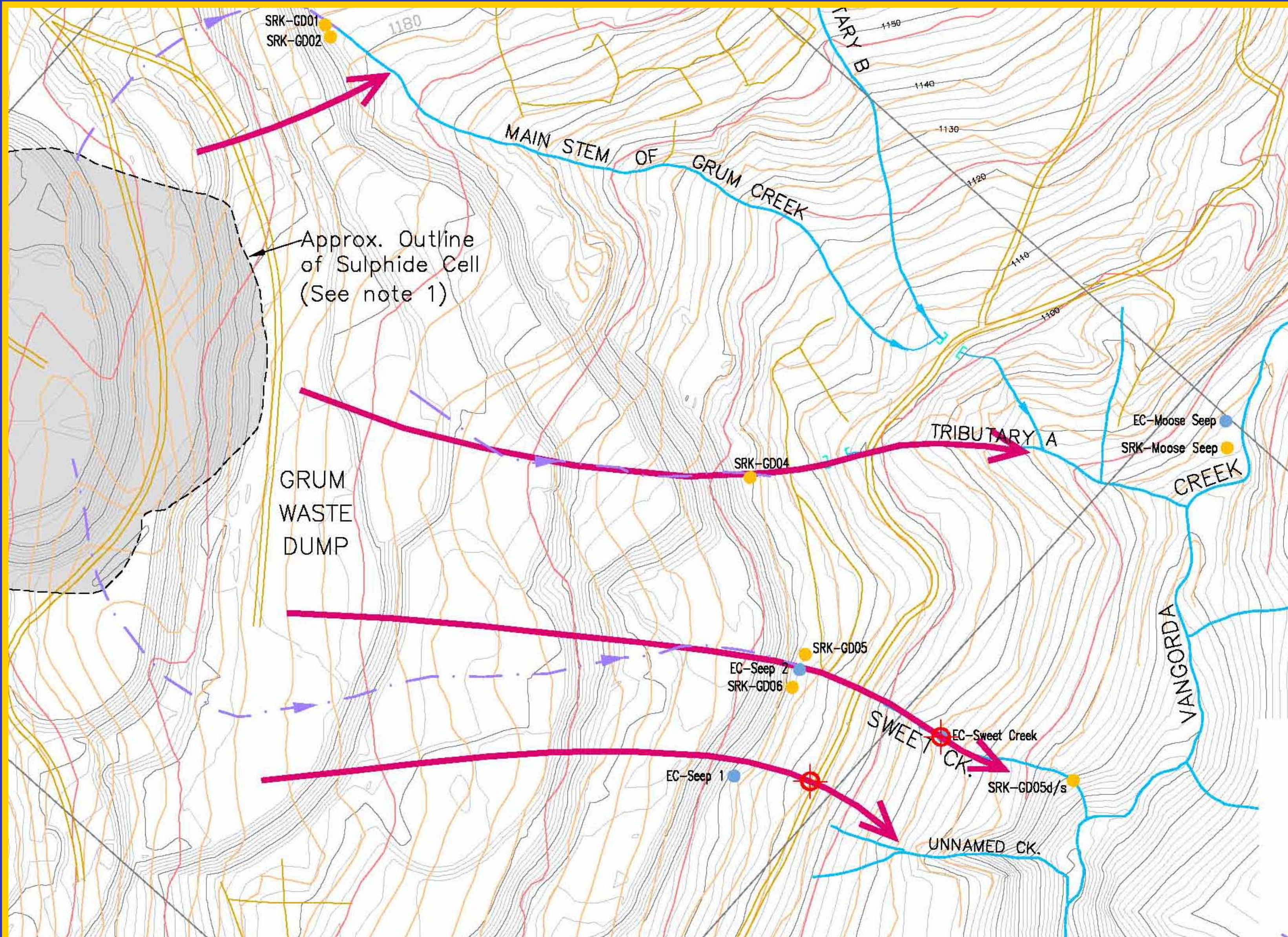
Closure Method Option 2



Closure Option 3

- Groundwater Collection Wells as a contingency if seepage collection system is not effective enough in capturing the contaminant loading
- Water would be pumped from the wells to the WTP
- Location of wells and depth of wells would be determined by a proposed groundwater investigation
- Investigation would involve the installation of two piezometer nests,
- Water quality in the wells would be compared with the water quality in the surface seep to assess the proportion of the contaminant loading from each source.

Proposed Groundwater Monitoring Program



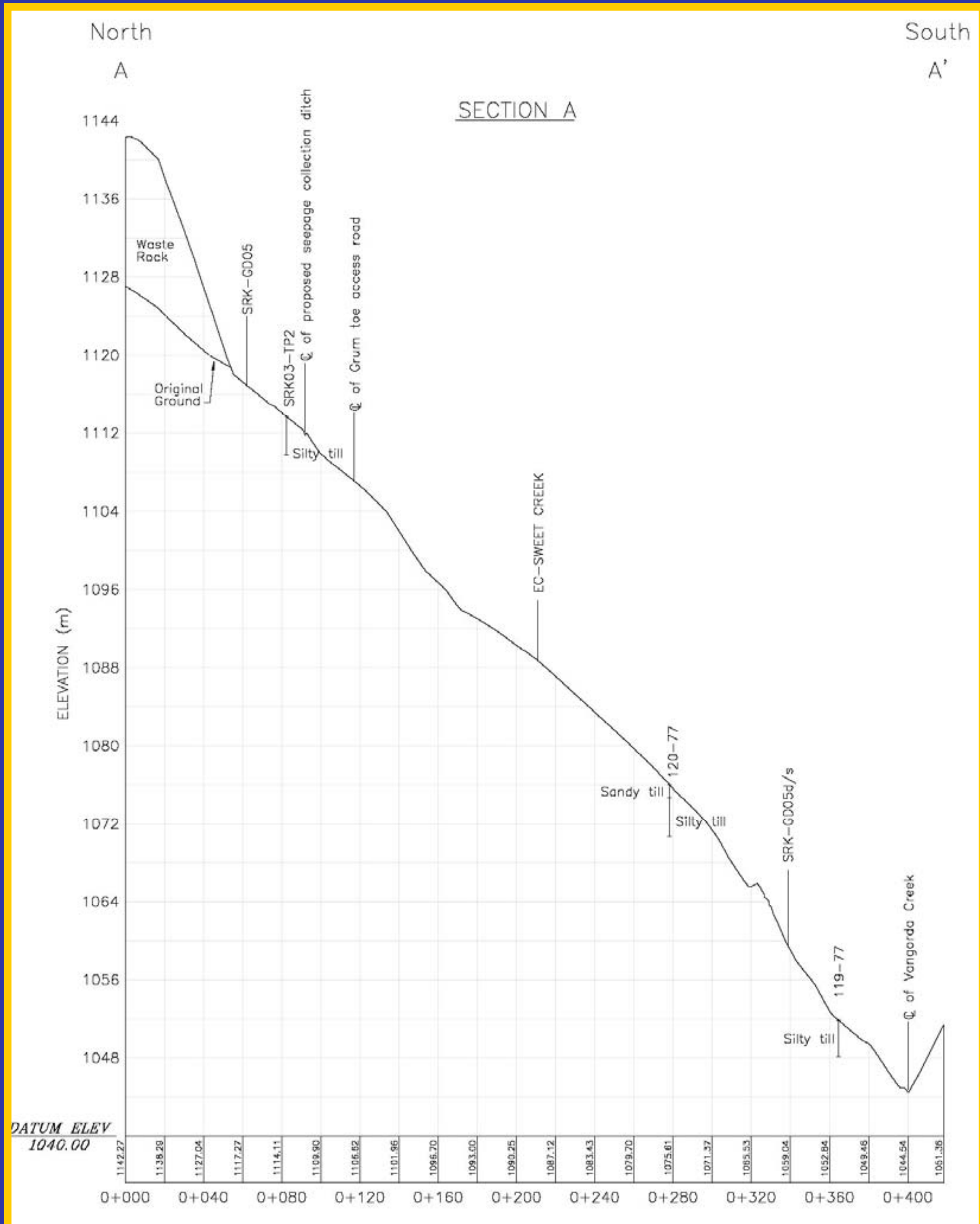
Grum Dump from the Overburden Stockpile

Grum Dump from Little Creek Dam

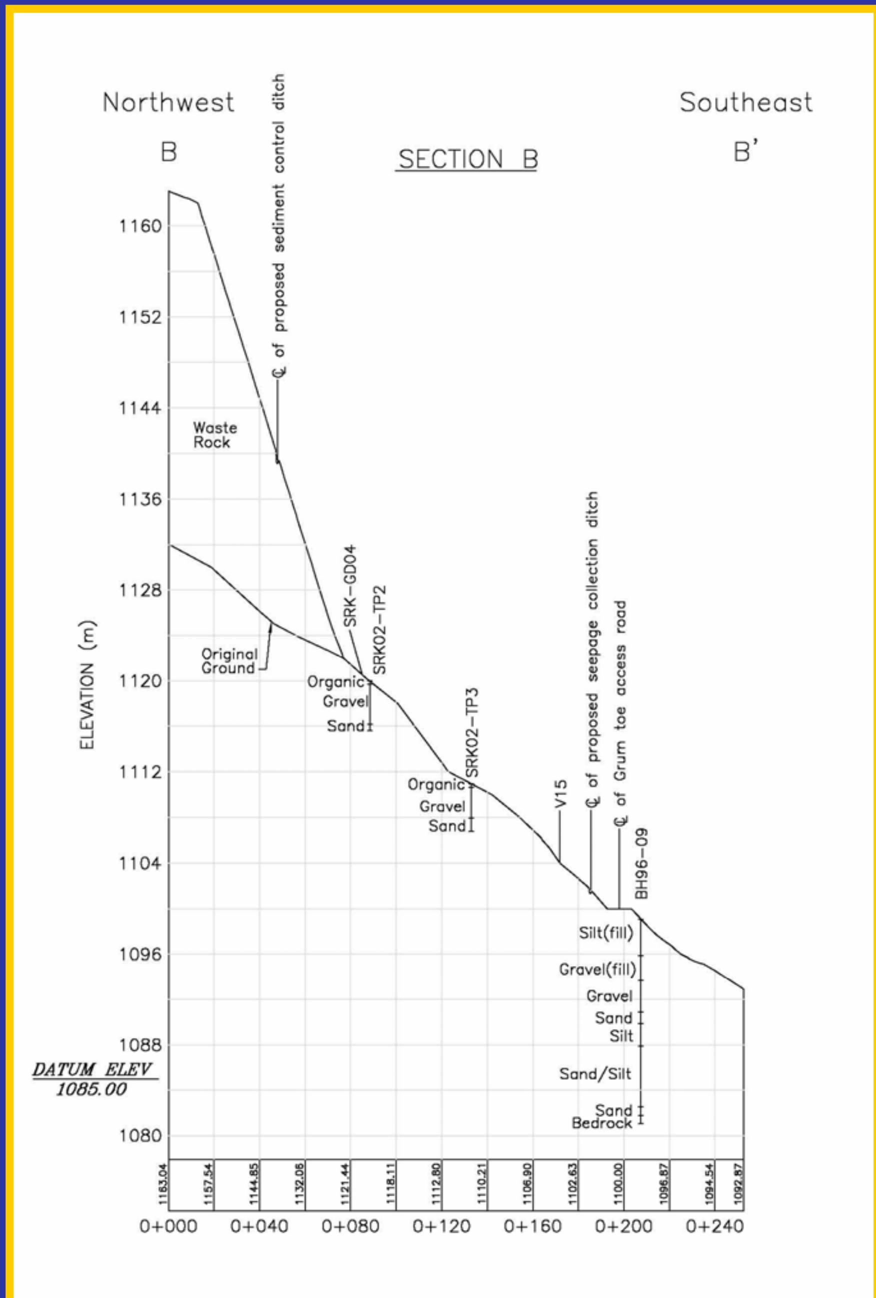
This is a another lovely shot……Title????

Grum This is a lovely shot…………Title????

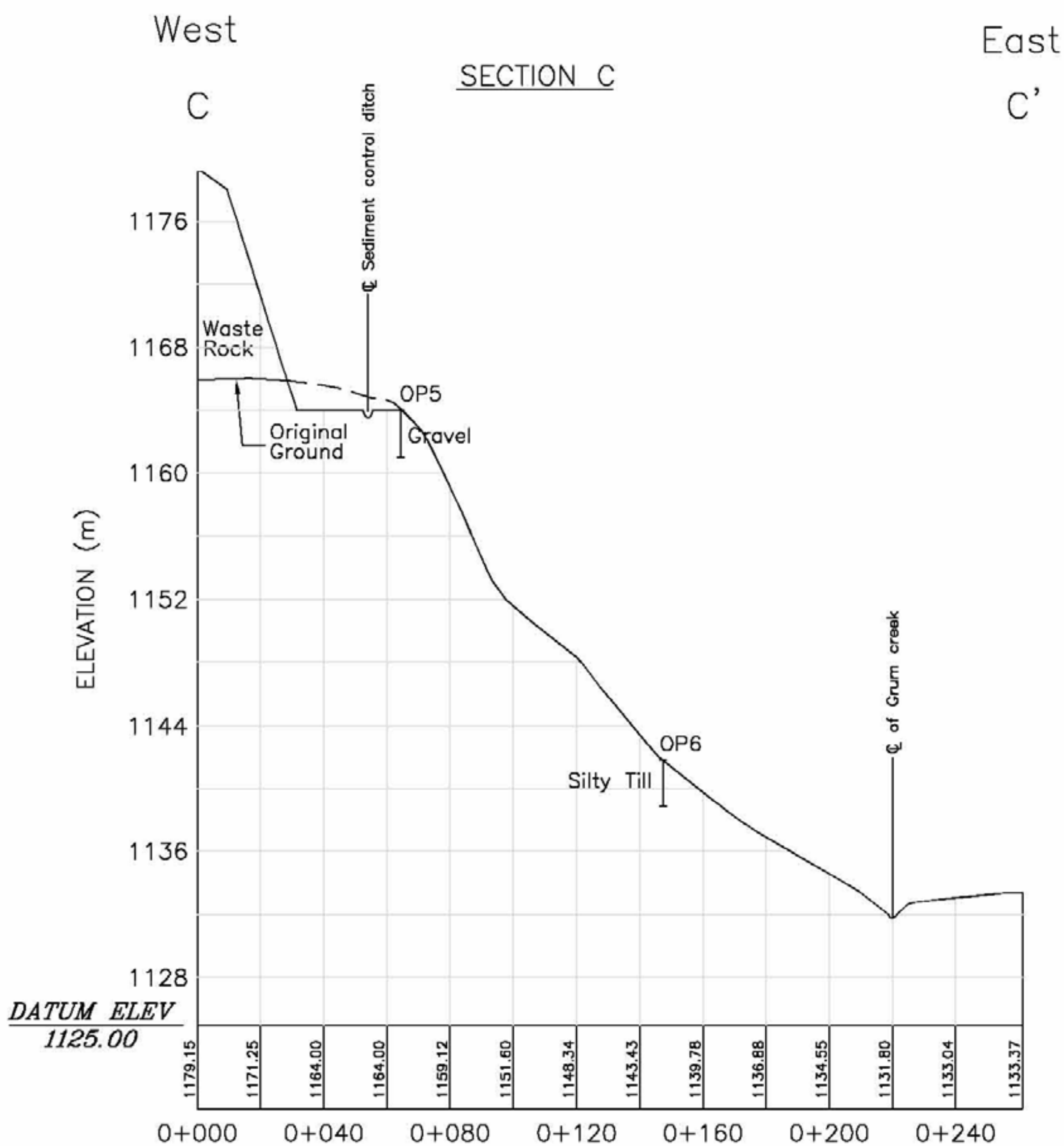
This is a lovely shot…………Title????



Cross Section A-A’



Cross Section B-B'

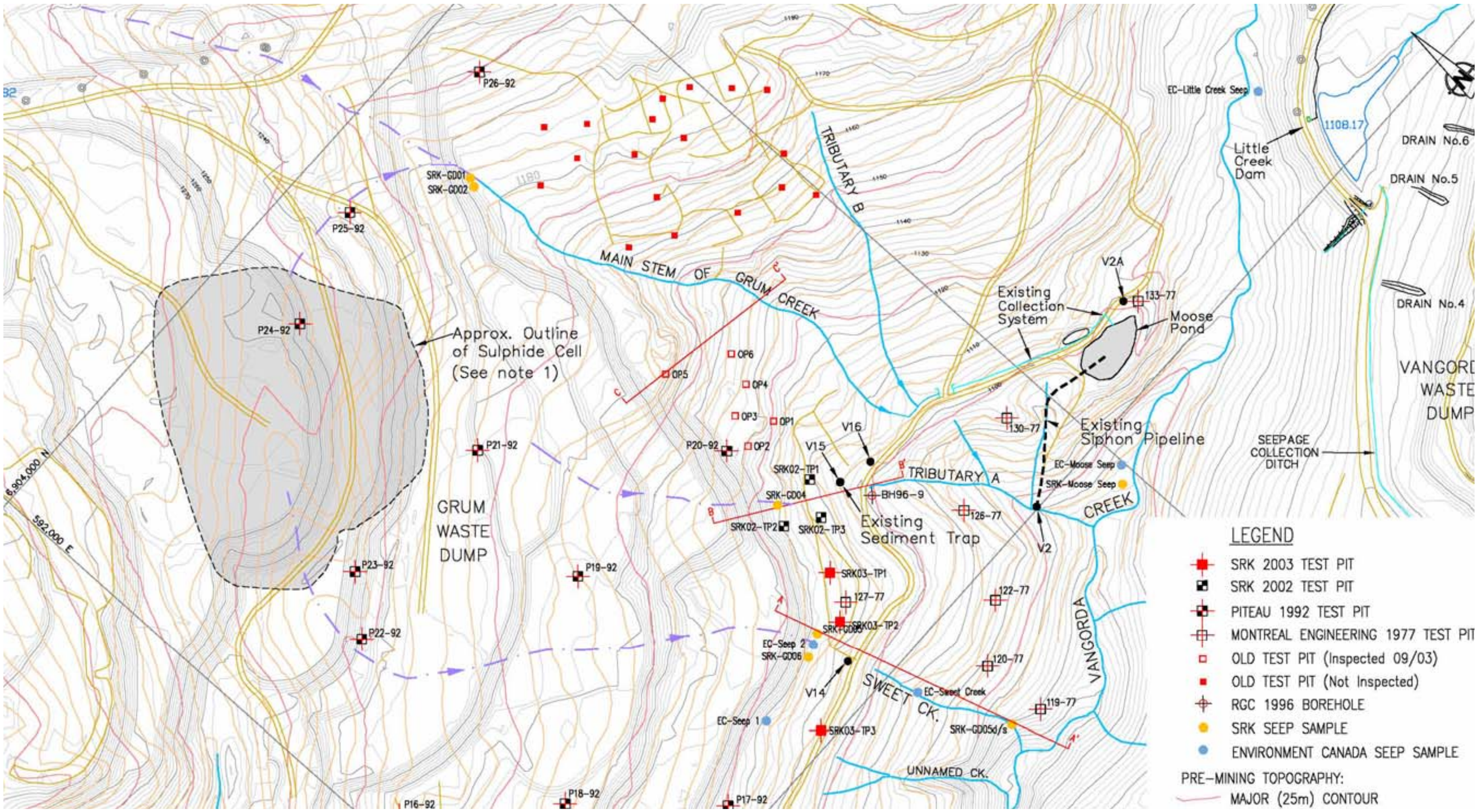


Cross Section C-C'

This is a lovely shot…………Title????

This is a lovely shot…………Title????

Test Pit Locations



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Design of a Detailed Terrestrial Effects Study Plan

Presentation slides for Feb/04 Closure Planning Workshop

Gartner Lee

Objectives for 2003

- design a study plan that would investigate effects on the terrestrial environment related to the mine
  - incorporate local knowledge in to the study design
  - work towards implementation of the study beginning in 2004
  - work towards a comprehensive report by end 2005
  - adhere to commitments in the Water Licence Renewal EA Report and Application (and Licence)

Starting Point

- **Local Knowledge / Observation**
- **Water Licence Renewal EA Report, reconnaissance level study of metal levels in vegetation**
- **YTG Wildlife Assessments**

Approach

- First pass - conceptual study layout (done)

- Meetings and gathering of input from local land users, traditional land users and government agencies (underway)

- Revised study design for implementation beginning in 2004 field season (subsequent to the above)

Approach

- Are there any short term terrestrial effects related to the care and maintenance activities that need to be addressed before the Final Closure and Reclamation Plan is ready?

- What are the effects, if any, on human users of terrestrial resources?

- What are the potential terrestrial effects, if any, that need to be addressed or monitored in the Final Closure and Reclamation Plan?

Conceptual Study Layout

- **what to study?**
  - **soil, vegetation, wildlife**
  - **selected species should be representative, available, meaningful**

Conceptual Study Layout

- where to study?
  - reference locations
  - repeatable locations, extend existing transects
  - special or unique forage/growth areas
  - special human use/gathering areas

- who to include?
  - Ross River Dena, Selkirk First Nation, local residents, outfitters, YTG

Input

• Initial meetings with Ross River Dena, Selkirk First Nation, YTG Environment, Environment Canada, YTG, Town of Faro, mine personnel

•Input from initial meetings:

- First Nations involvement in field work
- research initial mine exploration soil geochemistry
- investigate the geology and lechability of metals in soil
- include snow sampling

Input

- Input from initial meetings:
  - project links to regulatory Acts such as YESSA
  - identify community project leads
  - coordinate with other studies of contaminants in Country Foods
  - investigate dust contamination in homes?

Next Steps

• Follow up meeting in Pelly Crossing scheduled for April 2004 to collect Traditional Knowledge relevant to the study

• Follow up meeting in Ross River to be scheduled to collect Traditional Knowledge relevant to the study

• Finalize the study design

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Preliminary Derivation of Site Specific Water Quality Objectives

Presentation slides for Feb/04 Closure Planning Workshop

Gartner Lee

Objectives for 2003

- select a methodology within the CCME framework
- design a plan for collection of field information, as appropriate
- derive preliminary numerical values

Starting Point

- electronic water quality database
- extensive water sampling history
- salmonid fish species, already represented in the CCME toxicity database
- known substantive seasonal trends in hardness in the receiving waters

Project Working Group

- Type II Mines Projects Office
- Deloitte.
- Gartner Lee
- YTG, Water Resources
- Environment Canada
- (Don MacDonald, Peer Review)

Contaminants of Concern

- zinc and sulphate are the primary contaminants of concern, as these are the only contaminants discharged from the mine that :

  - Show concentrations in receiving water that exceed those in reference waters and;
  - Show concentrations in receiving waters that exceed either or both of the CCME or BC Environment Guidelines for protection of freshwater life, and
  - Have the potential to be toxic at the observed concentrations

Contaminants of Concern

- other metals were reviewed and copper is considered to be an additional contaminant of concern as follows:

    - Copper is either below CCME Guidelines or background reference concentrations in receiving waters on site but is elevated above CCME and reference levels in the site water discharges. It must therefore also be considered as a Contaminant of Concern

Strategy

- two Receiving Water Protection Strategies are in use in Canada

- the *Use Protection Strategy* is recommended for Faro over the *Antidegradation Stategy*

Most Sensitive Water Use

- protection of Fresh Water Aquatic Life was determined to be the most protective water use for zinc, copper and sulphate

Rationale for non-generic objectives

- hardness and alkalinity of the receiving waters are variable, thus modifying the toxicity of zinc, copper and sulphate
    - natural seasonal variability
    - lime treated discharge water
    - BC Hardness calculation does not allow for consideration of variable pH, alkalinity and calcium
- local fish species not specifically represented in the toxicity database, although other cold-water salmonid species and Chinook salmon are represented

Derivation Methods

- 4 methods available in CCME guidelines:
  - Background Concentration
  - Recalculation
  - Water Effect Ratio
  - Resident Species

- Water Effects Ratio is recommended
  - determine the difference in toxicity between standard test water and site water and modify the generic objectives accordingly

Gartner Lee Limited

Test Procedures

- test water from Rose Creek and Vangorda Creek collected in both spring and late summer

- also test lime treated discharge water

- conduct toxicity tests for Fathead Minnow, water flea and algae (practical combination of acute and chronic indicators)

- test toxicity for zinc, copper and sulphate

Next Steps

- conduct rigorous quality control checks in the electronic water quality database (underway)
- calculate a quick-reference zinc guideline using the BC Hardness method
- re-assess other metals for the possible applicability of the Background Concentration Procedure
- proceed with toxicity testing for zinc, copper and sulphate according to the WER Procedure

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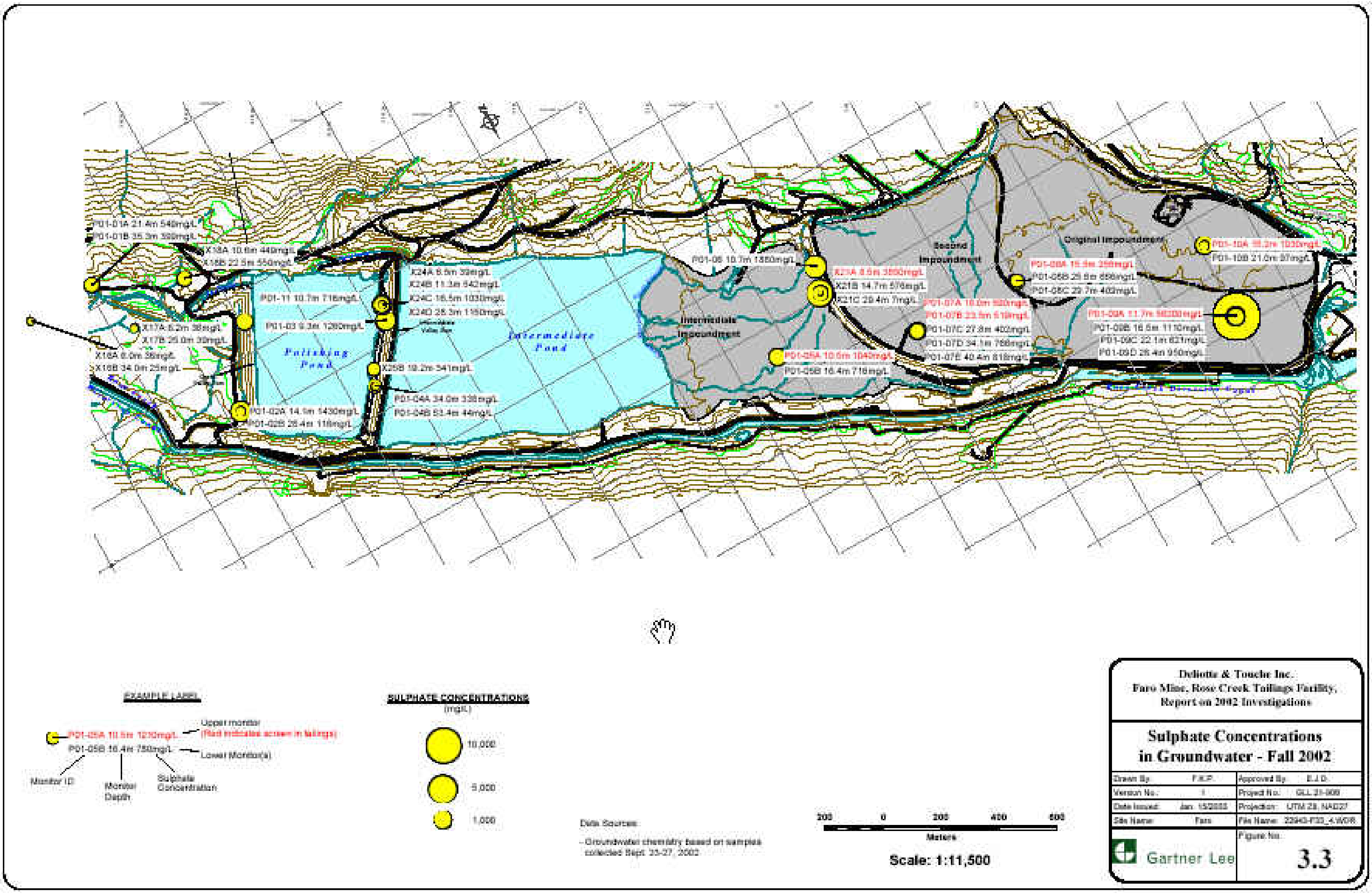
2003 Groundwater Studies

Rose Creek Tailings Facility

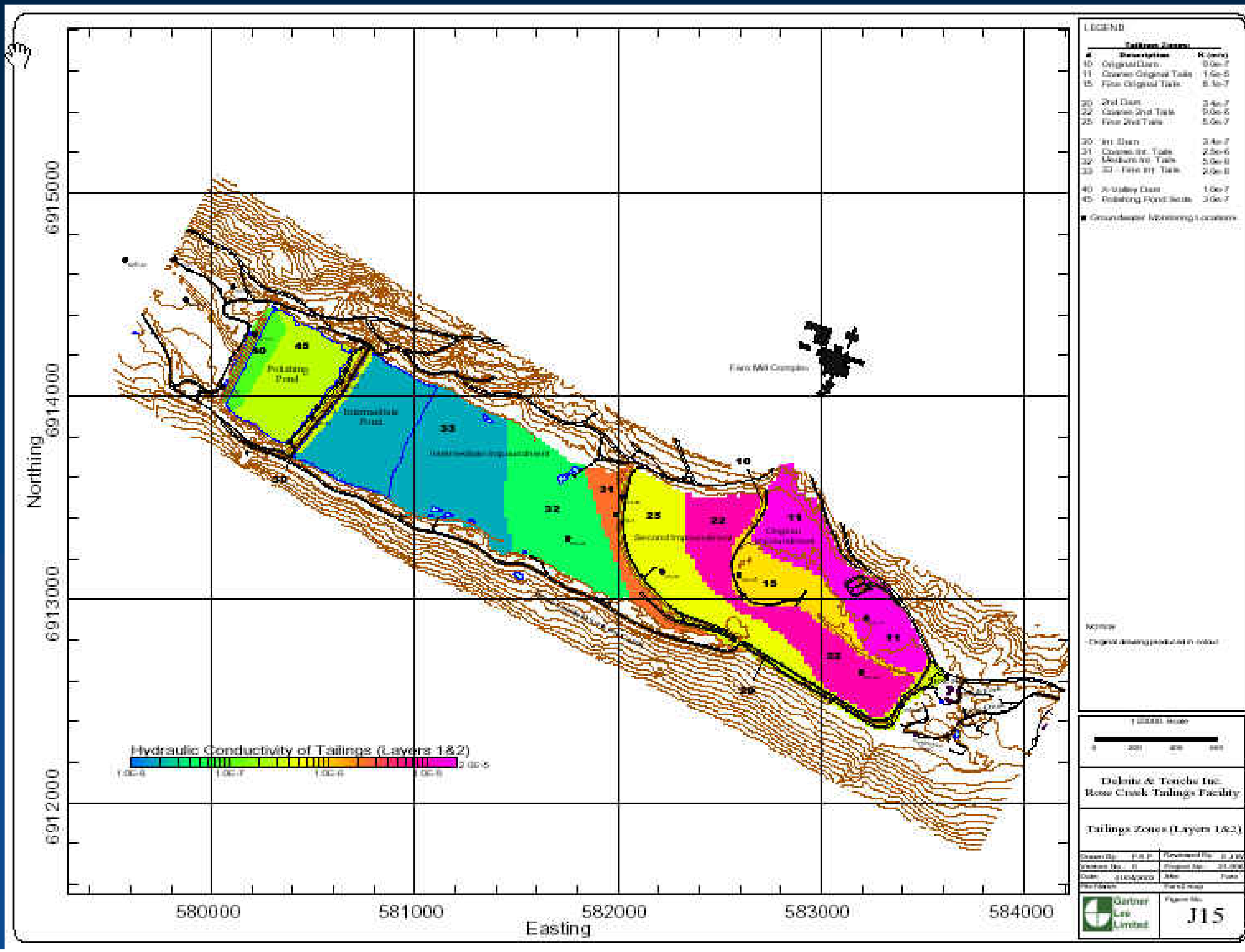
Presentation slides for Feb/04 Closure Planning Workshop

Gartner Lee

Fall 2002 Sulphate Concentrations



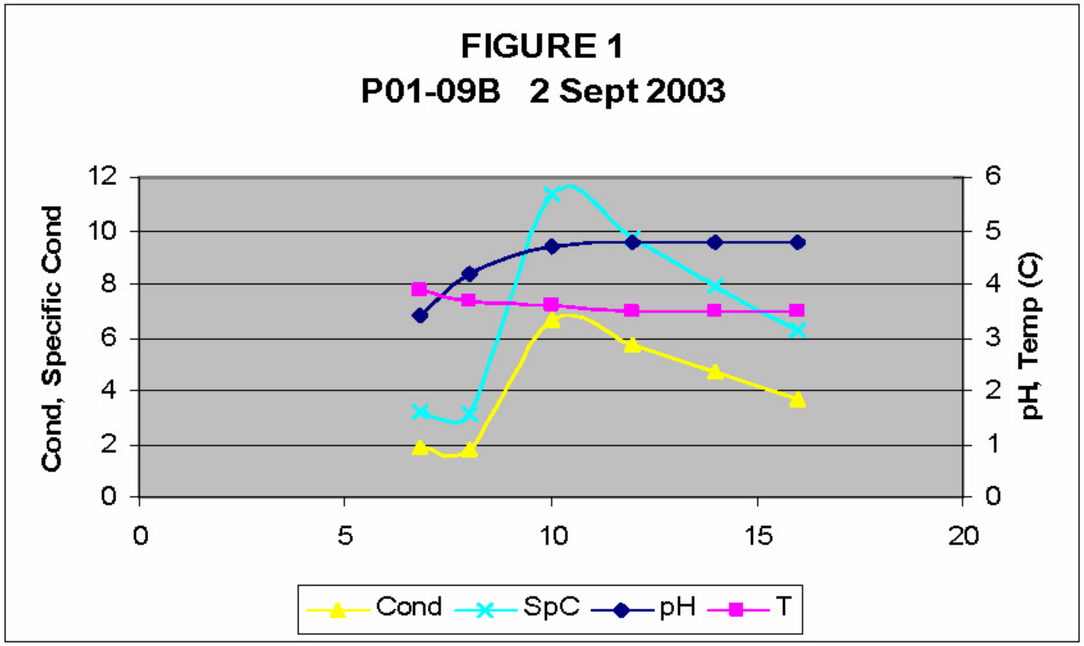
Inferred Coarser versus Finer Areas

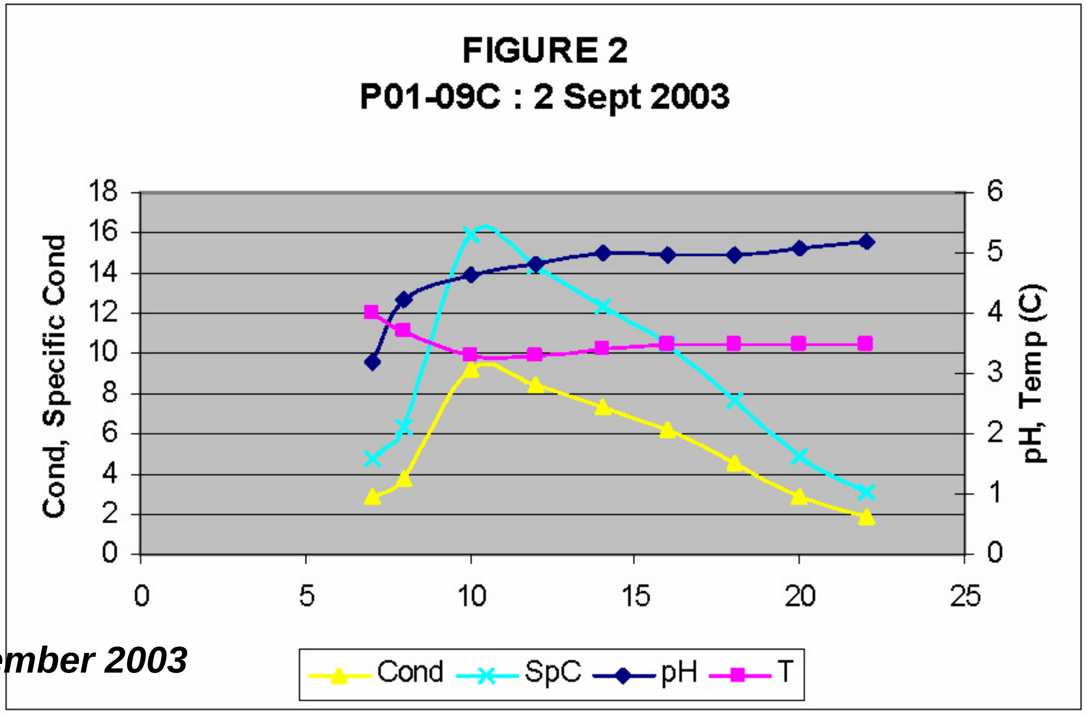


P01-09 Questions

- possible leakage of tailings porewater into monitoring wells

- possible failure of a PVC screw joint; crack in the PVC pipe





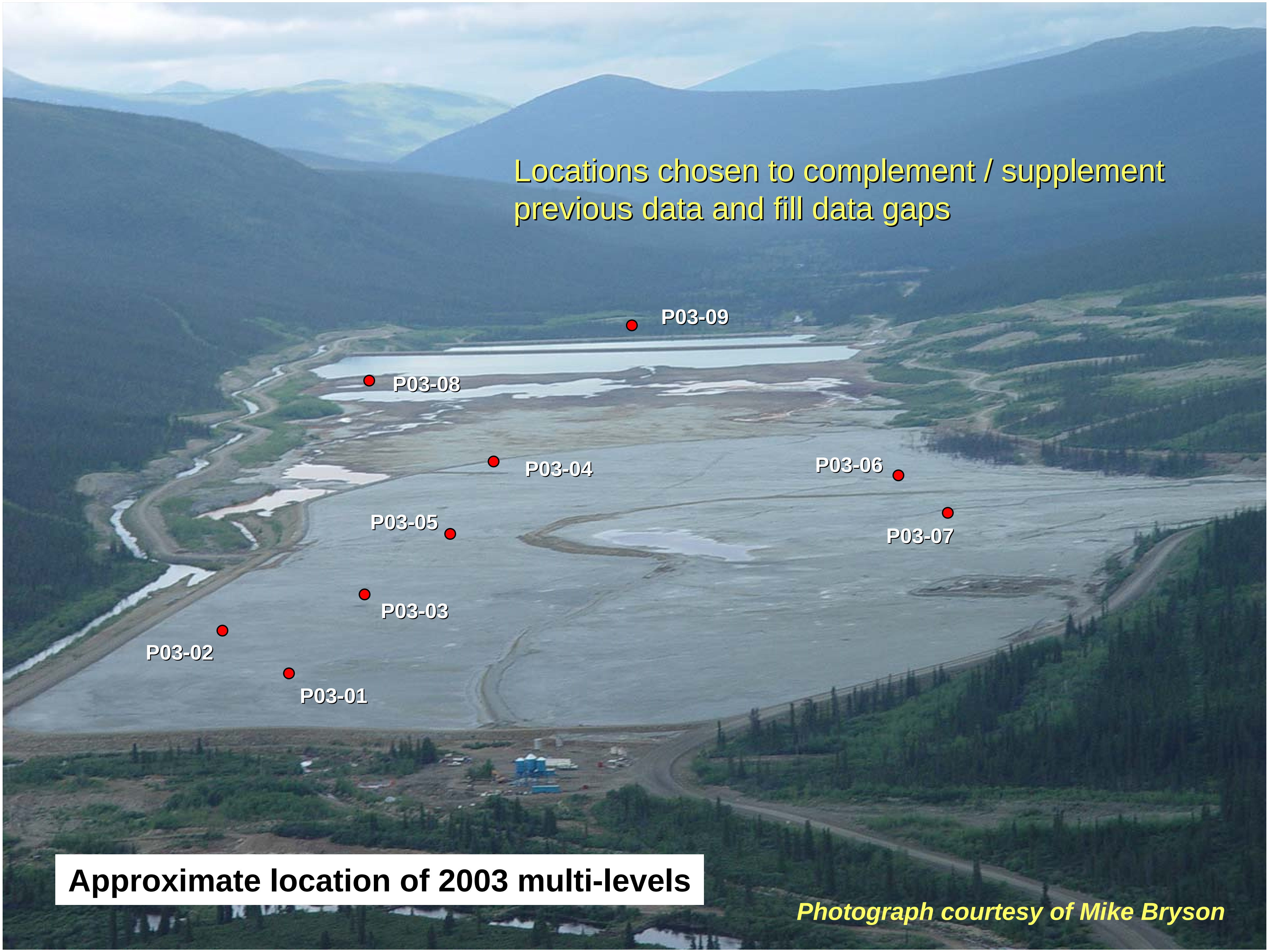
Graphs from Environment Canada, November 2003

Objectives for 2003

- detailed stratigraphy through the aquifer
- additional groundwater monitoring wells

(focus on areas of "coarser" tailings)

- refine hydrogeology model
- additional geochemical analyses (secondary)
- *"increased confidence"*


Locations chosen to complement / supplement previous data and fill data gaps
P03-09
P03-08
P03-04
P03-06
P03-05
P03-07
P03-03
P03-02
P03-01
Approximate location of 2003 multi-levels
Photograph courtesy of Mike Bryson

Sonic Drilling

• minimal disturbance of sediments

•detailed stratigraphic log

• Efficient for field geologist

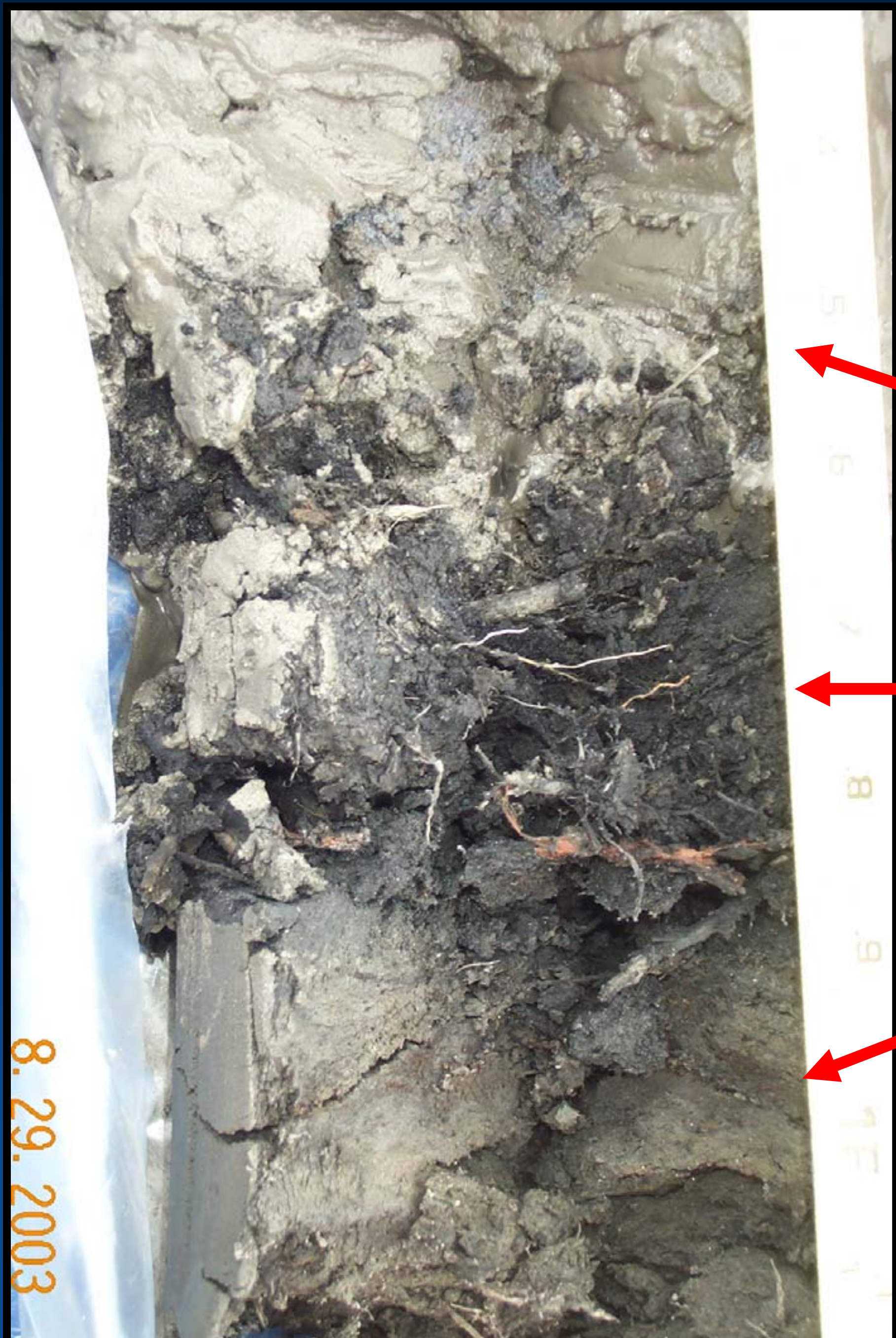
• Quick coring rate

(>150ft / day with well construction and installation)

Soil Cores

Oxidation Zone

Interface Characteristics

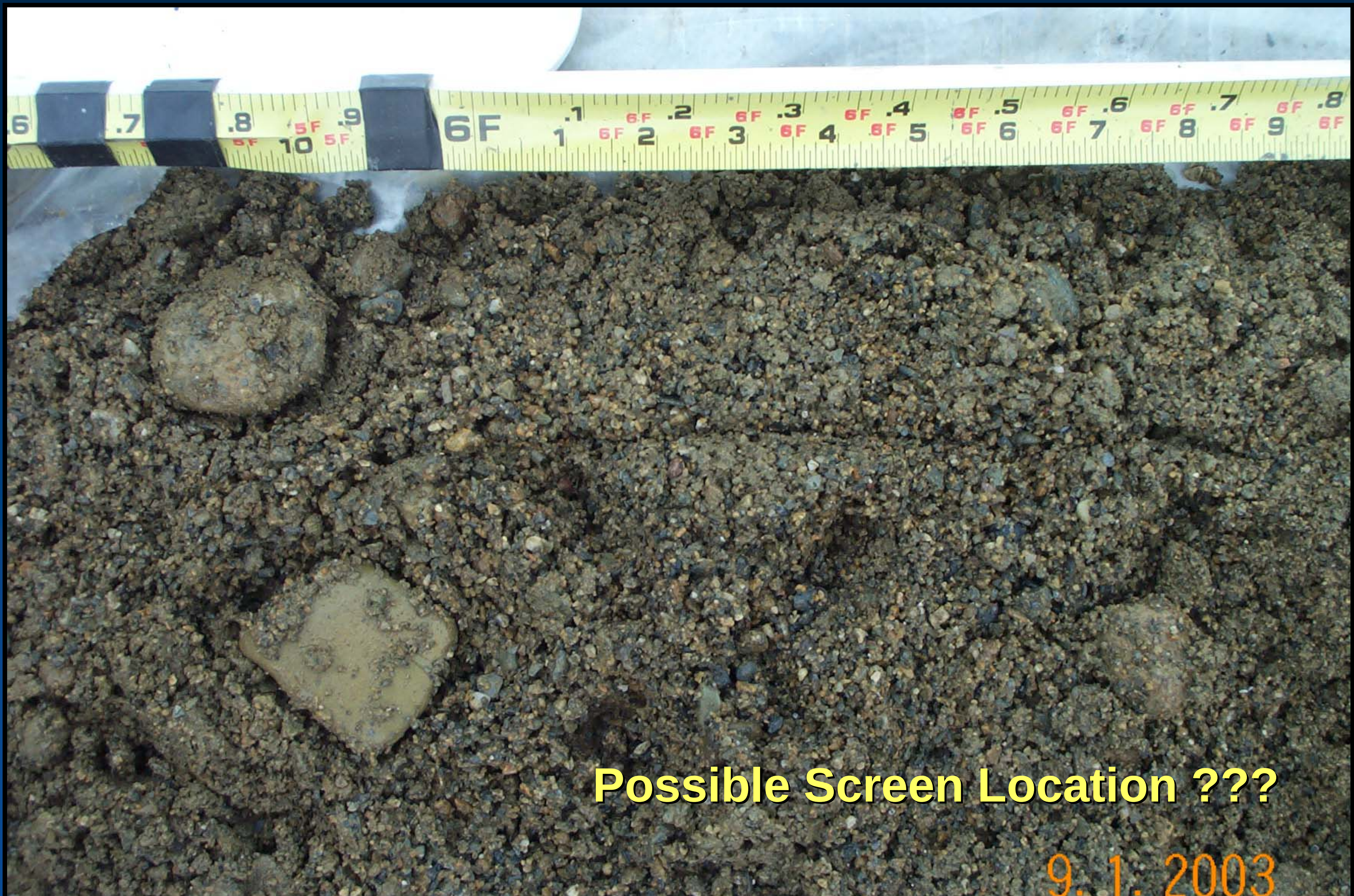


Tailings

Organics

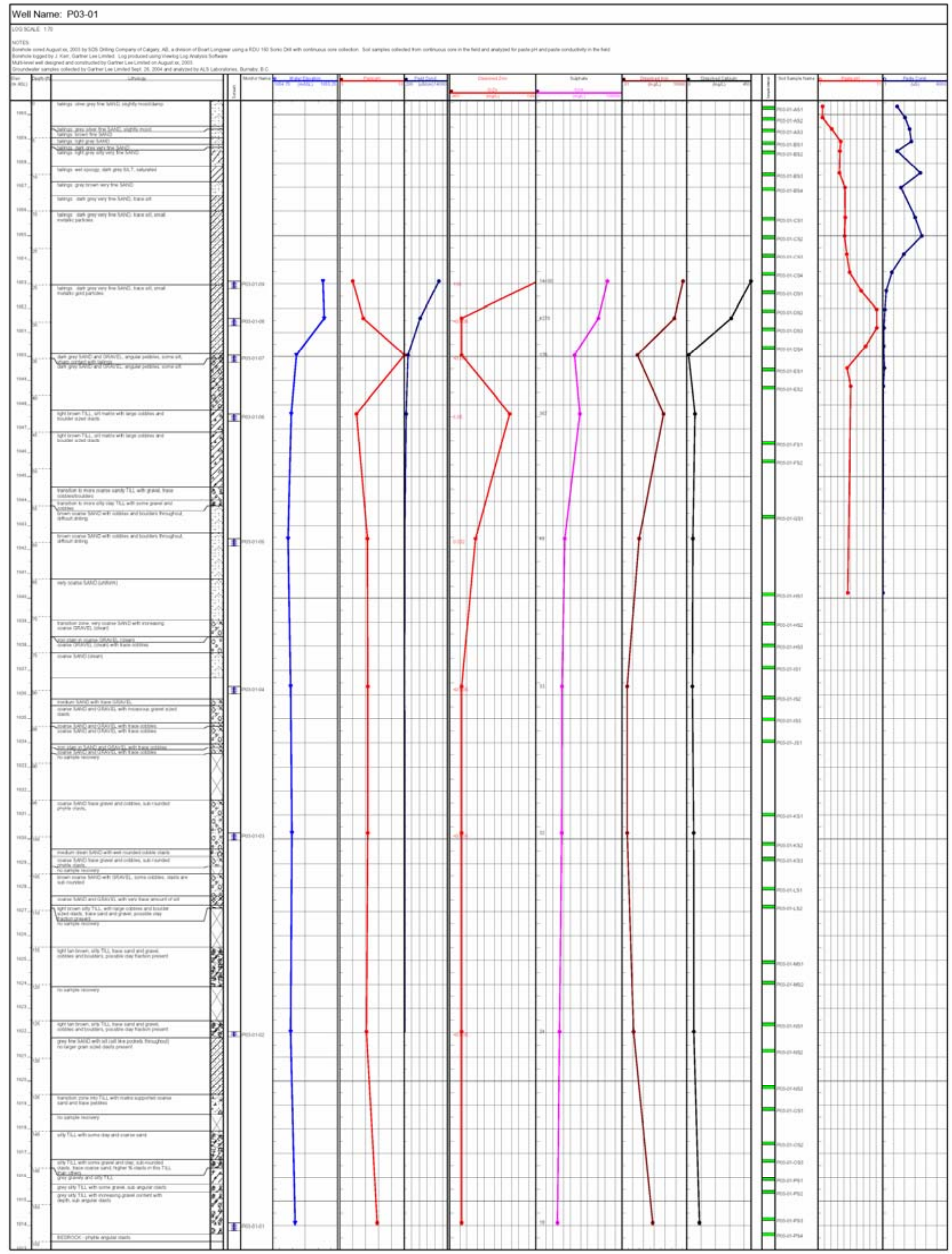
Native Sediments

Sand and Gravel



Depth of Bedrock

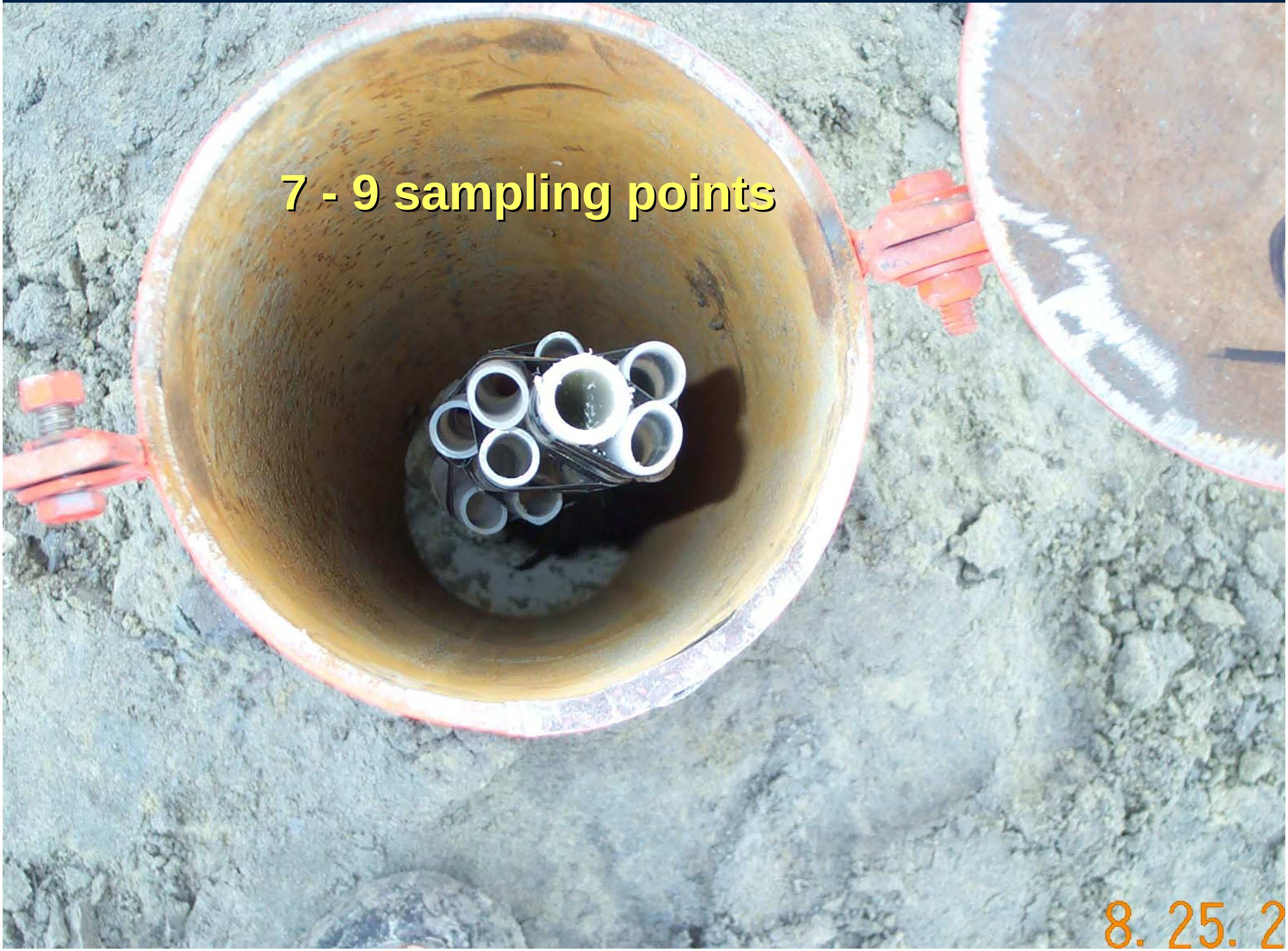
Detailed Stratigraphic Logs



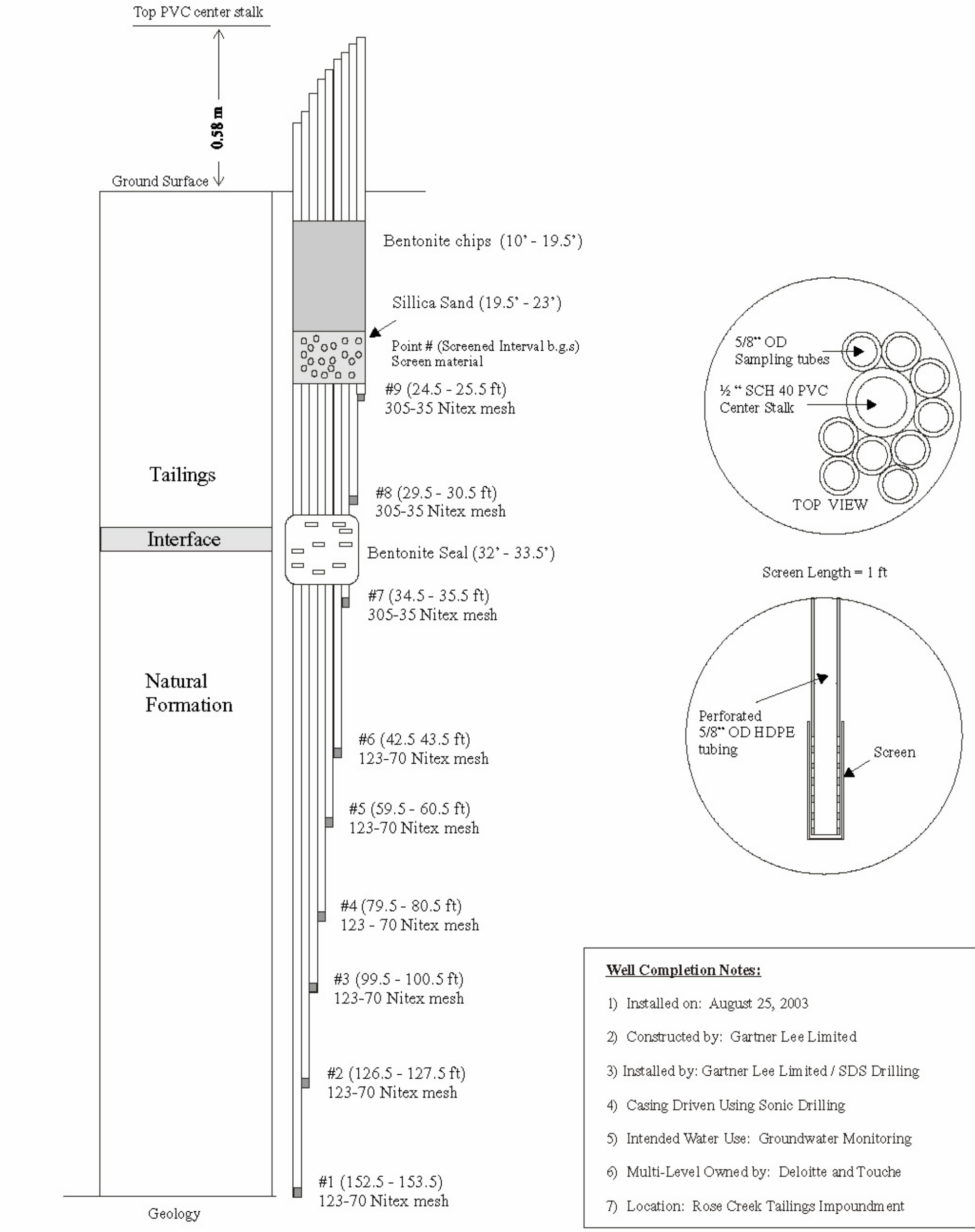

screen
packer
8 25 200

Multi-Level Well Installation

7 - 9 sampling points



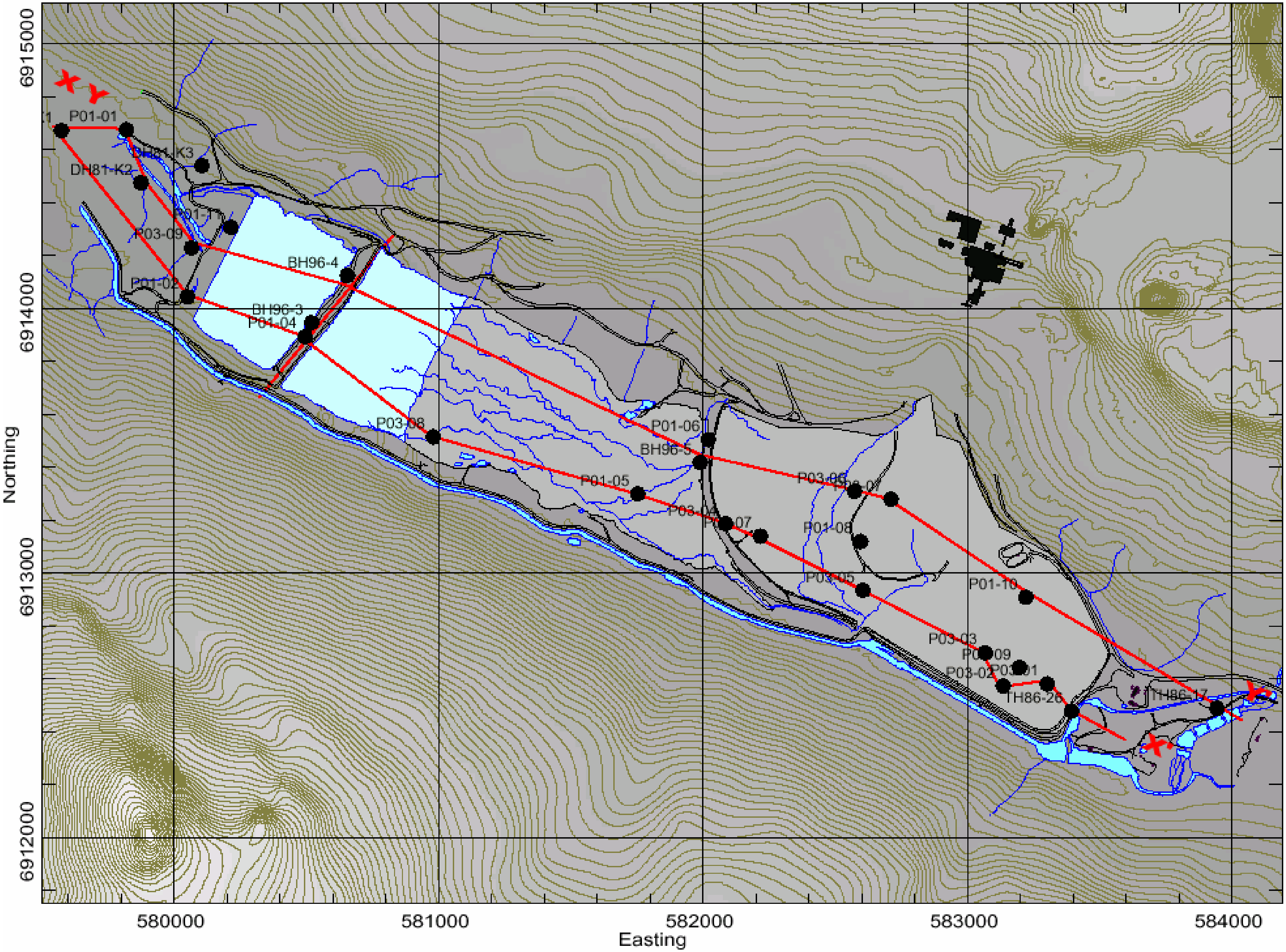
Well Completion Details



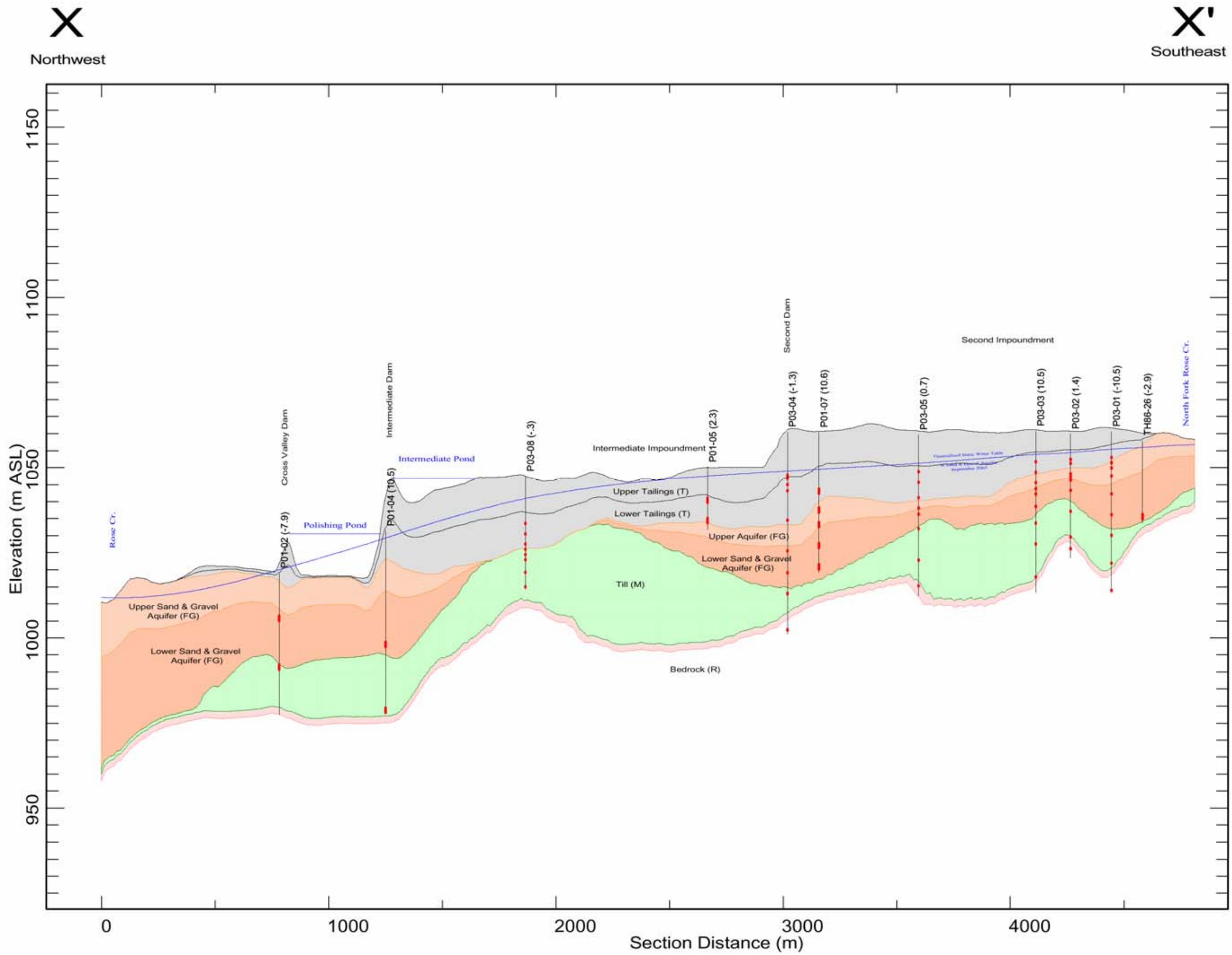
Well Completion Notes:

1) Installed on: August 25, 2003
2) Constructed by: Gartner Lee Limited
3) Installed by: Gartner Lee Limited / SDS Drilling
4) Casing Driven Using Sonic Drilling
5) Intended Water Use: Groundwater Monitoring
6) Multi-Level Owned by: Deloitte and Touche
7) Location: Rose Creek Tailings Impoundment

Not to Scale Drawn by: MG Gartner Lee	DRAFT **PO3-01 Multi-Level Completion Diagram** project # 23-576 Location: Faro Mine, Yukon Territory	FIGURE 1

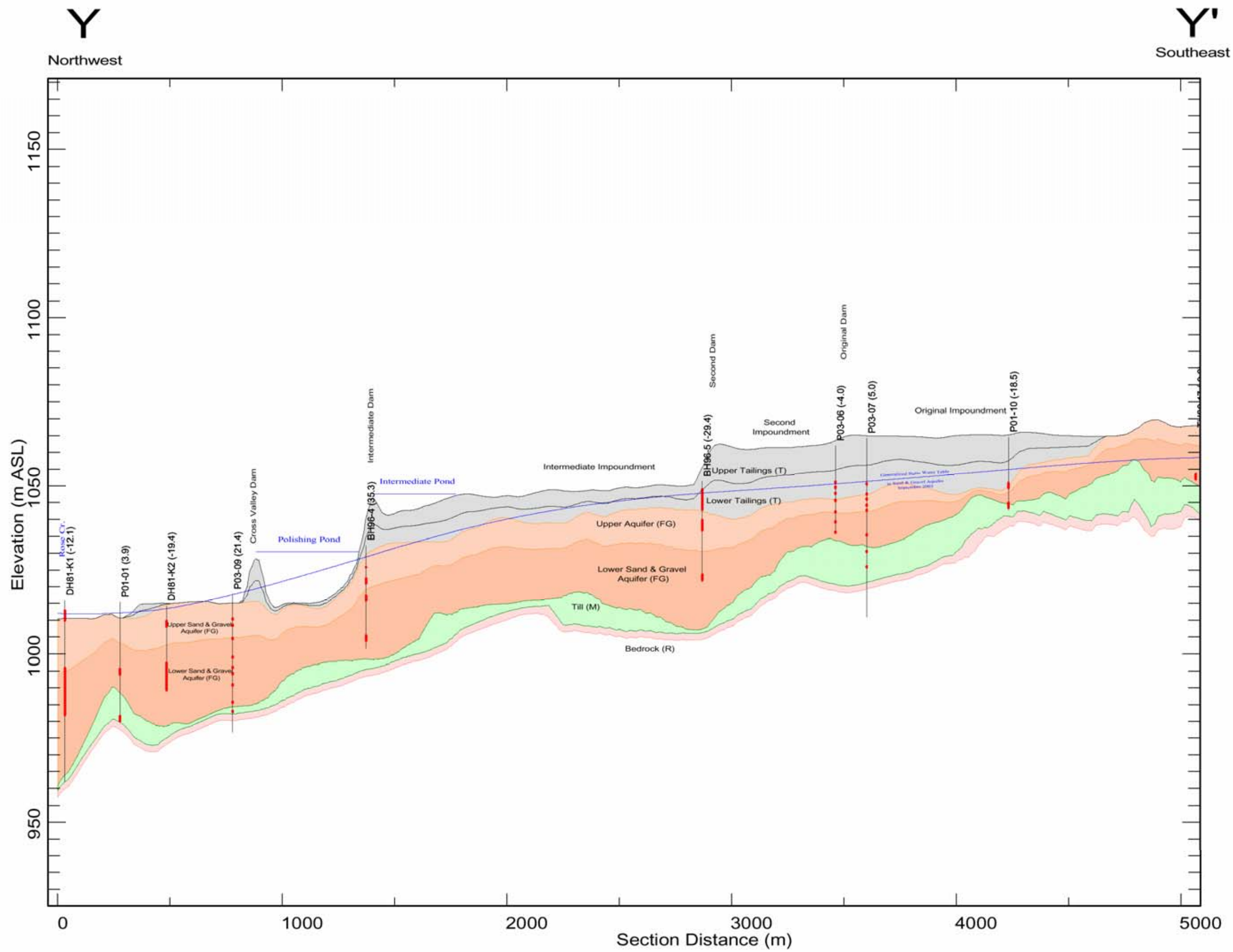


P01-01
DH81-K3
DH81-K2
P03-09
P01-02
BH96-4
BH96-3
P01-04
P03-08
P01-06
BH96-5
P01-05
P03-04
P03-06
P01-08
P03-05
P01-10
P03-03
P03-02
TH86-26
TH86-17
6915000
6914000
6913000
6912000
580000
581000
582000
583000
584000
Northing
Easting

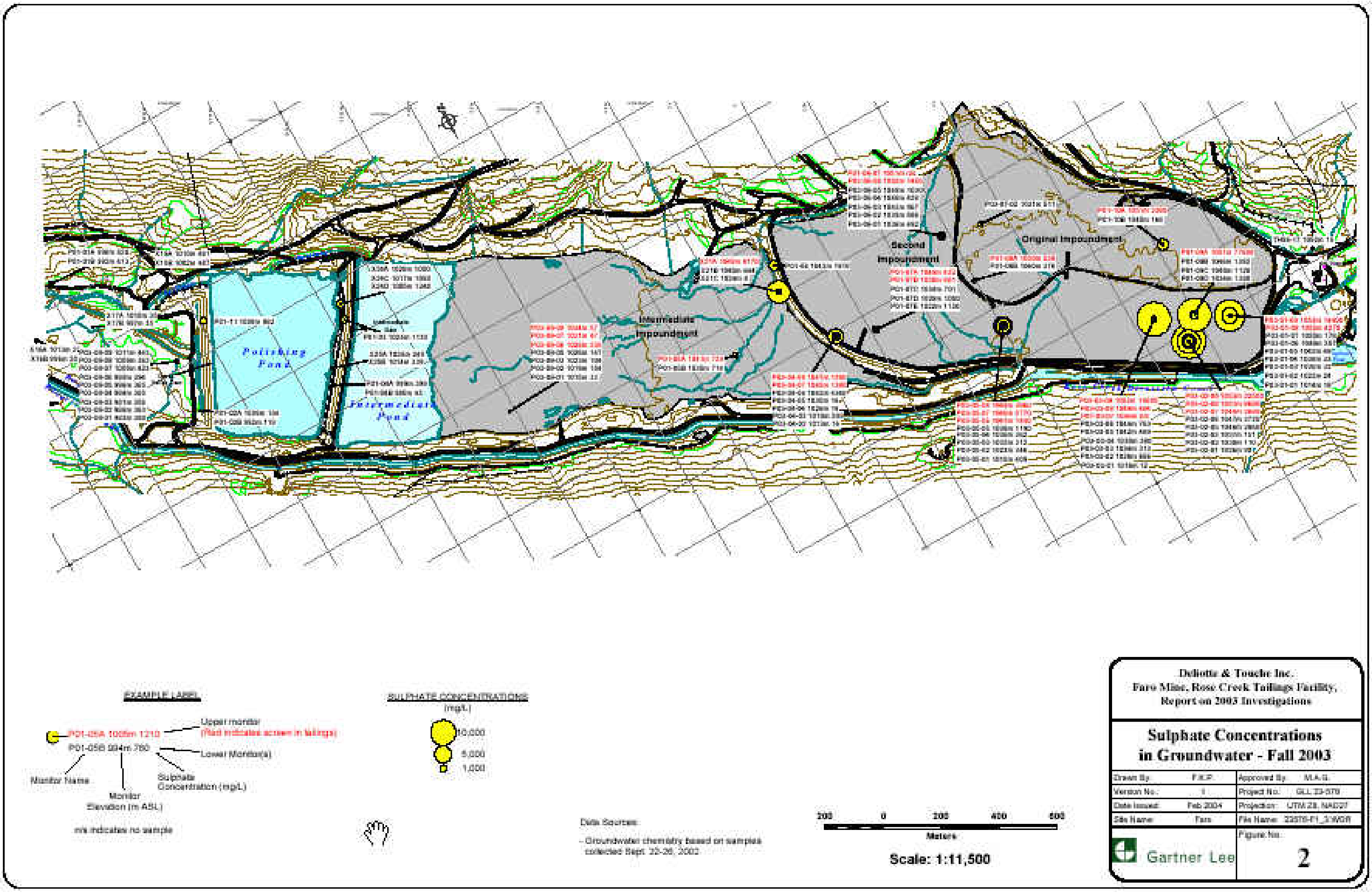


X
Northwest
X'
Southeast
Elevation (m ASL)
1150
1100
1050
1000
950
0
1000
2000
3000
4000
Section Distance (m)
Rose Cr.
Cross Valley Dam
Intermediate Dam
Intermediate Pond
Polishing Pond
P01-02 (-7.9)
P01-04 (10.5)
P03-08 (-3)
Intermediate Impoundment
P01-05 (2.3)
Second Dam
P03-04 (-1.3)
P01-07 (10.6)
P03-05 (0.7)
Second Impoundment
P03-03 (10.5)
P03-02 (1.4)
P03-01 (-10.5)
TH86-26 (-2.9)
North Fork Rose Cr.
Upper Tailings (T)
Lower Tailings (T)
Upper Aquifer (FG)
Lower Sand & Gravel
Aquifer (FG)
Till (M)
Upper Sand & Gravel
Aquifer (FG)
Lower Sand & Gravel
Aquifer (FG)
Bedrock (R)

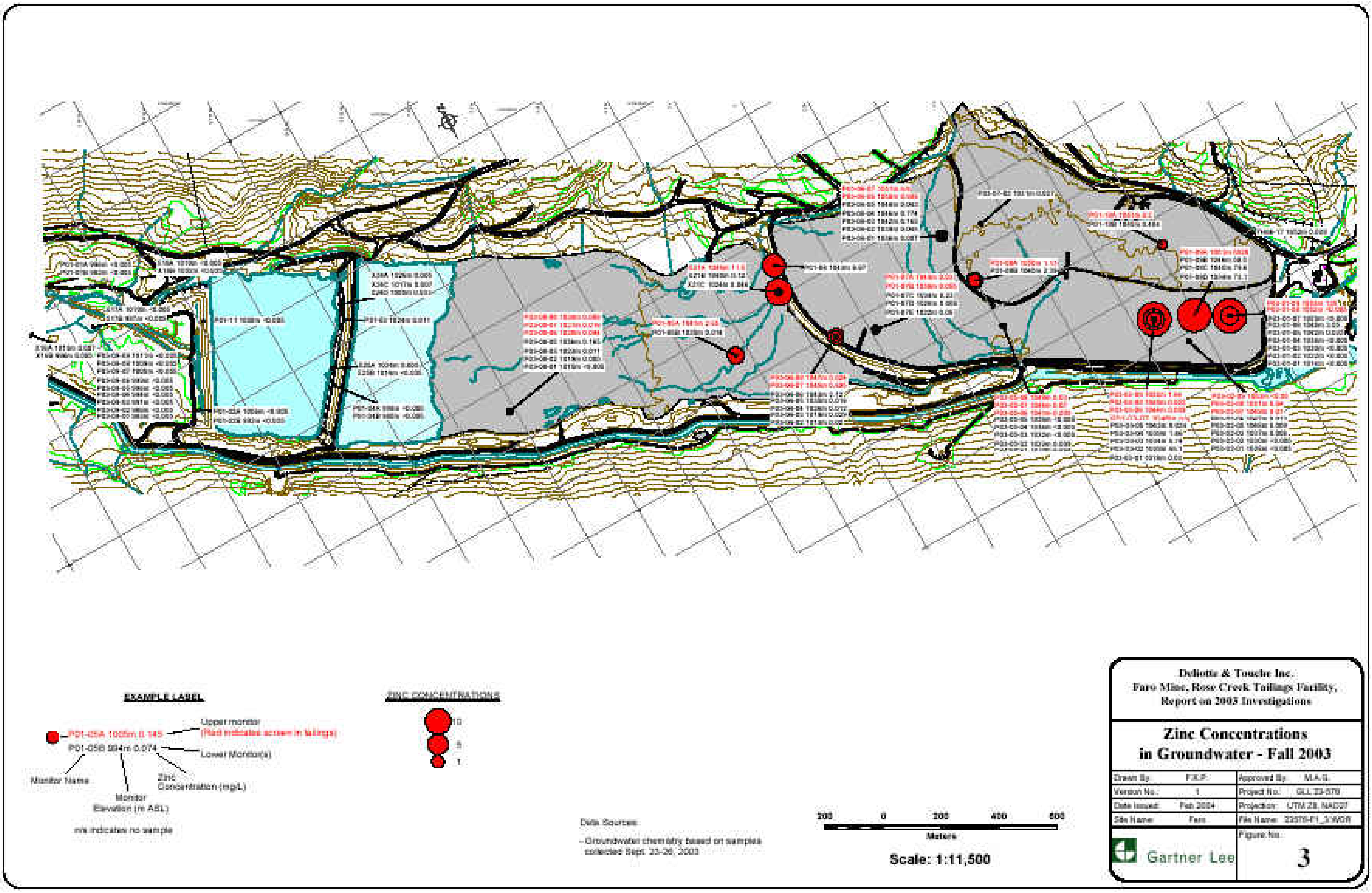
ted


Y
Northwest
Y'
Southeast
Elevation (m ASL)
1150
1100
1050
1000
950
0
1000
2000
3000
4000
5000
Section Distance (m)
Rose Cr.
DH81-K1 (-12.1)
P01-01 (3.9)
DH81-K2 (-19.4)
P03-09 (21.4)
Cross Valley Dam
Polishing Pond
BH96-4 (35.3)
Intermediate Dam
Intermediate Pond
Intermediate Impoundment
Second Dam
BH96-5 (-29.4)
Second Impoundment
Original Dam
P03-06 (-4.0)
P03-07 (5.0)
Original Impoundment
P01-10 (-18.5)
Upper Tailings (T)
Lower Tailings (T)
Upper Aquifer (FG)
Lower Sand & Gravel Aquifer (FG)
Upper Sand & Gravel Aquifer (FG)
Lower Sand & Gravel Aquifer (FG)
Till (M)
Bedrock (R)

Fall 2003 Sulphate Concentrations



Fall 2003 Zinc Concentrations



Geochemical Testing

- 80 shake flask tests representing tailings from each drill location (results just returned)
- 5 grain size test of aquifer soils (results just returned)
- 2 metal sorption tests (underway)
    - site specific water sample
    - oxygen depleted procedures
    - constant mix ratio / varied solution strengths from 10% to 100%

Observations 1

- SO_4 and Zn are migrating from the tailings into the native soils underlying the tailings impoundments
- The migration of SO_4 has proceeded to downgradient of the Cross Valley Dam with diminishing concentrations in the downgradient direction and with SO_4 distributed to depth in the native soils
- The migration of Zn within the native soils at concentrations greater than 0.5 mg/L (arbitrary benchmark) appears to be restricted to approximately upgradient of the Second Impoundment Dam

Observations 2

• The initial results from the three 2003 wells around P01-09 generally confirm the previous indications that this area contains some of the highest contaminant concentrations in tailings but do not clearly resolve the "P01-09 questions"

• The initial results from the 2003 wells display the generally anticipated trend of decreasing concentrations with depth at many, but not all, locations.

• *" increased confidence"*

Next Steps

- Complete metal sorption tests
- Conduct “packer tests” on P03-09 wells
- Assess the geochemical database to:
  - verify estimates of total and soluble metal loads
  - refine estimates for rates of contaminant migration
  - assess the influence of metal sorption onto aquifer soil
- Continue spring & fall groundwater quality monitoring

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Rose Creek Tailings Facility

Groundwater Interception

Presentation slides for Feb/04 Closure Planning Workshop

Gartner Lee

Premise

• some portion of groundwater flow in the Rose Creek valley aquifer requires interception for treatment

Photograph courtesy of Mike Bryson

Approach

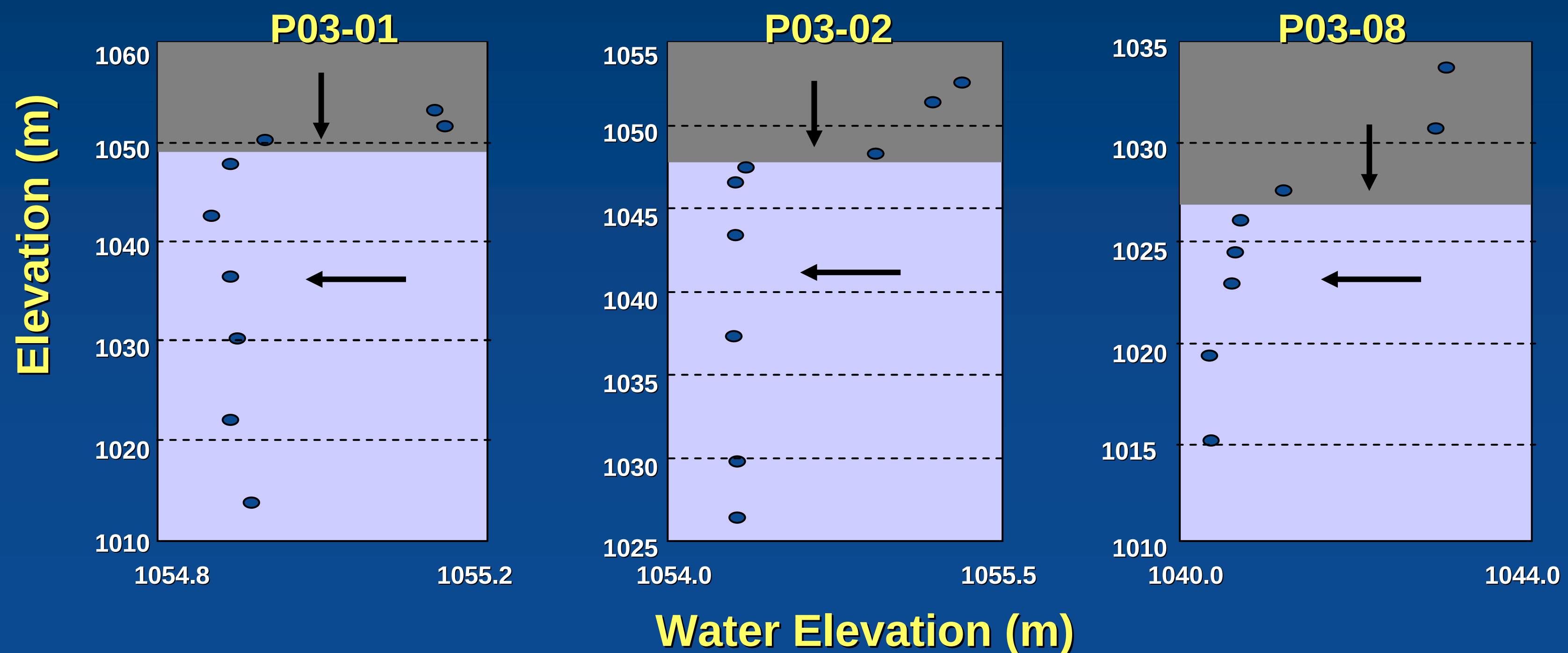
• refine the hydrogeological model and use it to simulate pumping scenarios for comparative evaluation

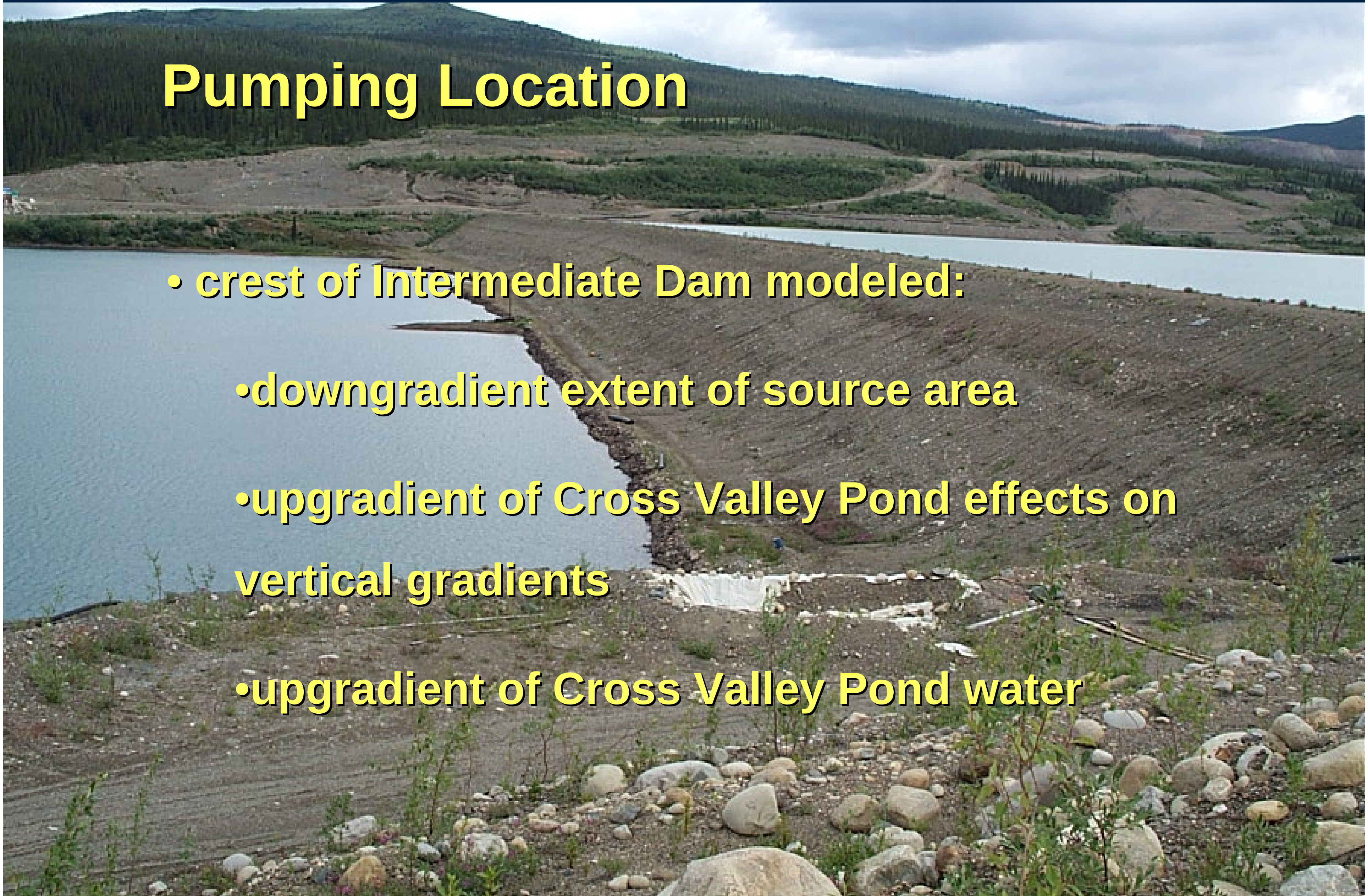
Model Refinement

• focussed on new information collection and updated calibration in the Cross Valley Pond area where groundwater discharges to surface

Model Refinement

• 2003 multilevel wells indicate downward gradients through the tailings and very low gradients in the aquifer (suggesting that groundwater capture can focus on the upper aquifer)





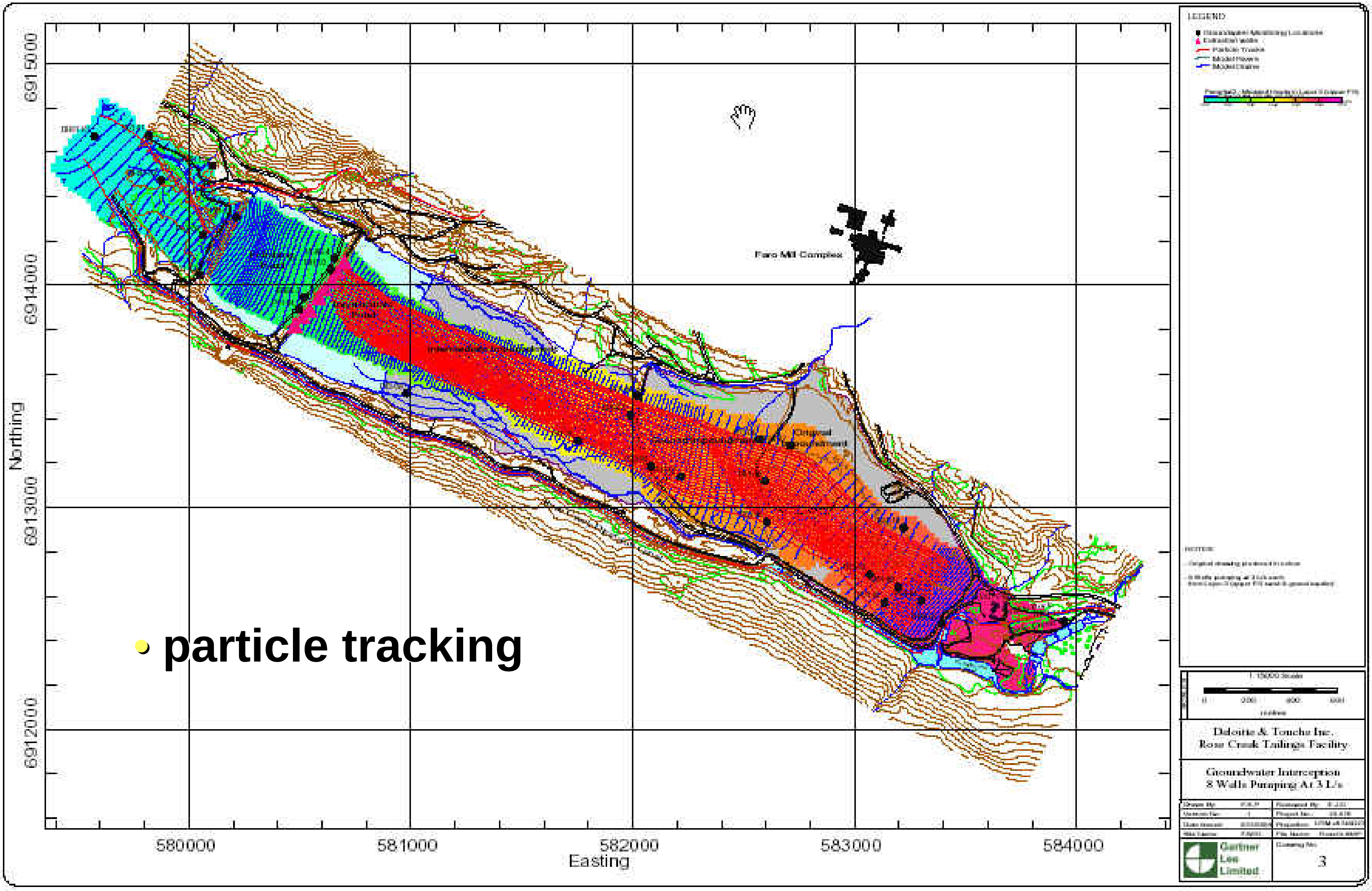
Pumping Location

- crest of Intermediate Dam modeled:
  - downgradient extent of source area
  - upgradient of Cross Valley Pond effects on vertical gradients
  - upgradient of Cross Valley Pond water

Pumping Scenarios

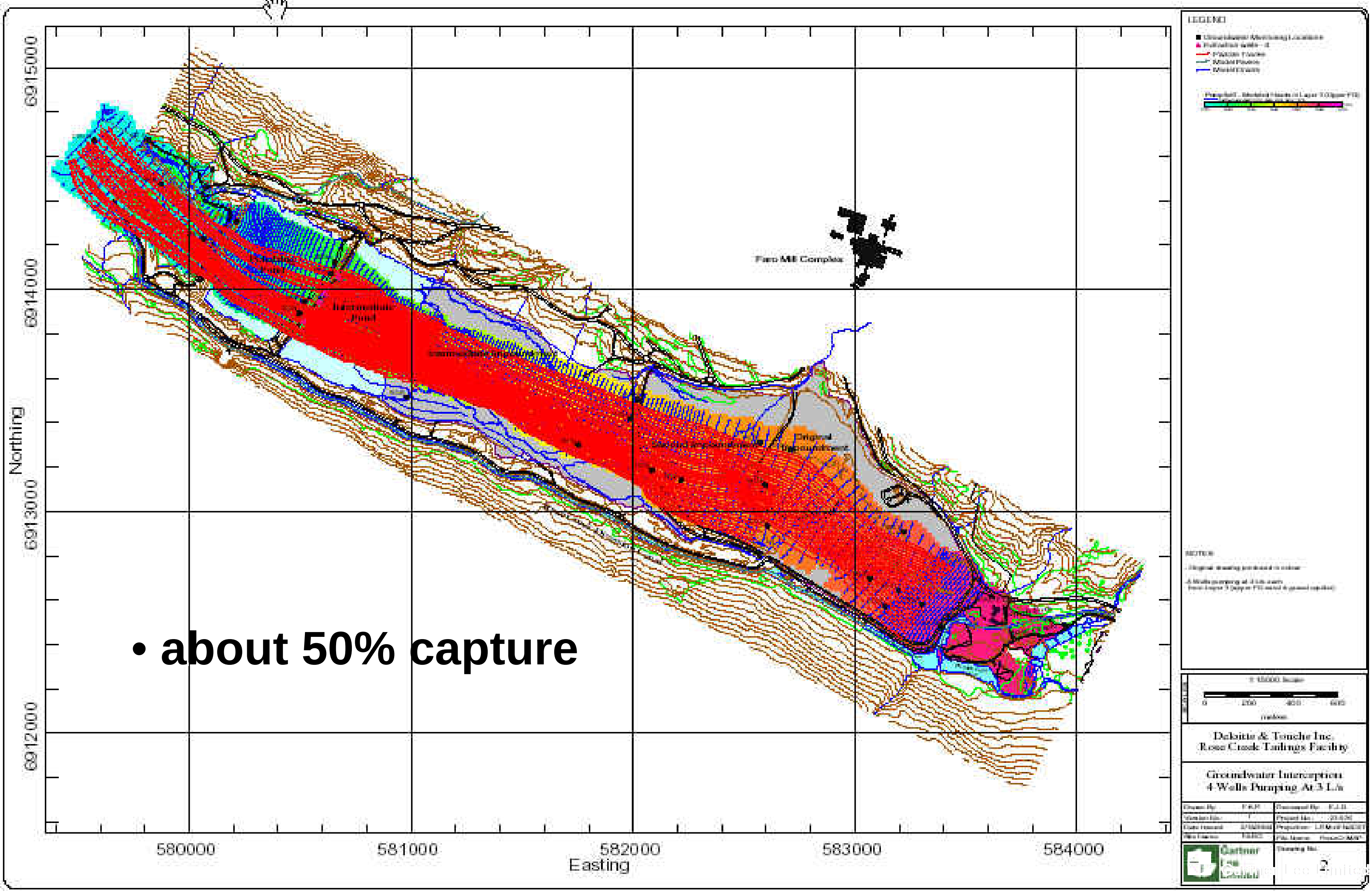
- 8 scenarios modeled:
  - vary the number of pumping wells (4 and 8)
  - vary the pumping rate (1.5 to 5 Lps per well)
  - vary the depth of well intake (upper 1/3 or lower 1/3 of the aquifer)

Pumping Capture Rate



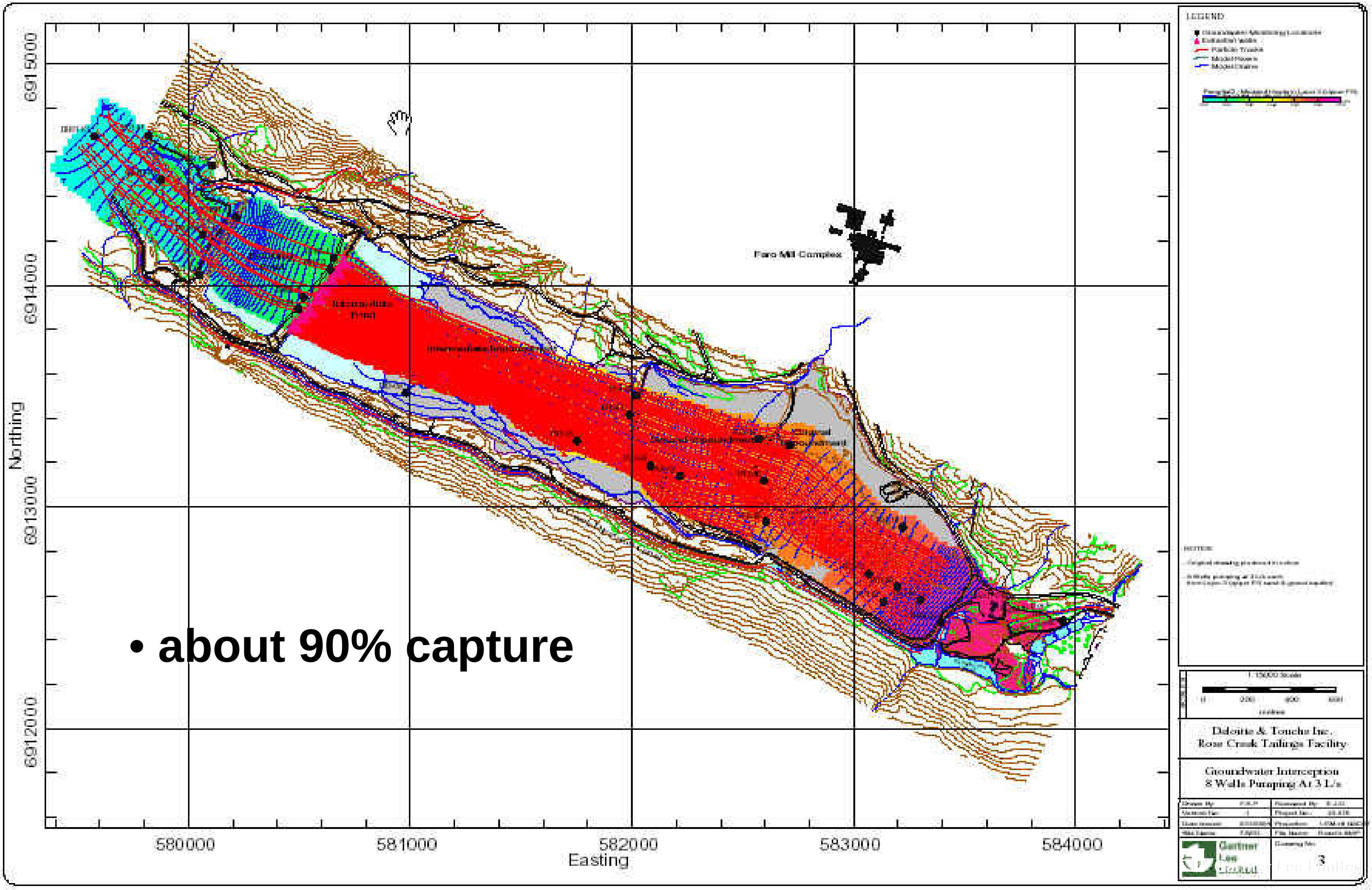
- particle tracking

4 Wells at 3 Lps Each



- about 50% capture

8 Wells at 3 Lps Each



• about 90% capture

Observations

• particle capture efficiency increased with a greater number of wells at a relatively low pumping rate as opposed to fewer wells at a higher pumping rate

• particle capture efficiency is increased for wells installed in the upper aquifer as opposed to deeper

Water Treatment

- pump to the mill water treatment system
    - requires pipeline and booster pumps
- treat in the Cross Valley Pond (Down Valley treatment system)
- consideration for 365 days/year pumping versus 6 months
    - does 6 months pumping provide environmental protection?
    - 365 days pumping could utilize storage in the Intermediate pond or the Faro Main pit?

Conceptual Costs

- install 4 wells: about $600K; 8 wells: about $700K
- install booster pump and pipeline to mill: about $1.1M
- install 3-phase power to Down Valley: about $??M
- treatment in Down Valley: about $0.351 @ 750,000 m^3 = $265K/yr
- treatment in mill: about $0.161 @ 750,000 m^3 = $120K/yr

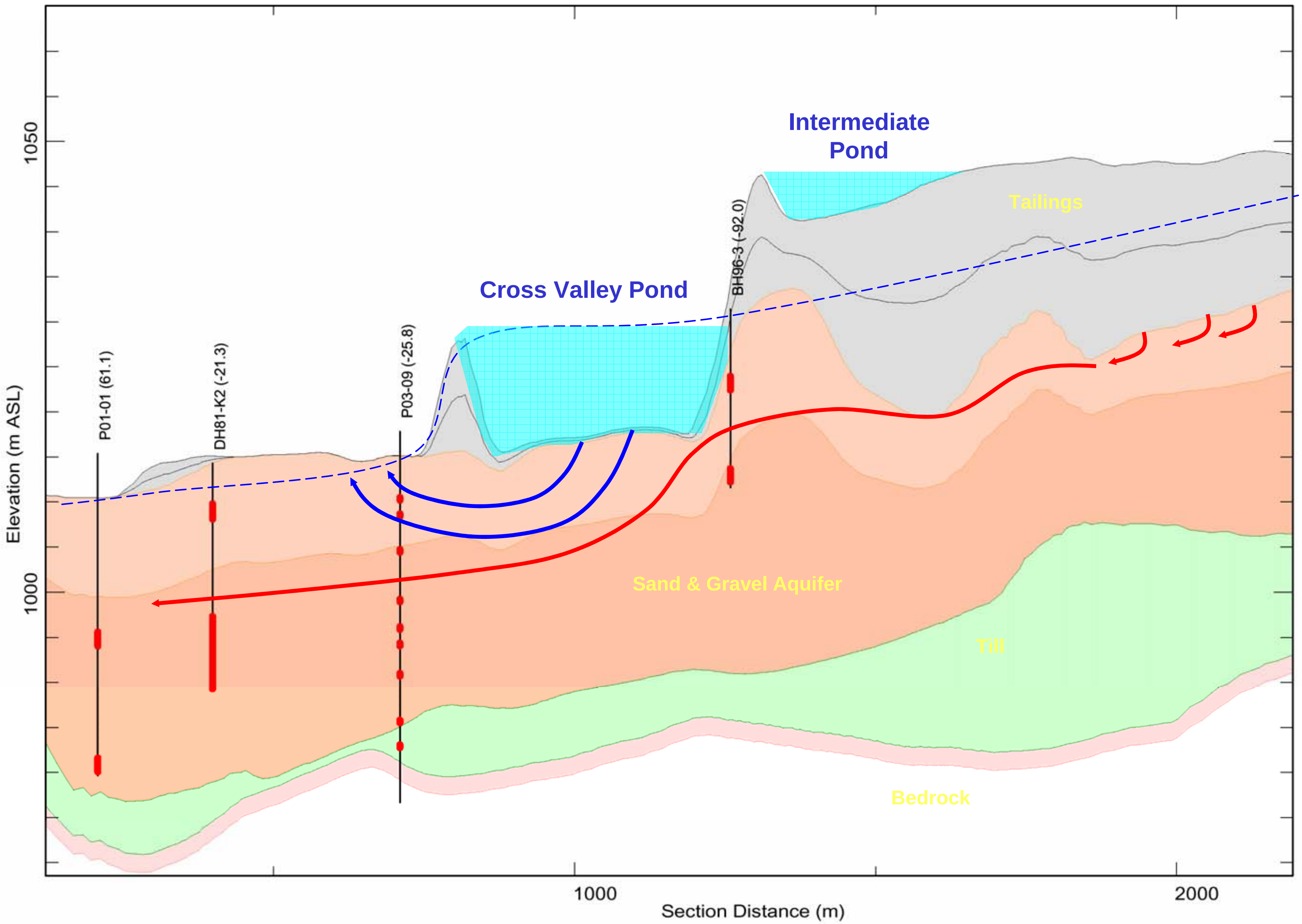
Alternate Concept

- lower the water level in the Cross Valley Pond such that it may become a substantive groundwater discharge zone

- treat the water in the Cross Valley Pond, possibly with a passive system

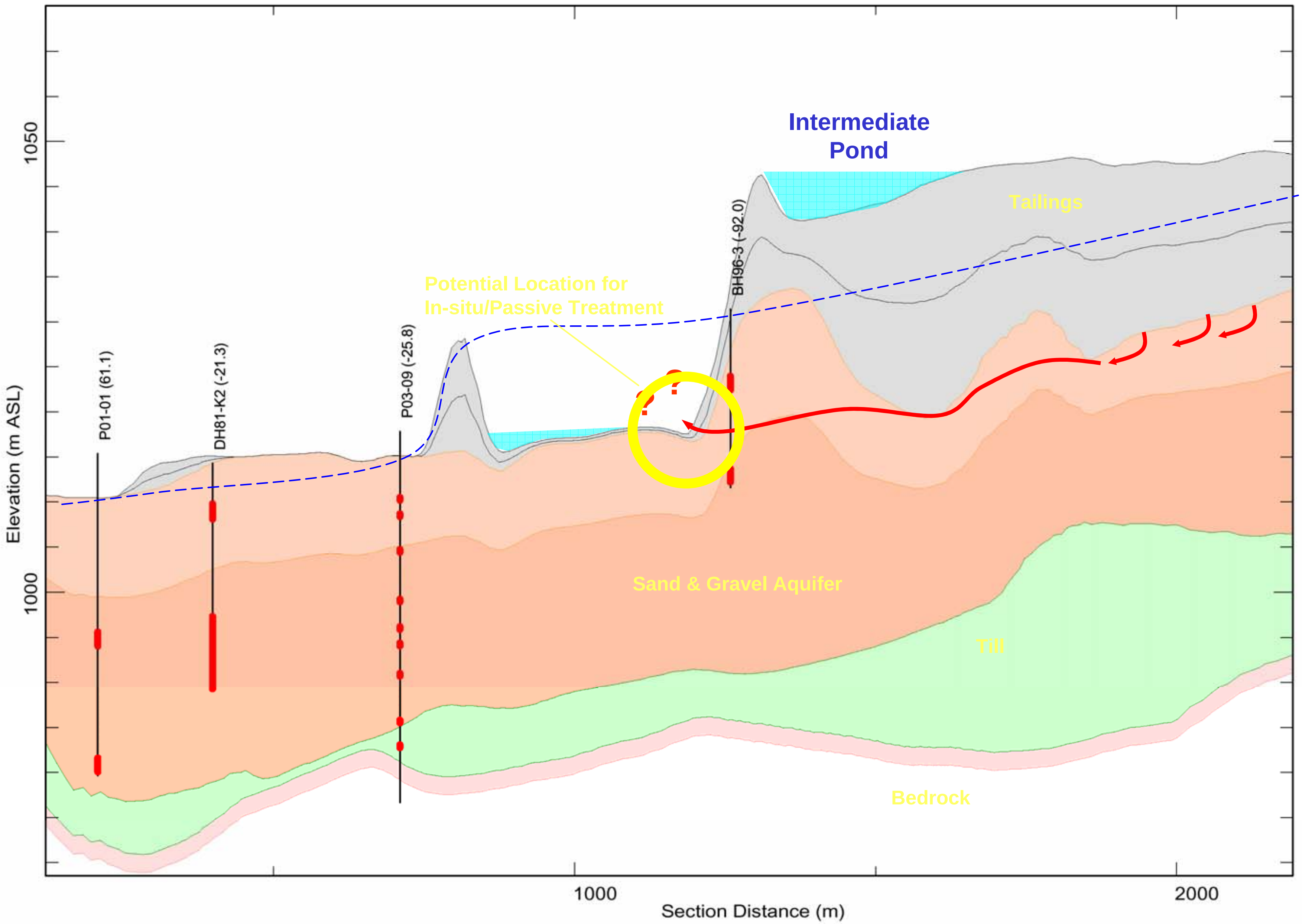
Conceptual Flow Model

Current Conditions



Potential Conceptual Flow Model

Lowered Cross Valley Pond Conditions



Next Steps

• link to Adaptive Management Planning for Water Licence

• consideration as a contingency plan for the FCRP

• further investigate the Cross Valley Pond concept (?)

• further investigate groundwater treatment concepts in context of further refinement of reclamation alternatives

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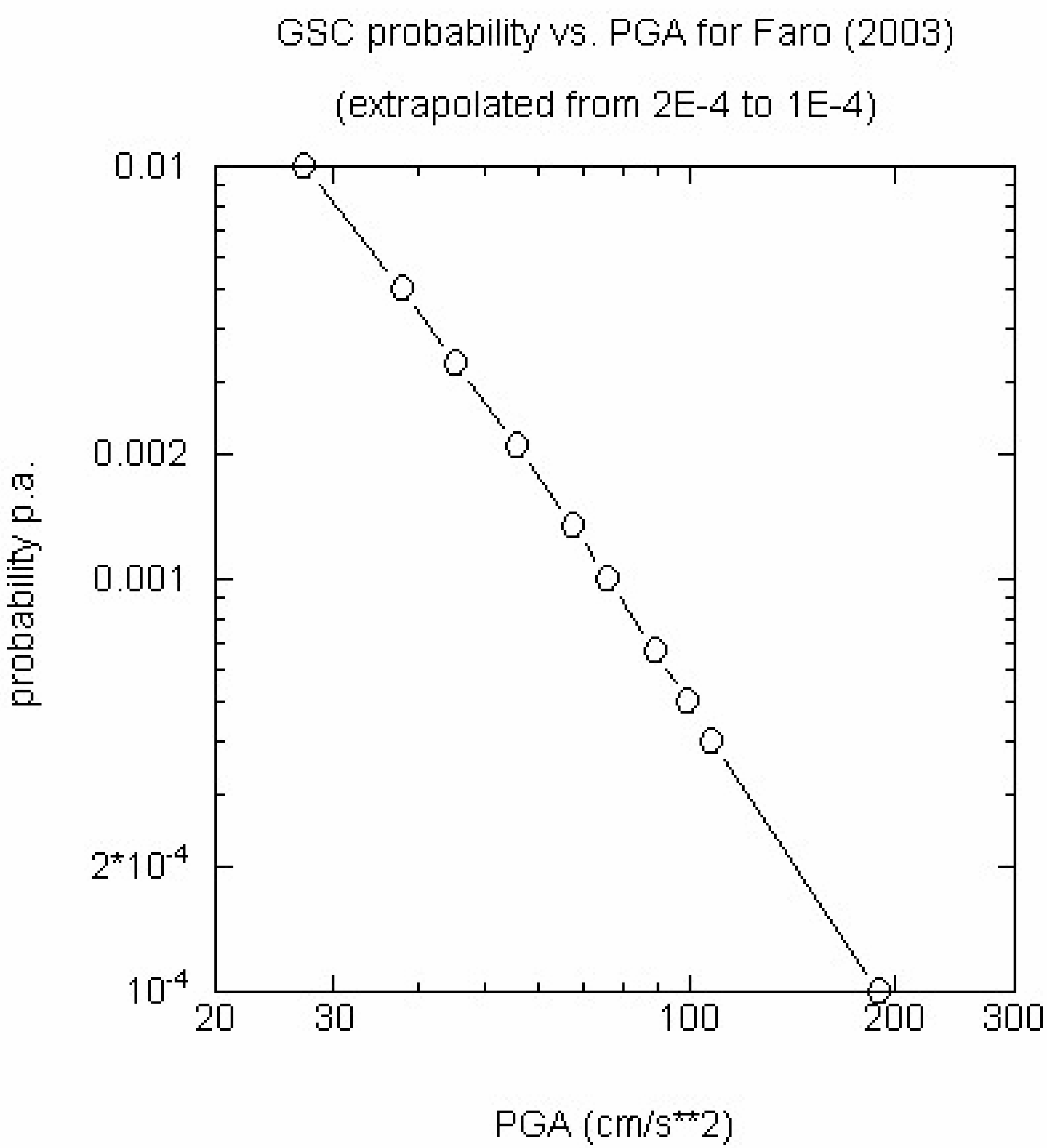
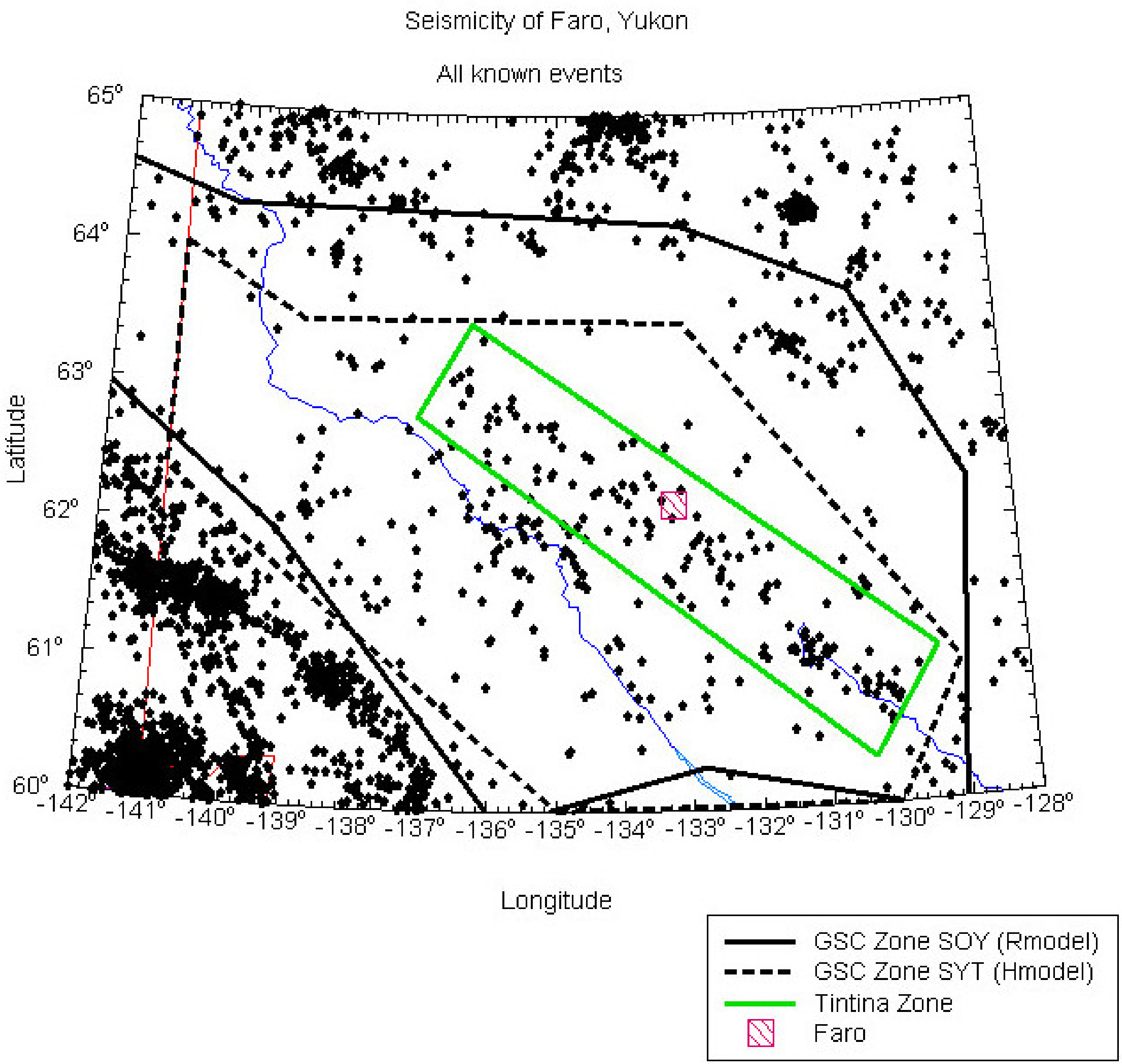
Earthquake Hazard at Faro

Feb., 2004

Gail M. Atkinson
Engineering Seismologist
(Professor of Earth Sciences, Carleton University)



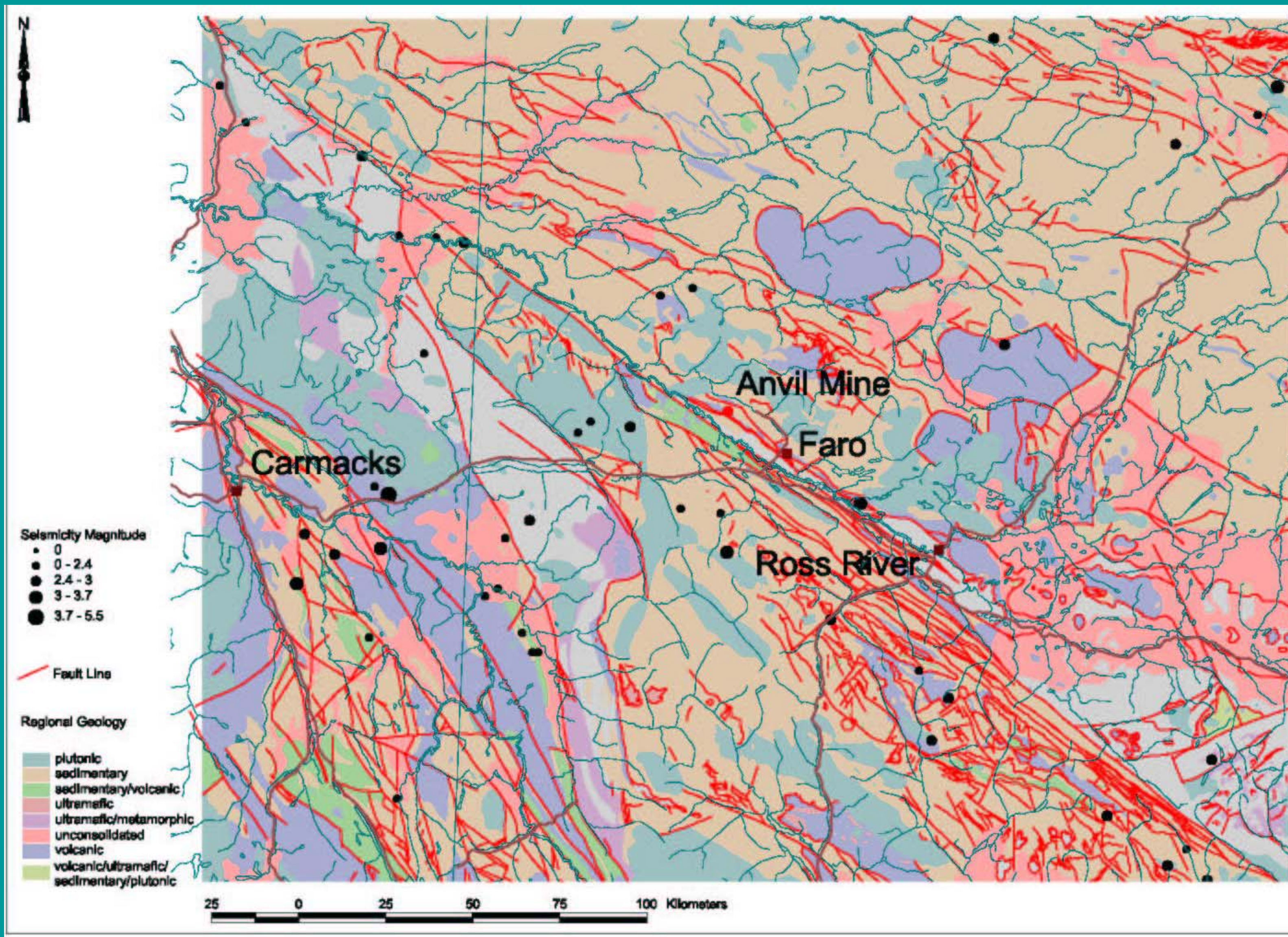
GSC PGA calculation for Faro – firm ground NEHRP C site conditions



Seismicity of Faro region – all known events.

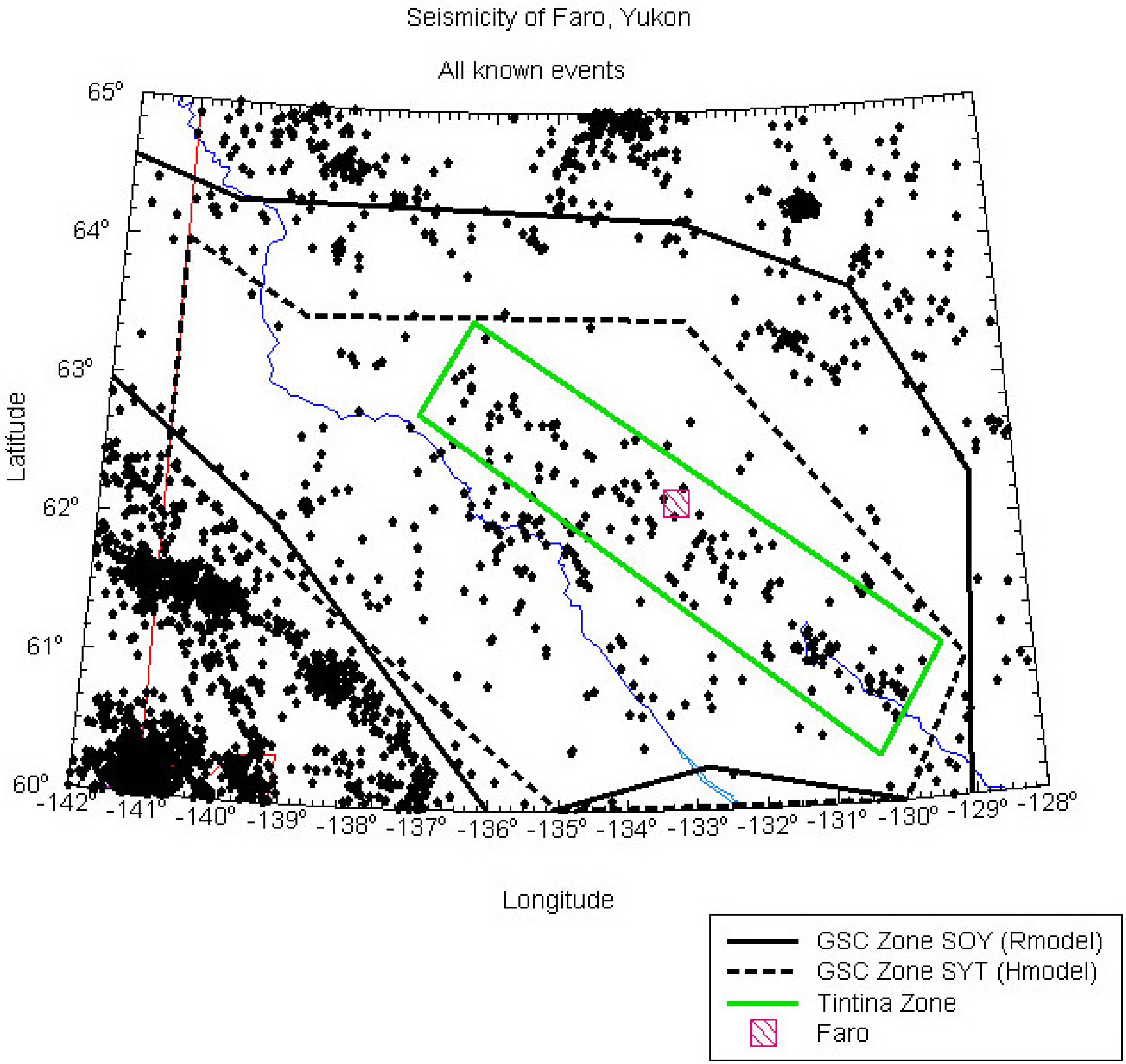
Green box outlines apparent linear seismicity trend along Tintina Trench

Bedrock faults from Smith (2003) report. Note the linear fault alignment near Faro that marks the Tintina Trench system.



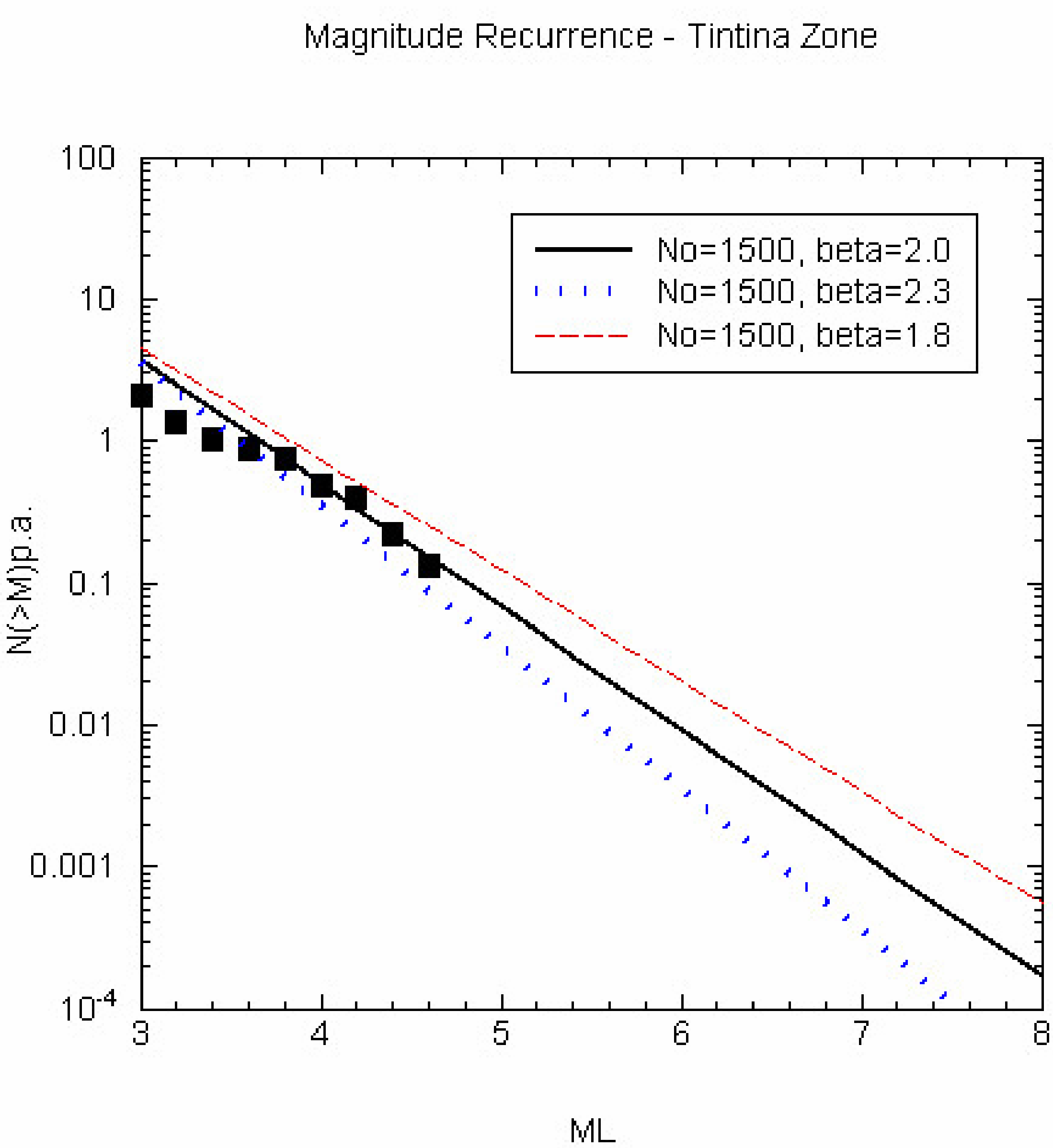
Hazard Analysis Parameters

- Seismic Source Models
- Magnitude Recurrence Parameters for Tintina Zone
- Ground-motion relations used by GSC for western crustal earthquakes (Boore et al., 1997 modified for B.C. distant attenuation)
- Results including uncertainty, for NEHRP C (firm ground) and D (conditions at Faro)
- Time histories



Weights given to various zone models in hazard analysis:

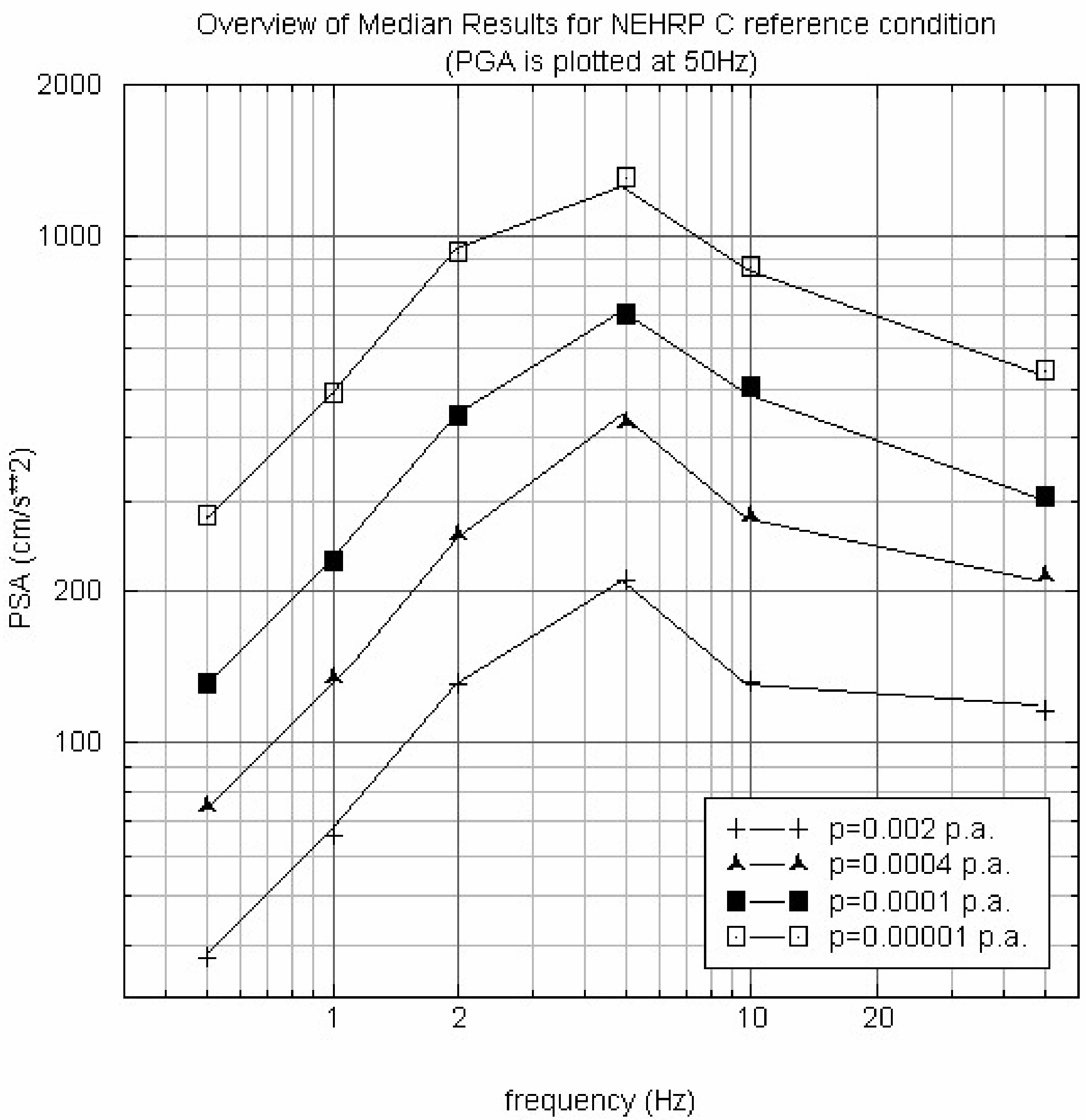
0.33 SYT
0.34 Tintina area source
0.33 Tintina fault source (3 dips considered)



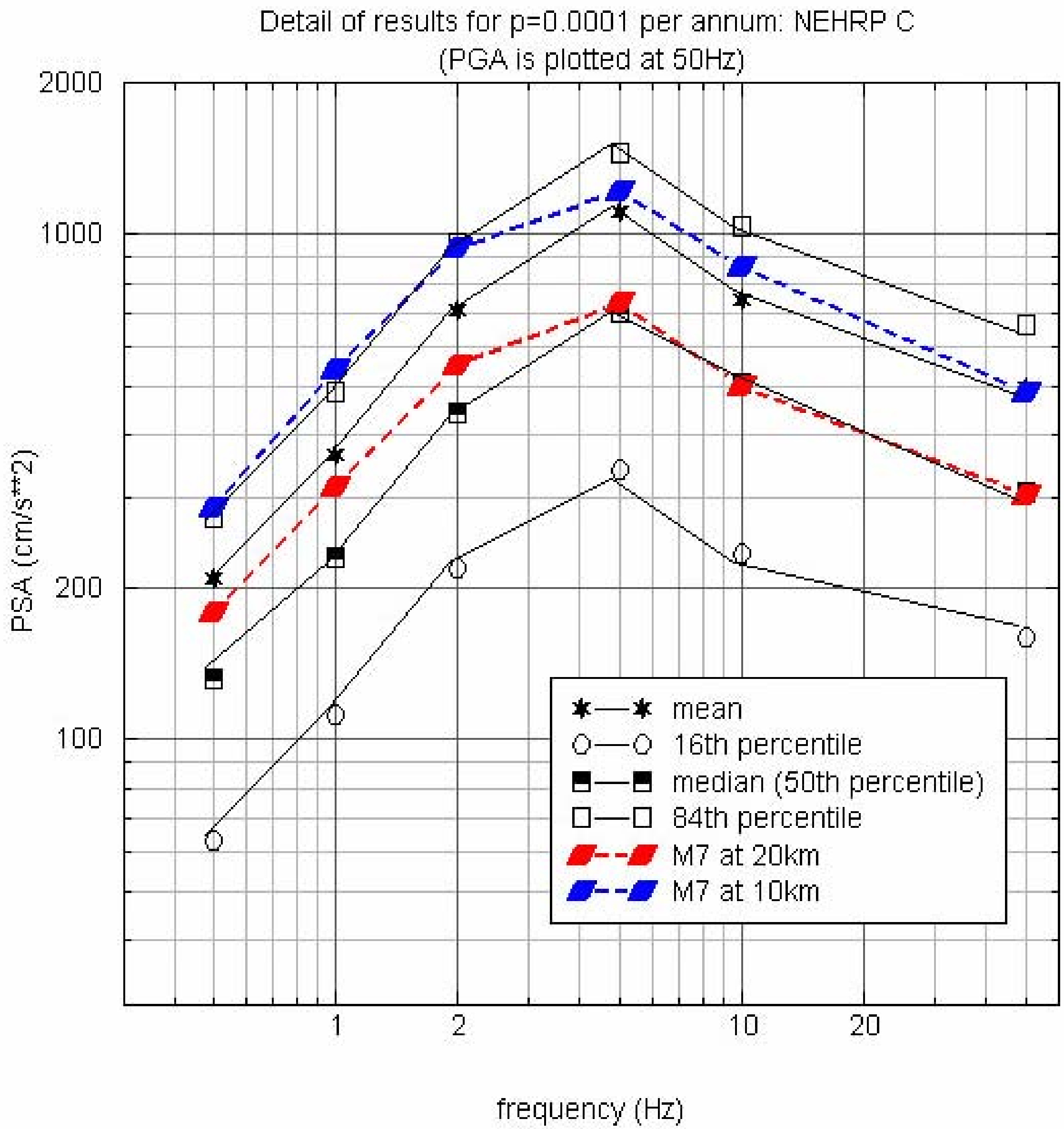
Magnitude recurrence relation for Tintina zone. Symbols are observed rates of activity (not complete at M<3.5). Lines show best estimate model for hazard analysis (black solid line) along with assumed uncertainty.

Geologic constraints on magnitude recurrence of Tintina Zone

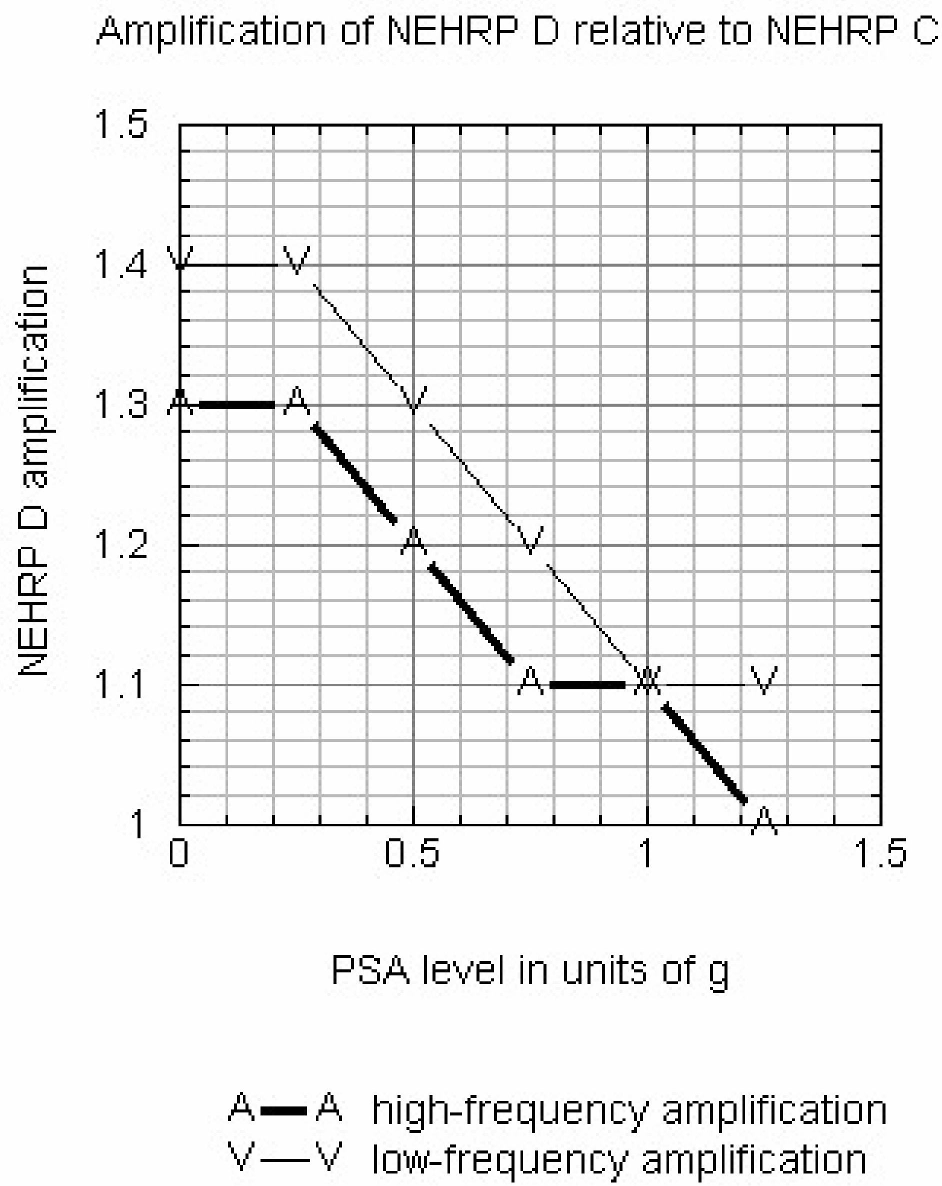
- Geologic slip of 500 to 1000 km in last 65 million yrs →8 mm/yr
- Other evidence (including GPS) suggests 1 to 5 mm/yr
- Seismicity rates consistent with about 4 mm/yr (ranging from 1 to 10 mm/yr from best-case to worst-case recurrence relations)
- Conclude that adopted recurrence relations are consistent with long-term slip rates on Tintina



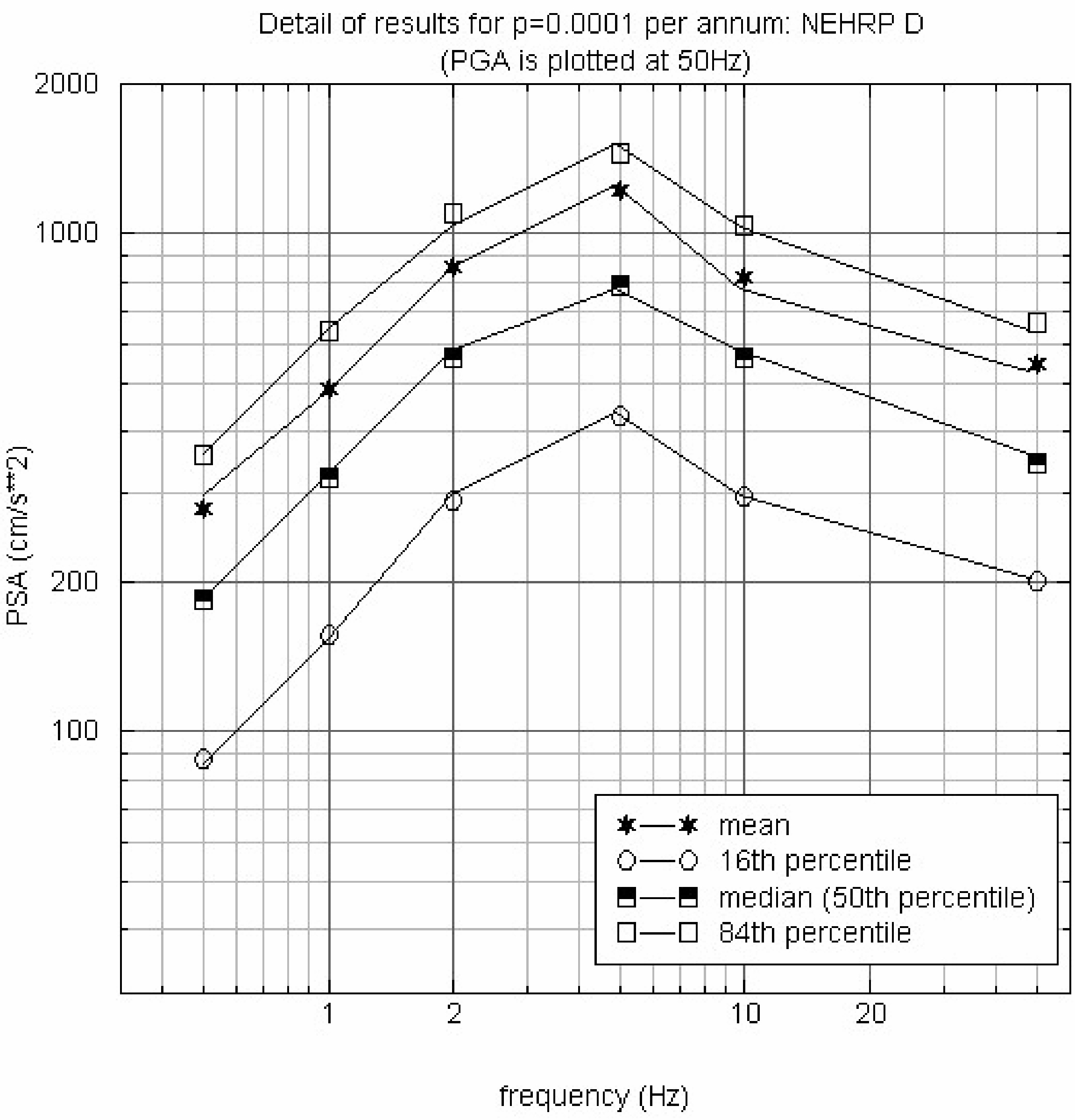
Median results for Faro for NEHRP C (reference site condition for calculations), for various probability levels. PGA is plotted at 50 Hz.



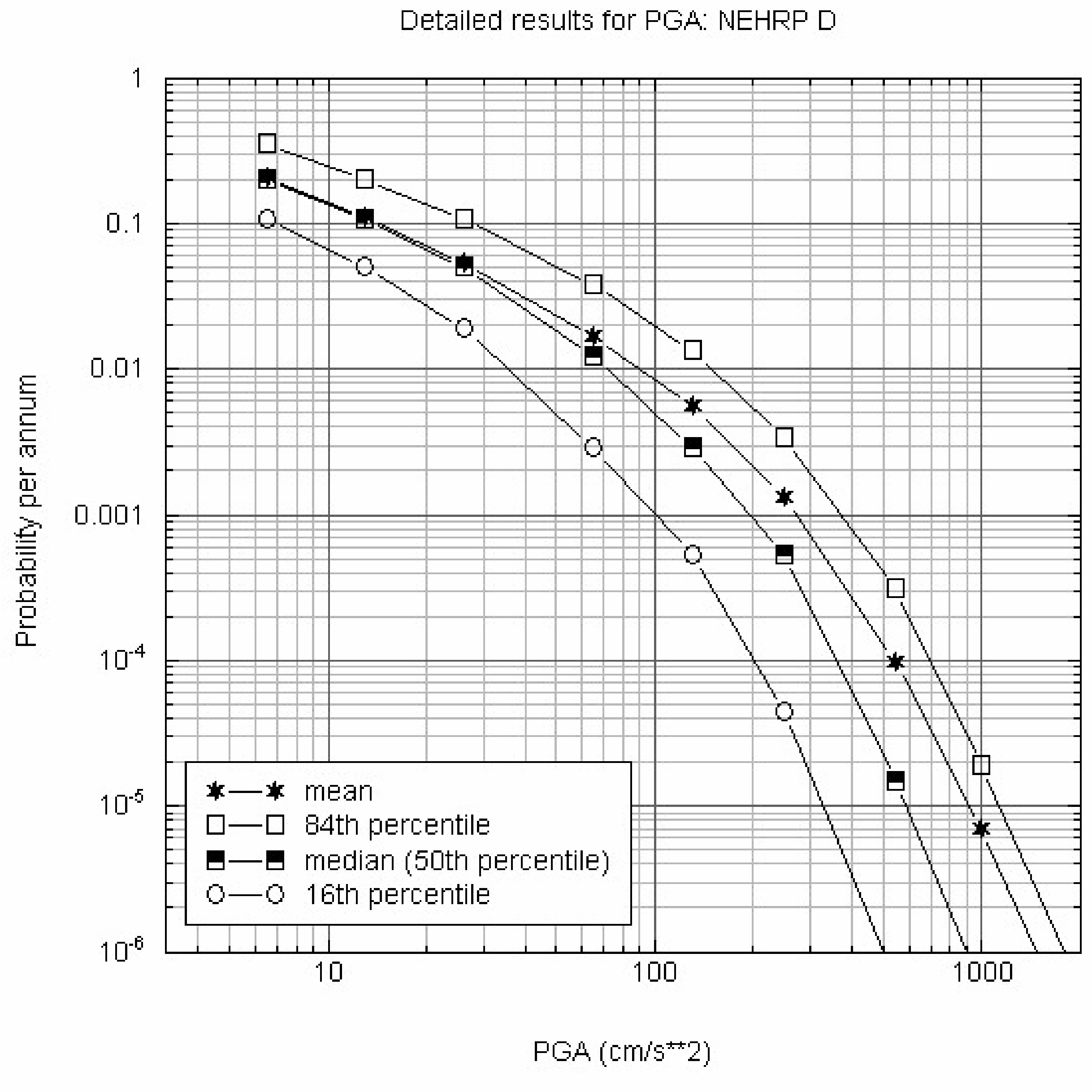
Results at Faro for NEHRP C, for annual probability of 10-4 per annum. Curves include uncertainty; thus we are 84% certain the true result lies below the 84th percentile. Coloured lines show the amplitudes for potential design or scenario events to match the target spectrum: a M7 at 10 to 20 km.



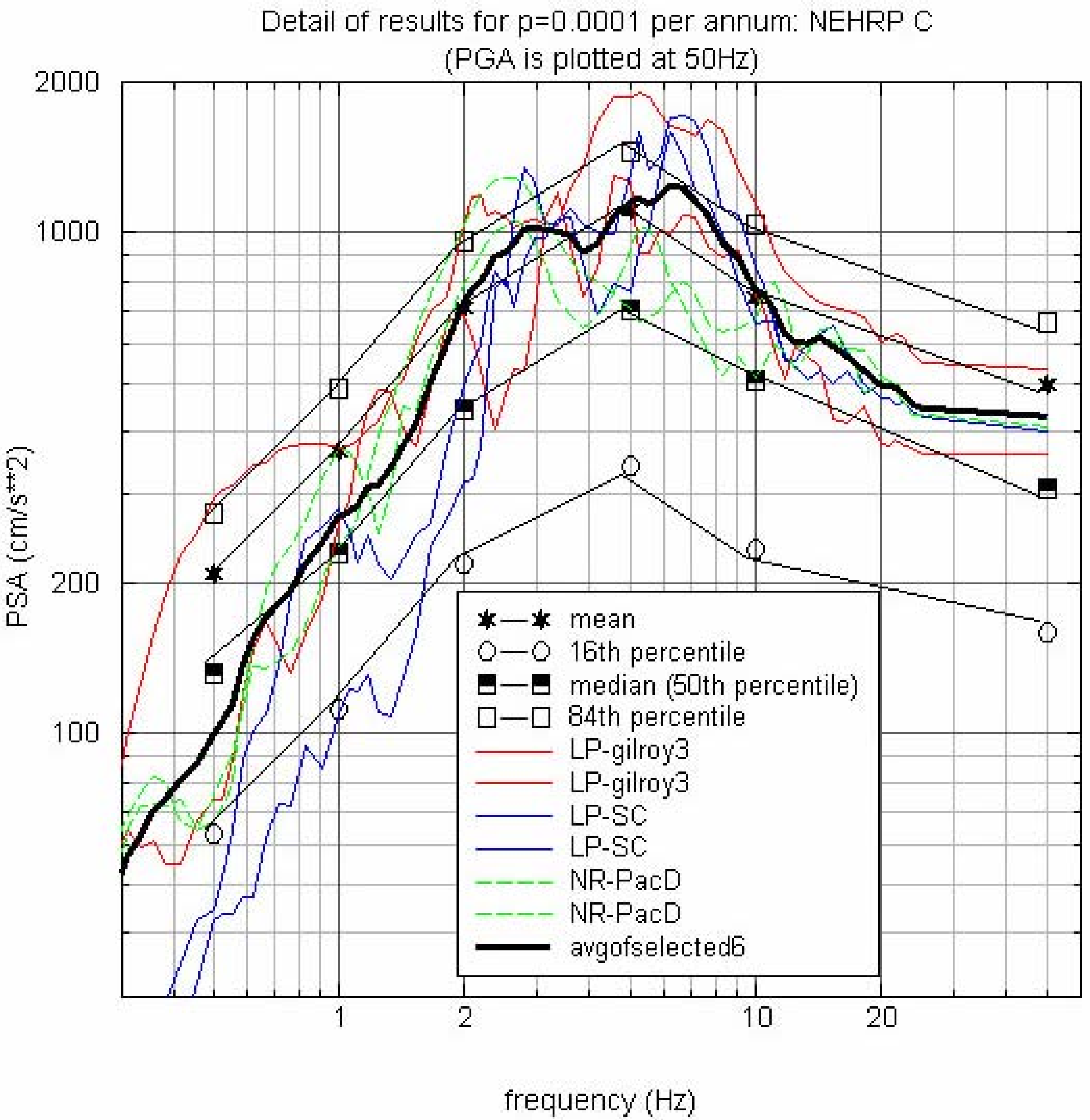
Soil amplification factors to apply to go from NEHRP C to NEHRP D conditions. A values apply to high frequencies (>5 Hz) and PGA, while V values apply to lower frequencies (0.5 to 1 Hz).



Detailed hazard results at Faro, for p=0.0001 per annum, for NEHRP D conditions.



Detailed view of PGA versus probability at Faro, for NEHRP D conditions



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Spectra for p=0.0001 per annum at Faro, for NEHRP C conditions, in comparison to the spectra of selected time histories. Records denoted LP are from the Loma Prieta earthquake (Gilroy3 and Lick Observatory); records denoted NR are from the Northridge earthquake (downstream record of Pacoima Dam).

Home

Engineering the
Earth's Development

Preserving the
Earth's Integrity

Anvil Range Mining Complex
Rose Creek Tailings Characterization

Presentation by :
John Cunning
Golder Associates Ltd.

February 17, 2004

Rose Creek Tailings Characterization

Study Objectives

- Define representative Geotechnical Properties of the Rose Creek Tailings Deposit for:
  - Tailings Relocation Study and
  - Seismic Stability Assessment

Rose Creek Tailings Characterization

Scope

- Conduct a Cone Penetration Test (CPT) site investigation program for in-situ characterization of the tailings deposit
- Conduct a Geotechnical Laboratory Testing program on two representative gradations of Tailings
- Review the existing Geotechnical design and construction reports for available tailings geotechnical properties and historical tailings deposition details

Rose Creek Tailings Characterization

Results - CPT Site Investigation

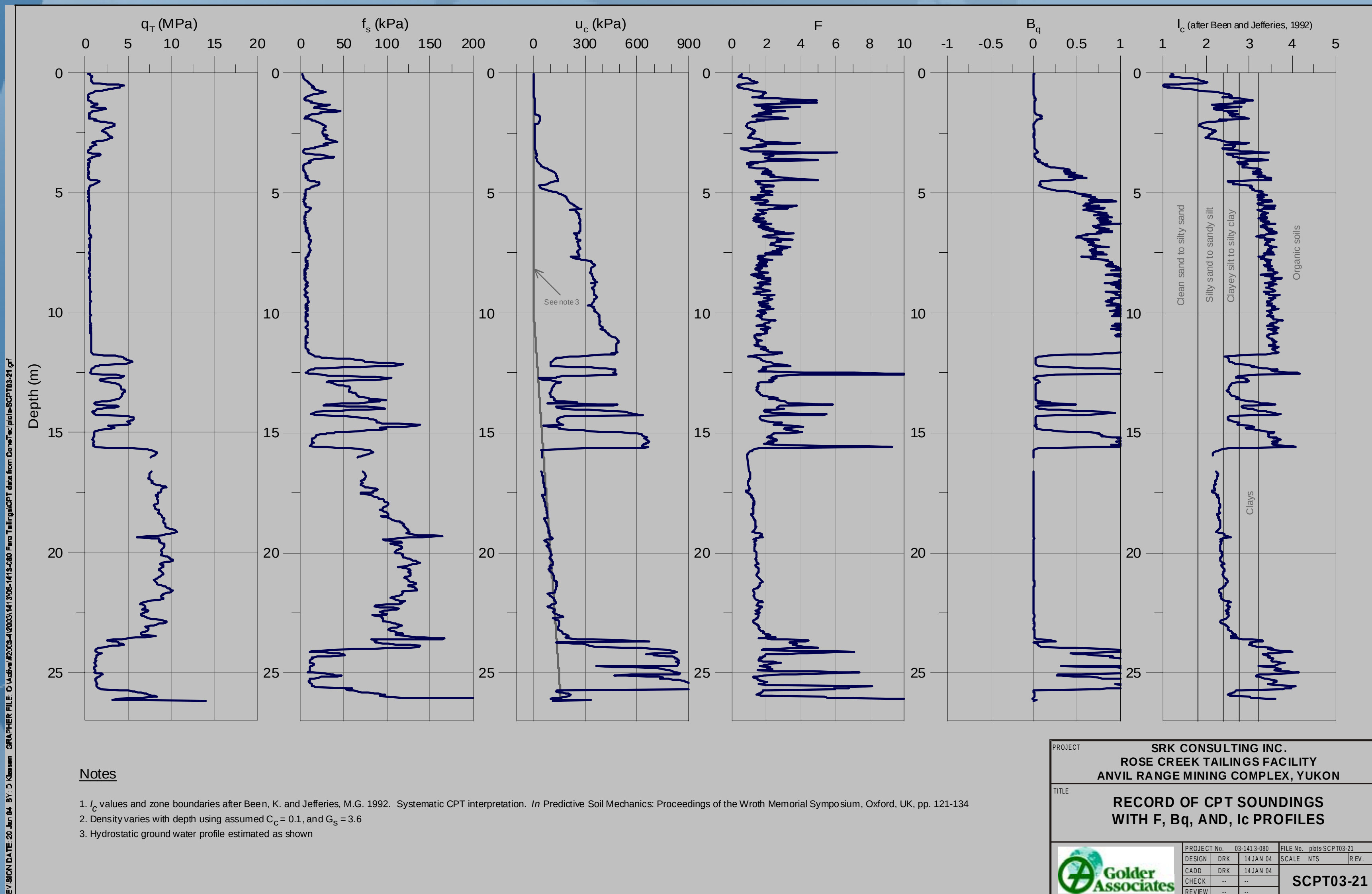
- Carried out 15-18 October 2003 using Midnight Sun Drilling Ltd. CME 750 rig and Conetec Investigations Ltd. CPT equipment
- 36 CPT soundings totaling 482 m, ranging in depth from 1 to 26 m from surface of tailings
- Including shear wave velocity measurement with depth in 5 SCPT soundings
- Pore pressure dissipation measurements at 35 locations
- Site plan showing CPT locations

Golder Associates

Site Plan – CPT Investigation

Golder Associates

Rose Creek Tailings Characterization



Rose Creek Tailings Characterization

- CPT Data reduced to soil type classification (I_c) following Been and Jefferies (1992)
- Shear modulus from Vs correlated with depth by soil type zone

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Rose Creek Tailings Characterization

Results –Laboratory Testing –January 2004

- 15 samples obtained from Gartner Lee Ltd. 2003 Sonic drill program
- Two bulk samples prepared with gradations representing FINE and COARSE tailings zones
- Index testing - grain size, Gs, max/min void ratio
- Triaxial Testing program for each to measure Critical State Properties

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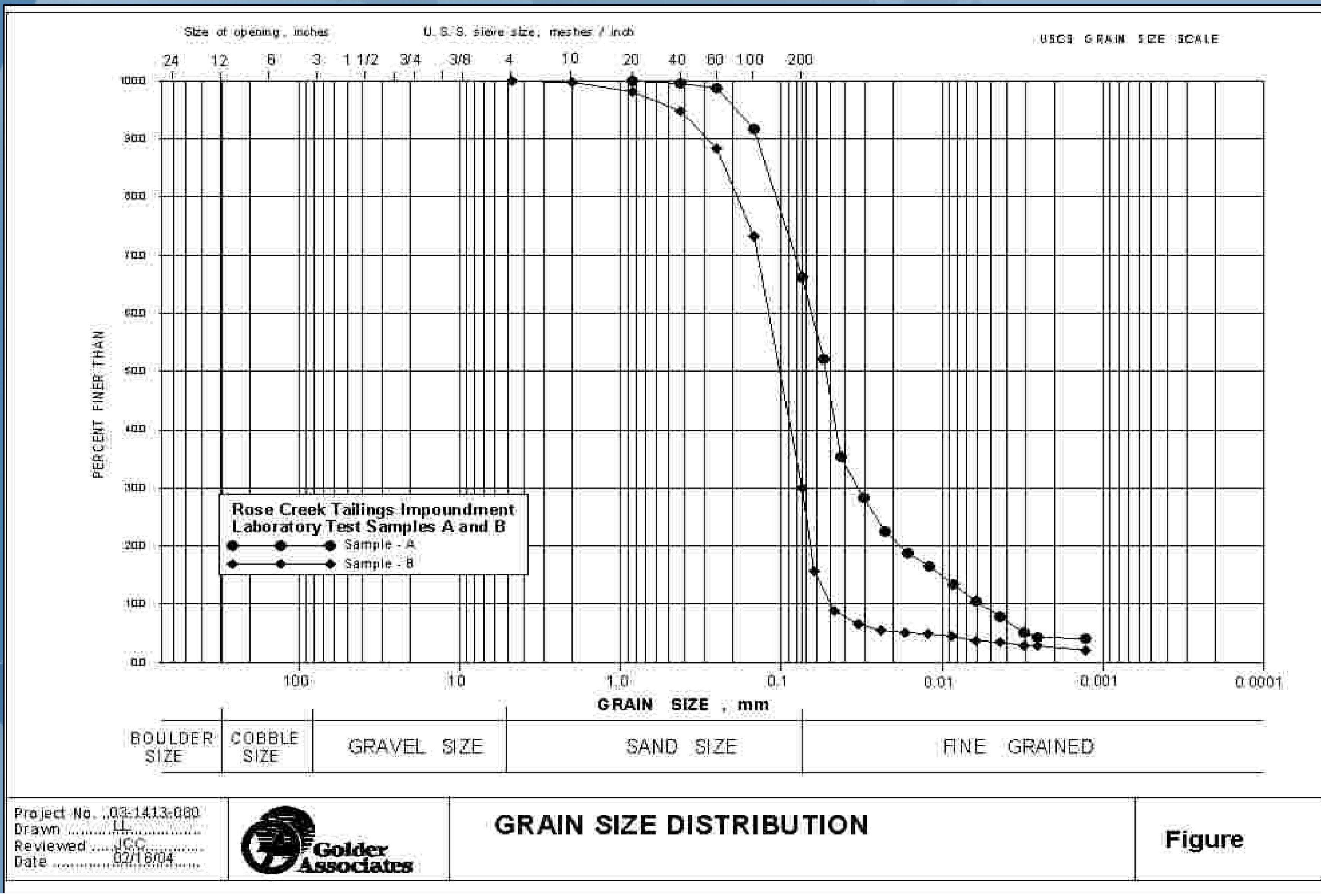
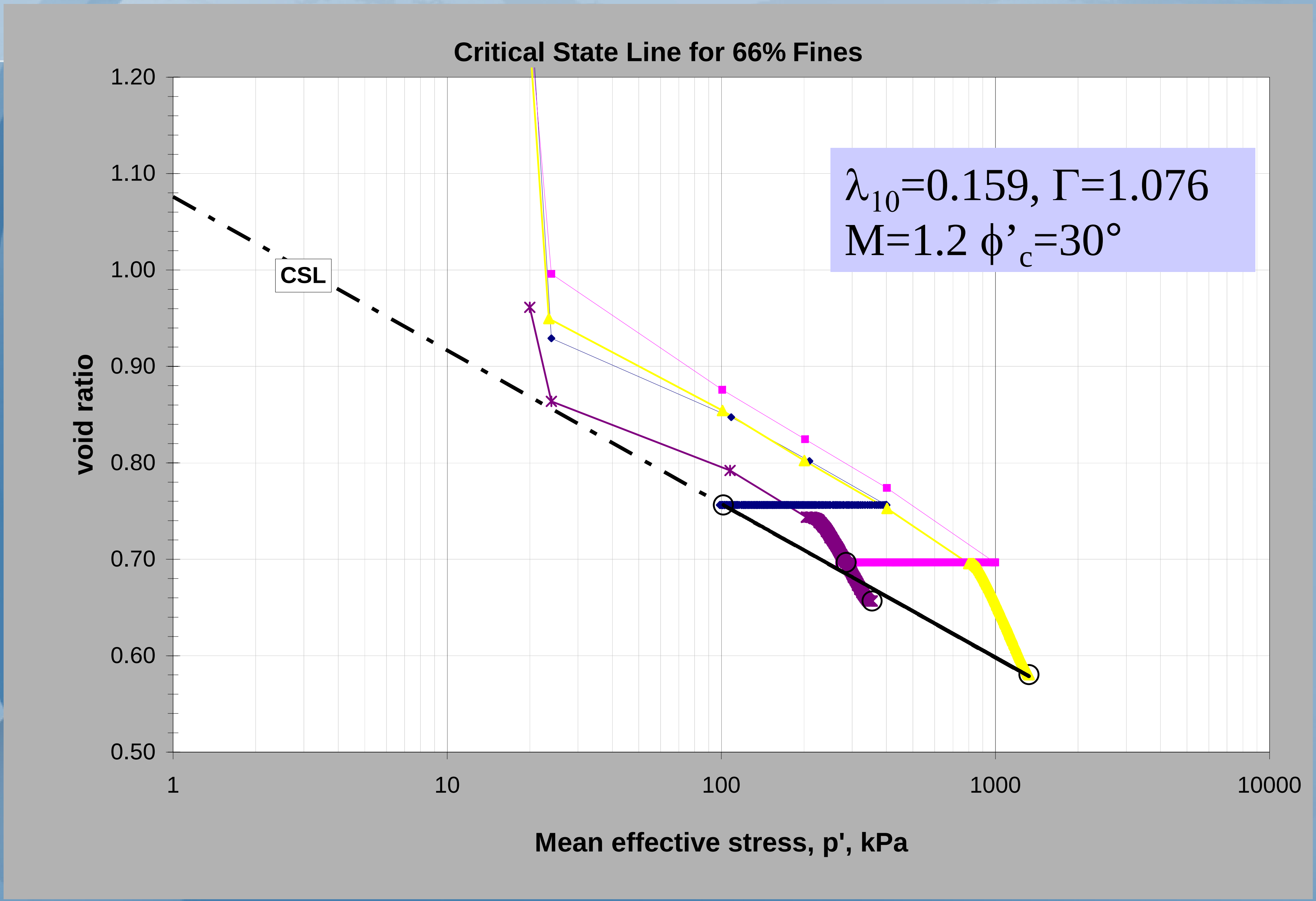
Rose Creek Tailings Characterization



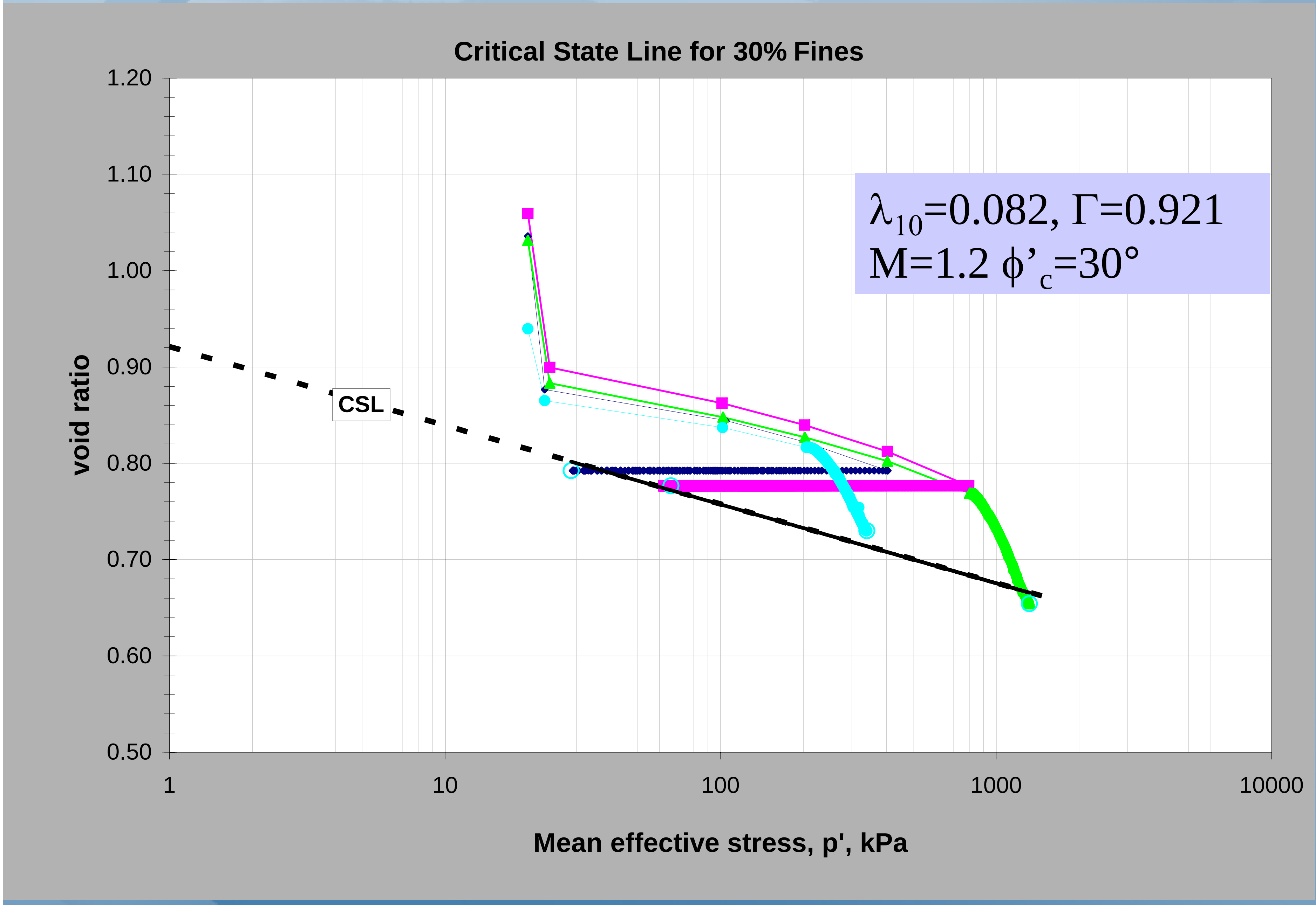
Rose Creek Tailings Characterization

Laboratory Data

- Gs range 3.6 to 4.5
- Critical State Properties from a series of CID and CIU Triaxial Tests on reconstituted sample of each the Fine and Coarse gradation



Critical State Line for 66% Fines
λ10=0.159, Γ=1.076
M=1.2 φ'c=30°
CSL
void ratio
Mean effective stress, p', kPa
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
1
10
100
1000
10000



Critical State Line for 30% Fines
λ10=0.082, Γ=0.921
M=1.2 φ'c=30°
CSL
void ratio
Mean effective stress, p', kPa
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
1
10
100
1000
10000

Rose Creek Tailings Characterization

Data Review

- Tailings Impoundment Aerial Photos from 1972, 1975, 1979, and 1997 reviewed to investigation historical Tailings deposition patterns and compare to recent CPT data
- CPT I_c classifications appear to agree with deposition patterns

Rose Creek Tailings Characterization

Status of Report

Draft Site Characterization Report – issued February 9, 2004:

- Detailed Laboratory Testing results
- Record of CPT sounding data with Soil Type Classification by I_c following Been and Jefferies (1992)
- Shear Modulus (from Vs) with depth by soil type zone
- CPT data (q_t, u_2, u_0 and I_c) presented in a series of cross sections through impoundment

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LIQUEFACTION ASSESSMENT OF THE INTERMEDIATE DAM, ROSE CREEK TAILINGS IMPOUNDMENT YUKON TERITORY

Home

Peter M. Byrne, Ph.D, P.Eng.
Mahmood Seid-Karbasi, M.Sc.

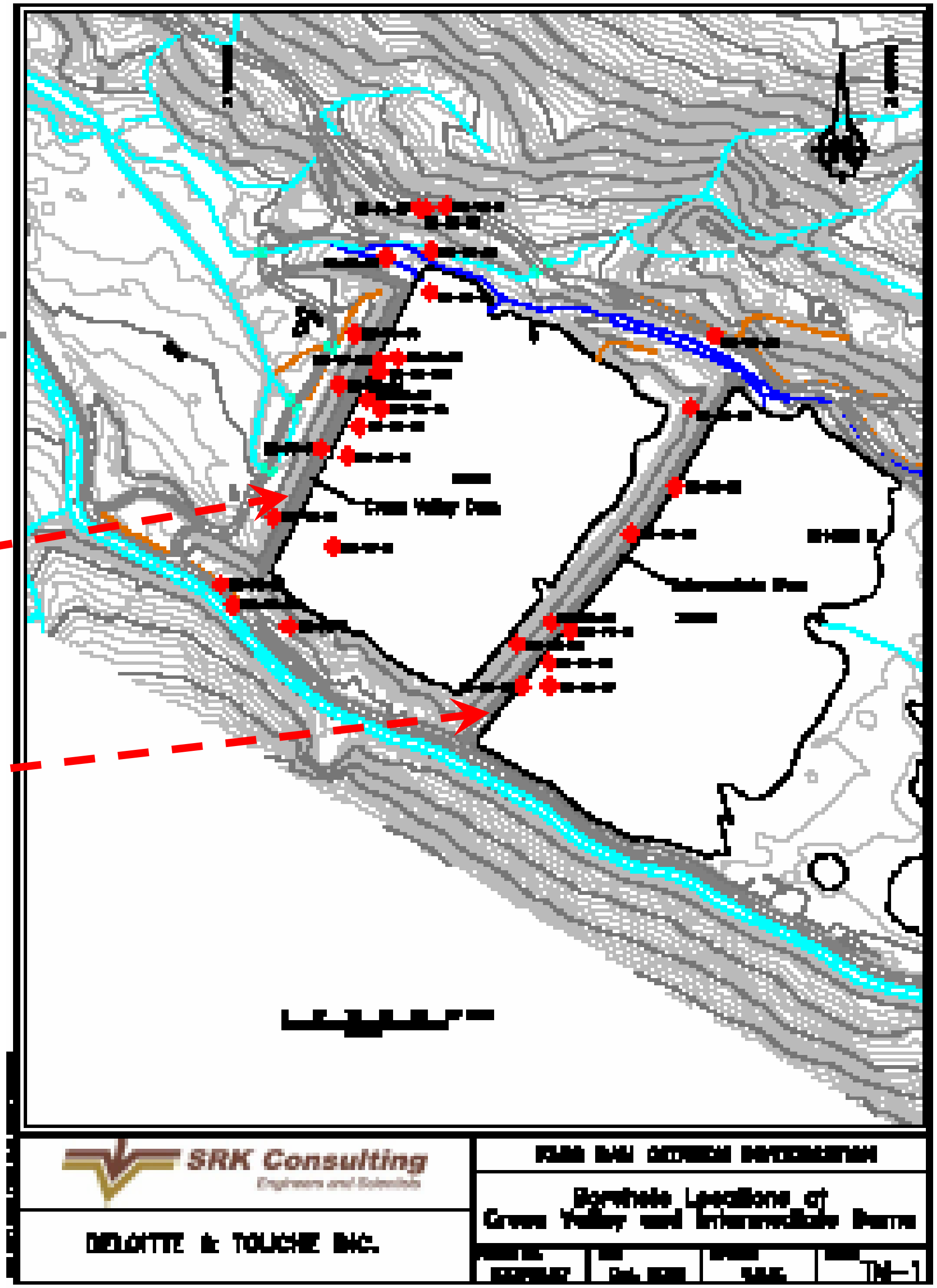
Feb. 2004

PLAN VIEW OF IMPOUNDMENT

Includes 2 Dams:

Cross Valley Dam

Intermediate Dam



OBJECTIVE

- **Evaluate the possibility of triggering LIQUEFACTION in the foundation soils beneath the INTERMEDIATE DAM in the event of the design earthquake.**

INTRODUCTION

- **The impoundment dams at this site have similarities with the San Fernando dams that liquefied during the M6.5 San Fernando earthquake, 1971.**

THE SAN FERNANDOW DAMS, 1971

FAILURE OF THE LOWER SAN FERNANDOW DAM

INTRODUCTION (Cont.)

- **Liquefaction involves a large drop in stiffness and strength that can lead to large displacements and severe damage to structures.**

- **Liquefaction is caused by high pore water pressures resulting from the tendency of granular soils to compact under cyclic loading.**

INTRODUCTION (Cont.)

- In dealing with liquefaction, 3 questions arise:

  1. Will liquefaction be triggered in significant zones by the design earthquake ?, if so,

  2. Could a Flow Slide occur?, if not,

  3. What displacements will occur?

LIQUEFACTION ASSESSMENT

- **State-of-Practice uses 3 separate analyses to answer these 3 questions:**

1. Trigger Analysis

2. Flow Slide Analysis

3. Displacement Analysis

SCOPE OF STUDY

- **Liquefaction triggering assessment only**

TRIGGER ANALYSIS

- Dynamic shear stresses caused by the design earthquake from SHAKE

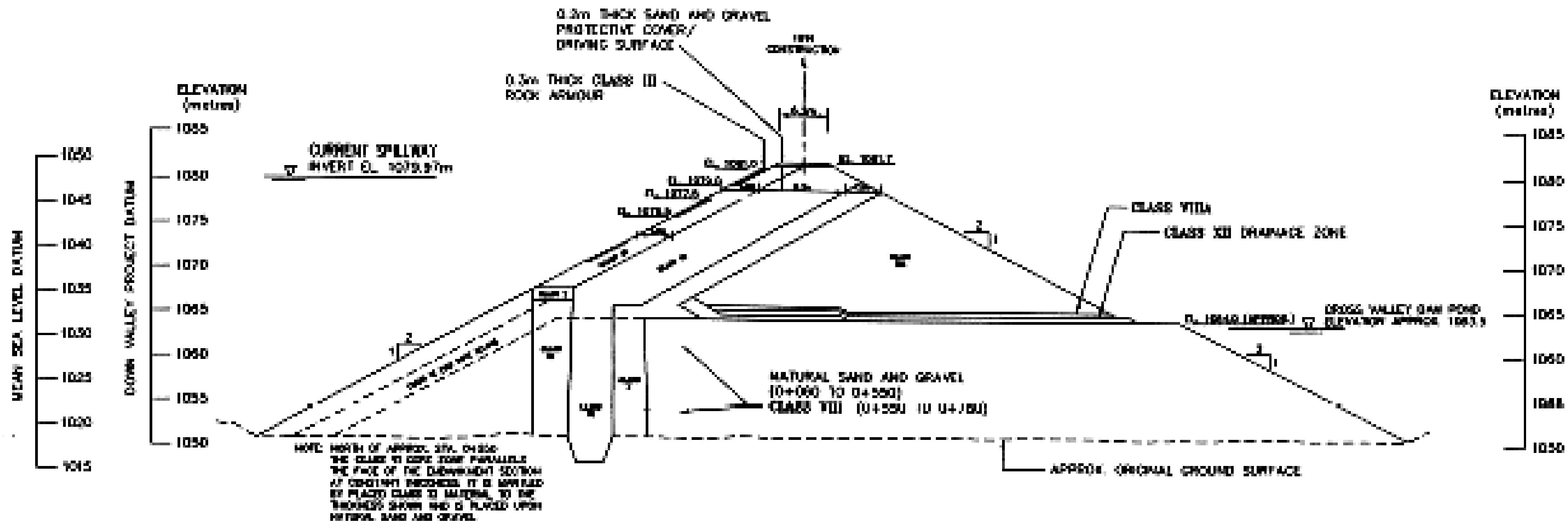
  ---------------- CSR

- Cyclic resistance from penetration tests and field experience during past earthquakes

  ---------------- CRR

CSR > CRR Liquefaction

THE INTERMEDIATE DAM CROSS SECTION



1. Embankment geometry and internal zoning as shown in Golder Associates Drawing 912-2402-3, Int. Dam Raising & C.V. Dam Toe Drain. Cross Section and Detailed Plan. Rev. 1. Aug. 8, 1991.

2. All elevations are referenced to Down Valley Project Datum. Subtract 32.3m from elevations shown to convert to mean sea level (NAD27) datum.

3. Refer to Golder Associates as built reports for detailed descriptions of material classes. General descriptions as follows :

CLASS VI	Dam Core (glacial till)
CLASS VII	Upstream Shell (silty sand and gravel)
CLASS VIII	Downstream Shell (sand and gravel)
CLASS VIIIA	Drainage Filter (sand and gravel)
CLASS IX	Upstream Filter (silty sand)
CLASS X	Downstream Filter (sand and gravel)
CLASS XI	Tailings Sand (fine to medium sand)
CLASS XII	Drainage Zone (gravel)

THE INTERMEDIATE DAM FOUNDATION SECTION

SPT Data available from

3 Boreholes

BH 80-37 **BH 79-33** **BH 80-46**

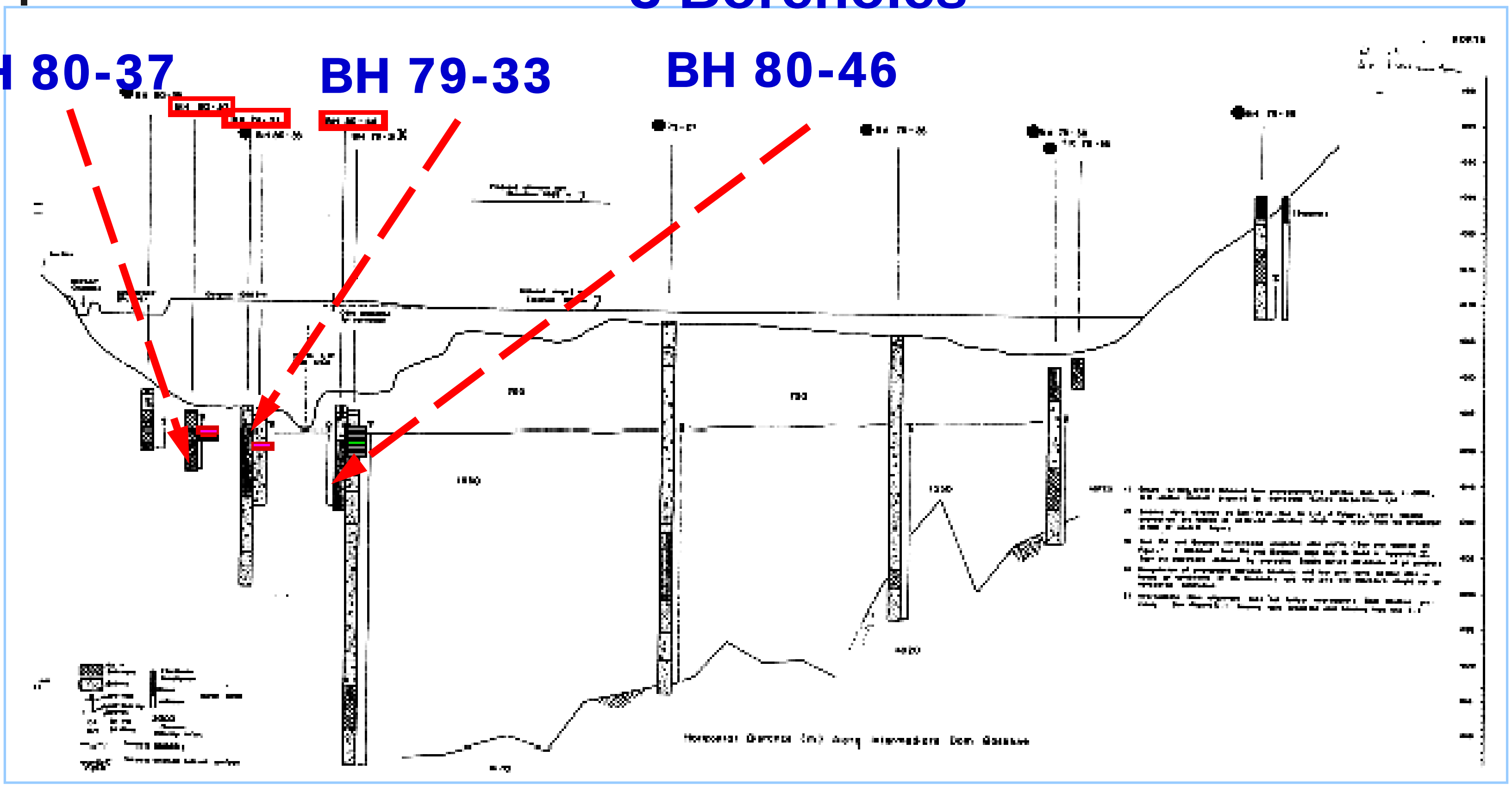


TABLE 1 AVAILABLE DATA ON INTERMEDIATE DAM FOUNDATION

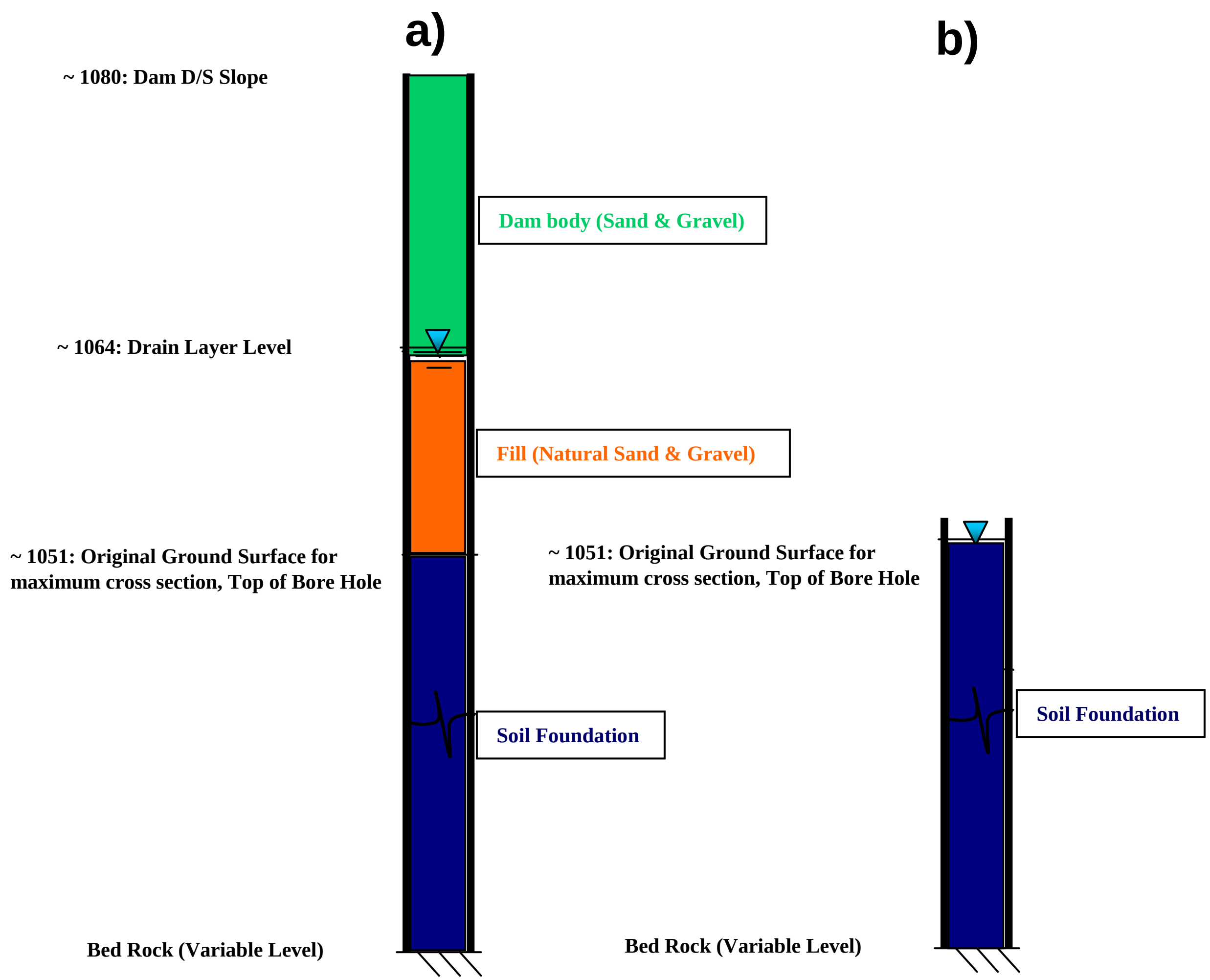
Elevation (m)	$(N_1)_{60}$ Values by Borehole		
	BH 80-37	BH 79-33	BH 80-46
1053	-	-	-
1052	-	-	154
1051	-	-	-
1050	-	-	-
1049	-	-	84
1048	11	-	-
1047	-	-	-
1046	-	-	22
1045	18	-	-
1044	-	-	-
1043	-	-	53
1042	-	12	-
1041	-	-	-
1040	-	-	40

AVAILABLE DATA ON CROSS VALLEY DAM FOUNDATION

Elevation (m)	$(N_1)_{60}$ Values by Borehole									
	BH 79-6	BH 79-21	BH 79-7	BH 80-41	BH 79-18	BH 80-38A	BH 79-15	BH 79-16	BH 79-1	BH 79-15
1052	-	-	-	-	-	-	-	-	-	14
1051	-	-	-	-	-	-	-	-	-	16
1050	-	-	-	-	-	-	-	-	-	-
1049	-	-	-	-	-	-	-	-	-	22
1048	33	-	-	-	-	-	-	-	-	30
1047	-	-	-	54	-	-	-	-	49	-
1046	14	11	113	50	-	-	-	22	73	19
1045	-	36	-	-	154*	-	-	-	-	18
1044	-	-	-	-	-	32	-	20	59	-
1043	33	116	74	-	-	-	21	18	31	42
1042	27	40	-	-	131*	-	-	-	-	-
1041	-	-	33	-	117*	-	-	20	24	38
1040	33	51	14	-	-	-	-	20	32	-
1039	-	-	-	-	105*	-	-	-	-	-
1038	-	-	21	-	11	-	-	28	-	-
1037	18	37	11	-	-	-	-	51	48	56
1036	-	-	-	-	11	-	-	-	-	-
1035	-	-	19	-	11	-	-	31	22	-
1034	-	74	35	-	-	-	-	23	53	24
1033	-	-	-	-	16	-	-	-	-	-
1032	-	-	13	-	10	-	-	29	-	-
1031	-	67	21	-	-	-	-	7	-	5
1030	-	-	-	-	11	-	-	-	-	-
1029	-	-	-	-	14	-	-	18	-	-
1028	-	62	-	-	-	-	-	-	-	10
1027	-	-	41	-	-	-	-	23	-	-
1026	-	-	-	-	14	-	-	-	-	-
1025	-	58	-	-	-	-	-	-	-	46
1024	-	-	-	-	-	-	-	23	-	-
1023	-	-	58	-	-	-	-	58	-	-
1022	56	-	-	-	31	-	-	-	-	-
1021	-	-	-	-	-	-	-	-	-	43
1020	-	-	-	-	-	-	-	-	-	-
1019	-	-	-	-	22	-	-	-	-	-
1018	-	-	-	-	-	-	-	-	-	-
1017	-	50	-	-	-	-	-	-	-	-
1016	-	-	-	-	-	-	-	-	-	-
1015	-	-	-	-	41	-	-	-	-	-

*Permafrost layers with frozen soil observed. SPT N-values not representative

1-D MODEL FOR GROUND RESPONSE ANALYSIS
a) With dam, and b) Without dam



SOIL PROFILE BASED ON BH-80-46 BOREHOLE DATA (WITH DAM)

6 INPUT MOTIONS RECORDS
(Atkinson, 2003)

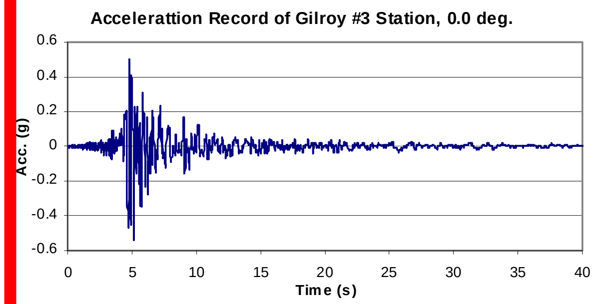


Fig. 1: Loma Prieta Earthquake record at Gilroy St. #3 at 0.0 deg.

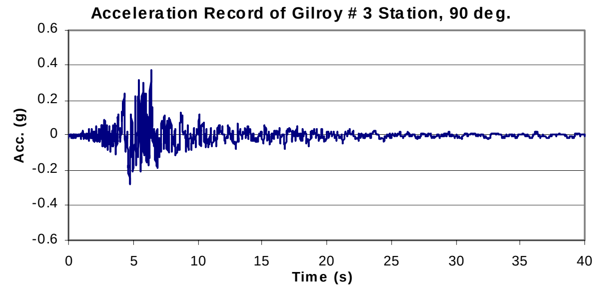


Fig. 2: Loma Prieta Earthquake record at Gilroy St. #3 at 90 deg.

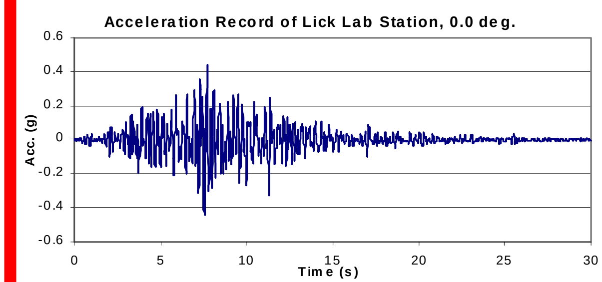


Fig. 3: Loma Prieta Earthquake record at Lick Lab St. at 0.0 deg.

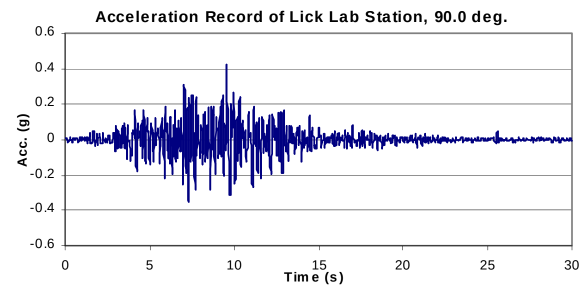


Fig. 4: Loma Prieta Earthquake record at Lick Lab St. at 90 deg.

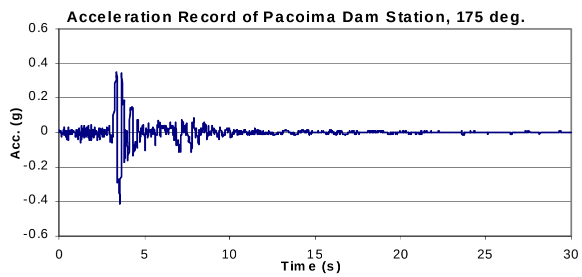


Fig. 5: Northridge Earthquake record at Pacoima Dam St. at 175 deg.

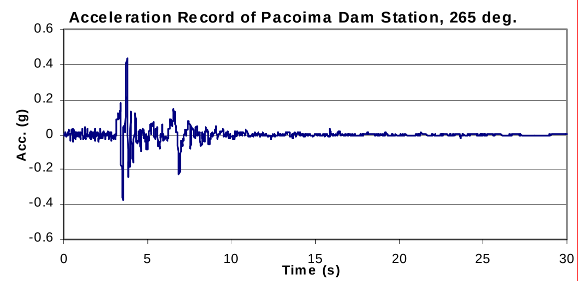


Fig. 6: Northridge Earthquake record at Pacoima Dam St. at 265 deg.

ANALYSIS

- **Apply design earthquake at base of soil columns and compute Cyclic Stress Ratio ……………...............………..CSR**

- **From Penetration tests compute Cyclic Resistance Ratio ……….CRR**

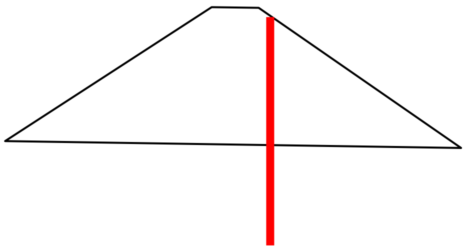
- **Liquefaction if CSR > CRR**

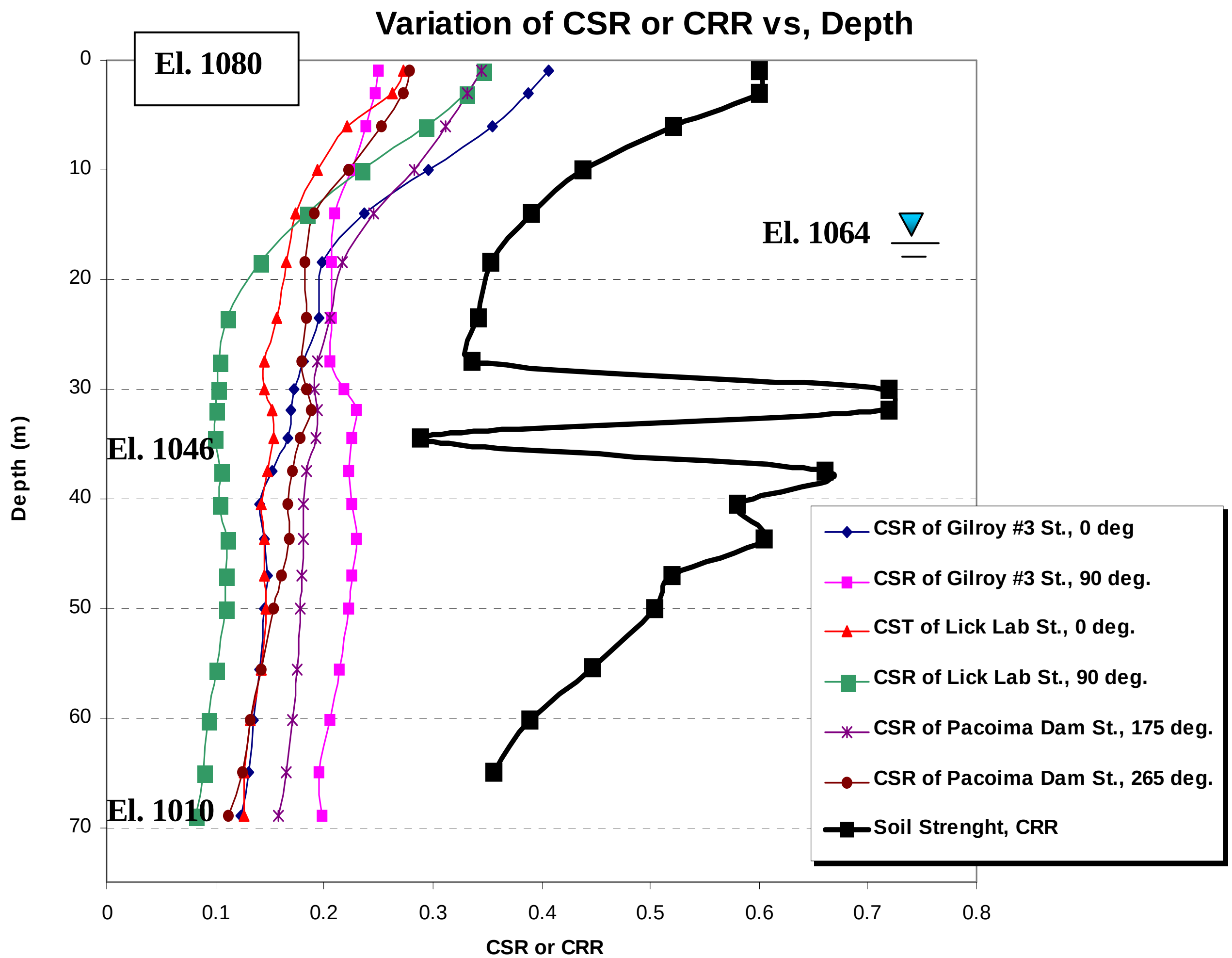
RESULTS

- **Compare CSR and CRR.**
- **2 Sections, Deep Valley and Shoulder.**
- **2 locations at each section, crest and toe.**
- **All 6 earthquake records applied for each condition.**

CSR AND CRR vs. DEPTH FOR BH 80-46 PROFILE

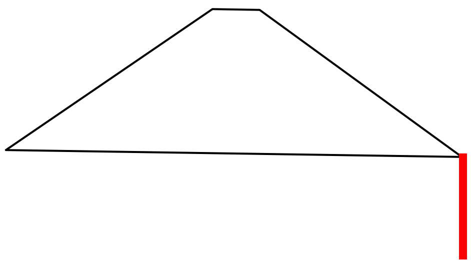
(Valley Section with Dam)

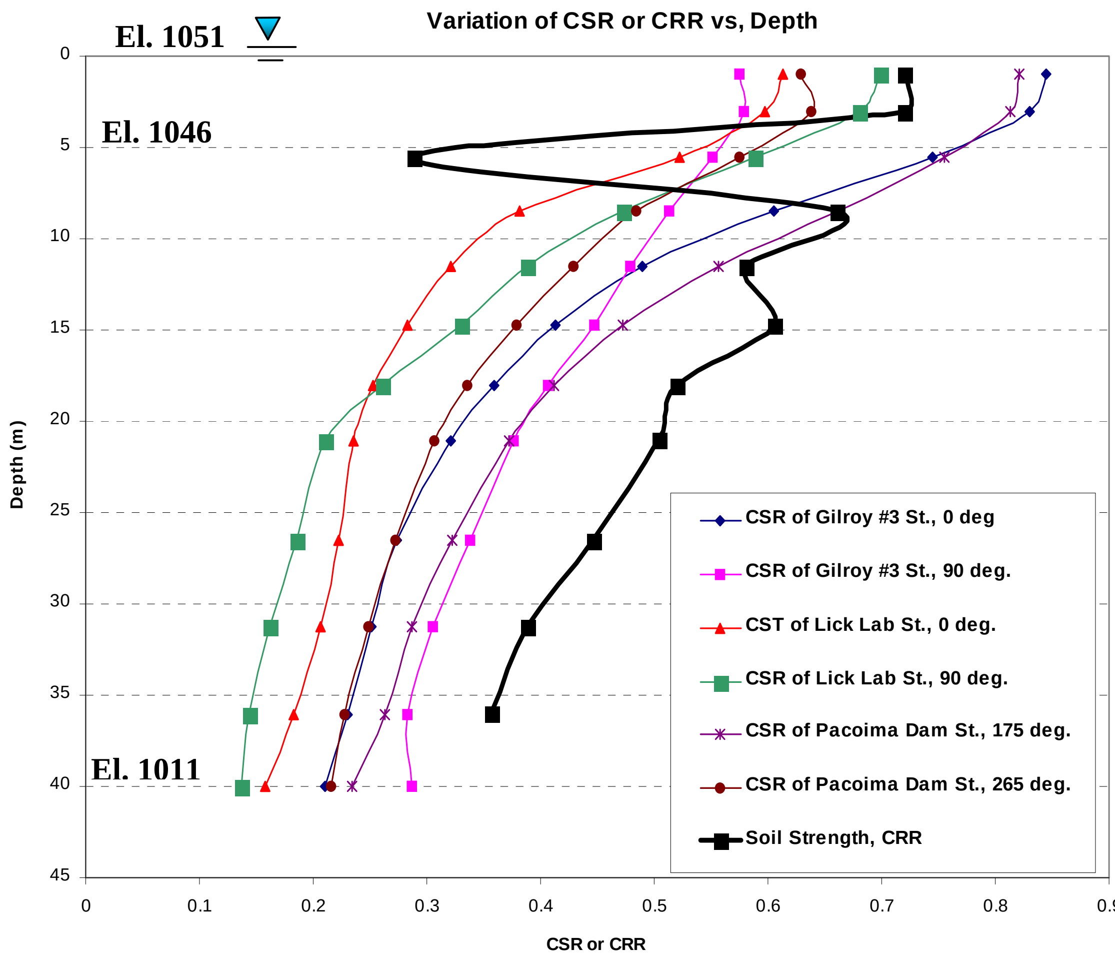




CSR AND CRR vs. DEPTH FOR BH 80-46 PROFILE

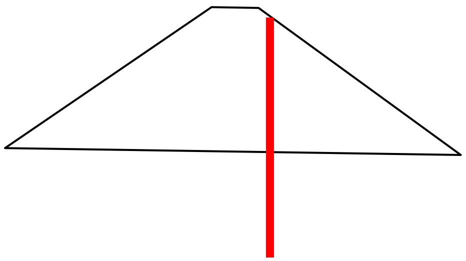
(Valley Section without Dam)

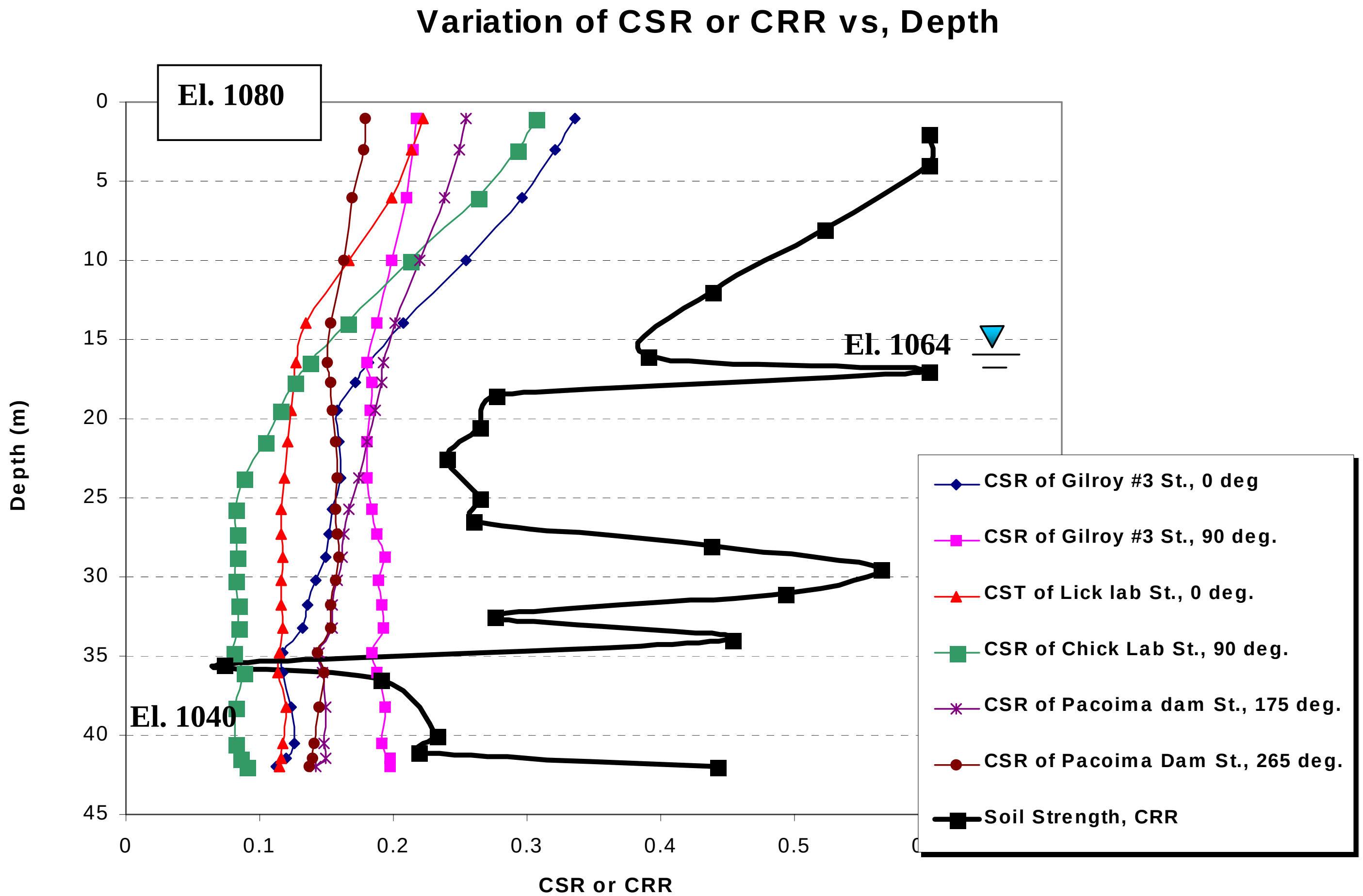




CSR AND CRR vs. DEPTH FOR BH 79-16 PROFILE

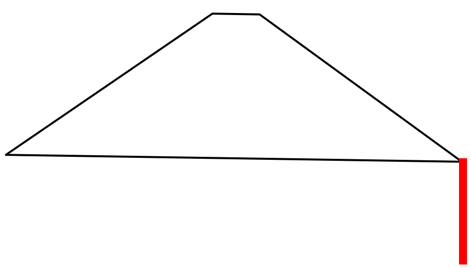
(Shoulder Section with Dam)

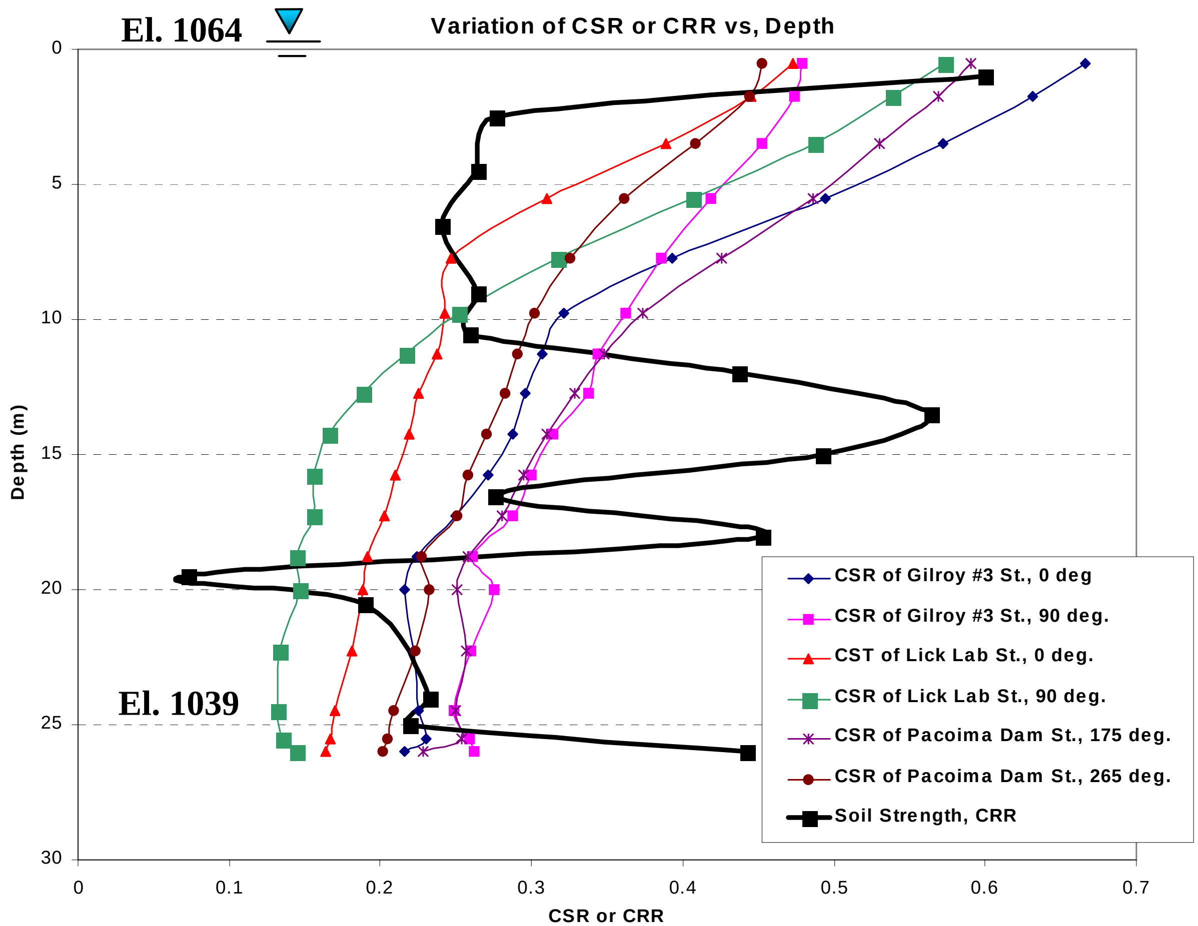




CSR AND CRR vs. DEPTH FOR BH 79-16 PROFILE

(Shoulder Section without Dam)





SUMMARY AND CONCLUSIONS

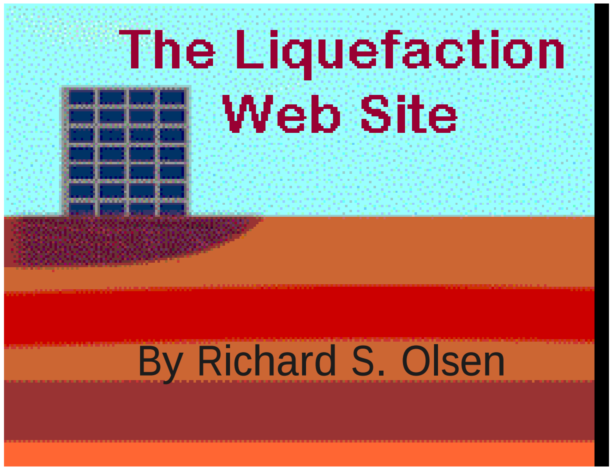
- **A screening level liquefaction assessment has been carried out for the Intermediate dam.**
- **Predicted liquefaction is marginal at the deep valley section.**
- **Predicted liquefaction is widespread in the shoulder area.**
- **Data base for soil property assessment is minimal.**

STATUS OF REPORT

- **Draft report issued January 29, 2004**
- **Title:**

"Liquefaction Assessment of the Intermediate Dam, Rose Creek Tailings Impoundment Yukon Territory"

THANK YOU FOR YOUR ATTENTION



- UBC Liquefaction Research Web site
- www.civil.ubc.ca/liquefaction/

THANK YOU FOR YOUR ATTENTION

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Engineering the Earth's Development

Preserving the Earth's Integrity

Anvil Range Mining Complex
Rose Creek Tailings Seismic Stability

Presentation by :
John Cunning
Golder Associates Ltd.

February 17, 2004

Rose Creek Tailings Seismic Stability

Study Objectives

- Define the need for seismic upgrade of the tailings impoundment to meet closure requirements
- If upgrade is required, provide conceptual upgrade options

Rose Creek Tailings Seismic Stability

Key Input provided by others

- Site Seismic Exposure based on Earthquake Hazard Studies by Gail Atkinson

- Liquefaction Assessment for Intermediate Dam foundation by Peter Byrne

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Rose Creek Tailings Seismic Stability

Scope

- Seismic stability assessment for the tailings impoundment based on
  - Tailings characterization and
  - Foundation liquefaction assessment
- Estimate extent of seismic deformations
- Options for seismic upgrade (if required)

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Rose Creek Tailings Seismic Stability

Liquefaction Assessment From CPT data

- Two stages
  - Assessment of whether or not liquefaction is initiated or triggered and
  - Assessment of what might happen if the soils liquefy, ie. deformation estimate

- Based on the NCEER Method of comparison of CSR due to the design seismic loading to the available CRR estimated from CPT data

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Rose Creek Tailings Seismic Stability

- CRR from CPT following Robertson and Wride (1998)
  - Reduce CPT to $(q_{c1N})_{cs}$, using variable exponent for normalization depending on I_c
  - Correct for fines content depending as a function of I_c to get CRR
  - Method suggests high fines content (silt) layers with normalized sleeve friction (F) >1% “likely non-liquefiable”

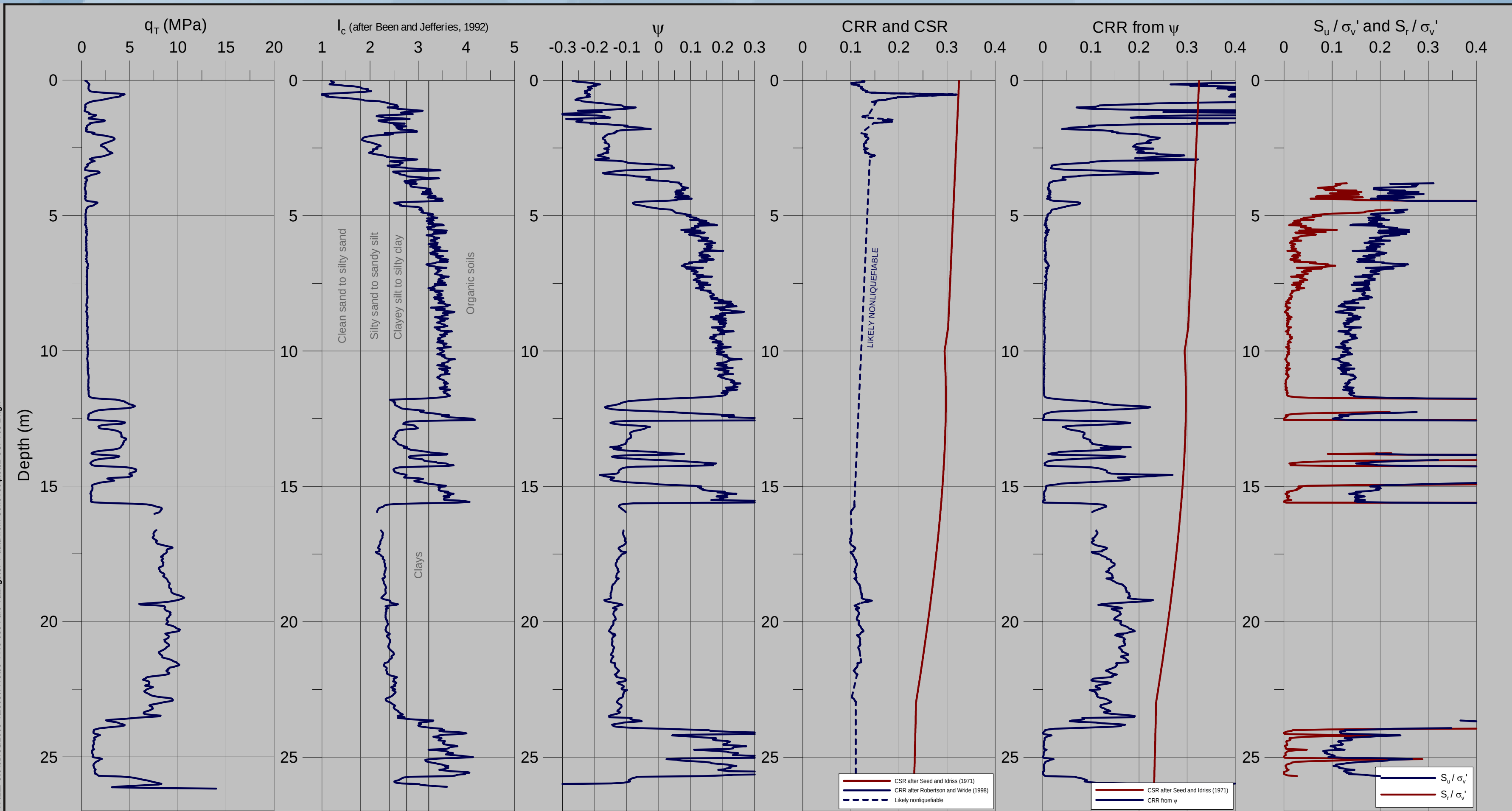
Rose Creek Tailings Seismic Stability

CRR from State Parameter

- State Parameter (ψ) is the difference between a soils current void ratio and the critical state void ratio at the same pressure
- ψ can be estimated from dimensionless CPT parameters following Been et al (1986, 1987)
- Need estimate of λ , either from CPT data or direct from laboratory data
- Liquefaction case history data reduced to a ψ vs. CRR plot
- No K_σ or K_c adjustments required, included in ψ from CPT

- CPT21 Data (Secondary Tailings Area)

Liquefaction Assessment CPT03-21



REVISION DATE: 2 Feb 04 BY: D Klassen GRAPHER FILE: O:\Active\2003-4\20031413\03-1413-080 Faro Tailings\CPT data from ConeTec\plots2-SCPT03-21.grf

Notes

1. For record of CPT see Appendix III
2. I_c values and zone boundaries after Been, K. and Jefferies, M.G. 1992. Systematic CPT interpretation. *In* Predictive Soil Mechanics: Proceedings of the Wroth Memorial Symposium, Oxford, UK, pp. 121-134
3. ψ after Plewes, H.D., Davies, M.P., and Jefferies, M.G. 1992. CPT based screening procedure for evaluating liquefaction susceptibility. *In* Proceedings of the 45th Canadian Geotechnical Conference, Toronto, Ont., pp. 4:1–4:9. Adjusted for seismic CPT data and Golder laboratory test data
4. Seismic results based on a_{max} / g = 0.5 and magnitude 7.0 (Gail Atkinson, "Draft Seismic Hazard Assessment for Faro, YK", Dec. 23, 2003)
4. CSR after Seed, H.B., and Idriss, I.M. 1971. Simplified procedure for evaluating soil liquefaction potential. Journal of the Soil Mechanics and Foundations Division, ASCE, **107**(SM9): 1249-1274.
5. CRR after Robertson, P.K., and Wride (Fear), C.E. 1998. Evaluating cyclic liquefaction potential using the cone penetration test. Canadian Geotechnical Journal, **35**: 442–459.
6. CRR estimated from ψ (see text of report)
7. S_u estimated from q_T using N_{kT} = 12 (see text of report)
8. S_r estimated from ψ using λ = 0.11, M = 1.2, K_0 = 0.7 (see text of report)

PROJECT
SRK CONSULTING INC.
ROSE CREEK TAILINGS FACILITY
ANVIL RANGE MINING COMPLEX, YUKON

TITLE
LIQUEFACTION AND RESIDUAL STRENGTHS FROM CPT DATA

Golder Associates

PROJECT No.	03-1413-080		FILE No. plots2-SCPT03-21	
DESIGN	DRK	29 JAN 04	SCALE NTS	REV.
CADD	DRK	29 JAN 04	**SCPT03-21**	
CHECK	--	--		
REVIEW	--	--		

Rose Creek Tailings Seismic Stability

Key Results

- Both methods predict triggering of liquefaction of the coarse tailings zones
- CRR from CPT following Robertson and Wride (1998) indicate fine tailings zones likely non-liquefiable
- State parameter approach indicates fine tailings zones liquefiable – consistent with high positive state parameter and very high excess pore pressures during CPT penetration

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Rose Creek Tailings Seismic Stability

Post seismic deformation potential

- Approached is to estimate post liquefaction strength
- For fine tailings
  - CPT Results indicate undrained S_u/σ'_v ratios in 0.1 to 0.2 range
  - Residual S_r/σ'_v ratios from ψ generally do not exceed 0.01
- For Coarse tailings
  - State parameter > -0.1 (dense) indicates S_r/σ'_v >0.25

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Rose Creek Tailings Seismic Stability

Status - Draft Seismic Stability Report Issued February 9, 2004

- Presented Methodologies for determining CRR from CPT data
- Prepared logs for all 36 CPT soundings showing
  - calculated liquefaction potential (CSR vs. CRR) using both methods
  - Calculated state parameter from CPT and Laboratory data
  - Estimated undrained strengths from both CPT data and residual strength from state parameter

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Closure Planning for Faro Mine Site Area

Hydrology

Presentation Topics

- Study Objective
- Scope of Work
- Results
- Key Conclusions
- Report Status

Study Objective

To assess Faro, Vangorda
and
Rose Creek hydrology

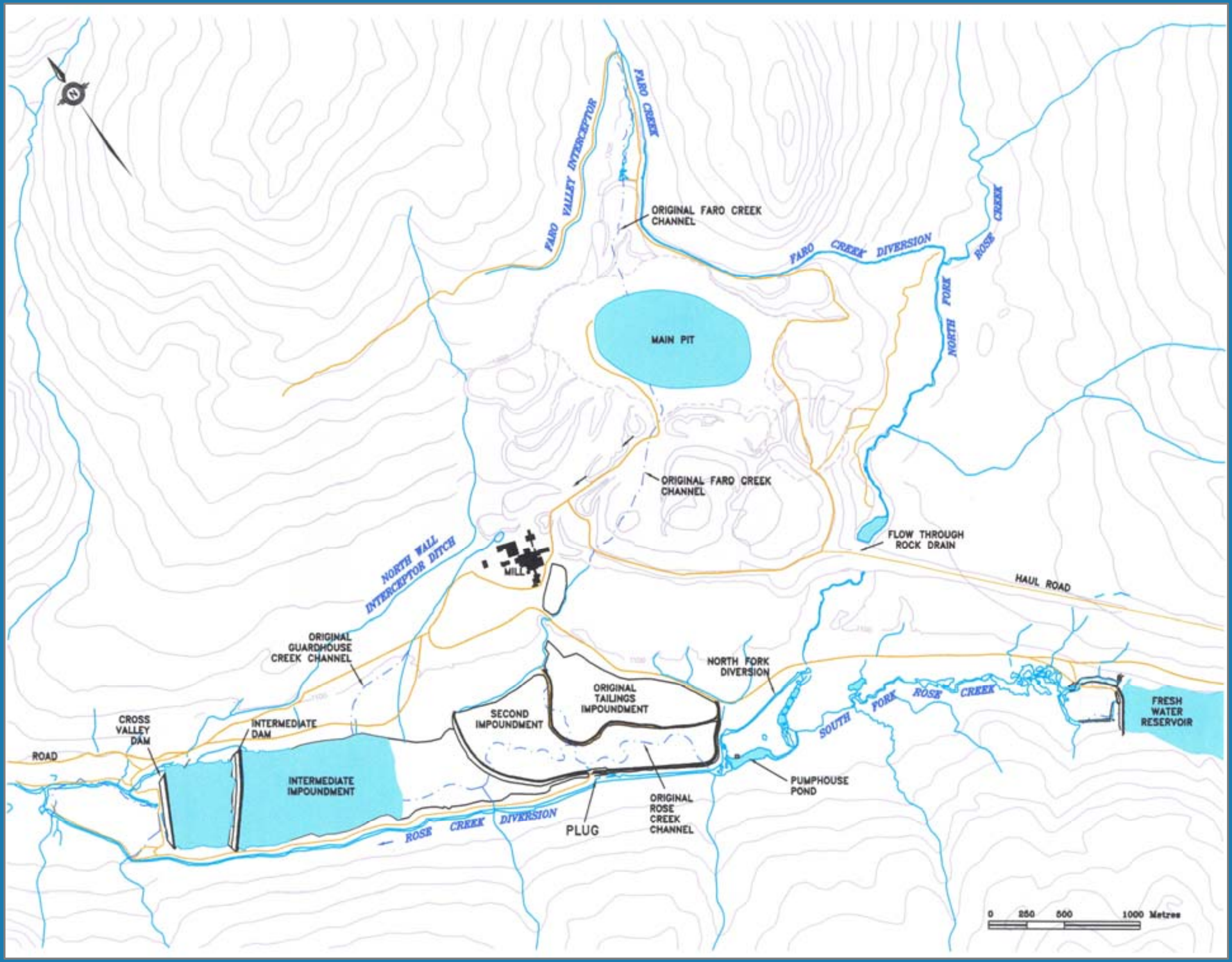
Scope of Work

- Review all flow data for Faro and Vangorda Creeks.
- Assess whether or not additional flow monitoring is required on Faro and Vangorda Creeks to better knowledge of runoff characteristics through correlation with Rose Creek flow data. The assessment to be made in the context of improving the level of flood predictions.
- Update flood estimates for mine site sub-basins up to the 1000-year flood.
- Review probable maximum flood estimates for Rose Creek.

Results

Faro Creek

- diverted in a channel to the northeast of the Mine Pit when the mine was developed
- drainage area of 16 km^2 at confluence with North Fork Rose Creek
- ungauged



Results

Vangorda Creek

- gauged by DIAND since 1977
- drainage area of 91 km^2 at DIAND gauge (Sta. 29BC003)
- gauge records summer flows only and does not always catch the annual peak
- second gauge established in 1999 by Mine Site personnel (Sta. V8) approximately 500 m downstream of the DIAND gauge.

Comparison of the two Vangorda Creek gauged data

- data collected at both gauges - June to July 1999 and May to June 200
- for 1999, daily discharges for Sta. V8 generally exceeds Sta. 29BC003 data by up to 280%
- for 2000, converse occurred, Sta. 29BC003 data generally exceeds Sta. V8 data by up to 160%

Results

Flow monitoring needs of Faro and Vangorda Creeks

Faro Creek:

- gauging station is not recommended as collection of 6 years or so of data would not significantly improve extreme flood estimates

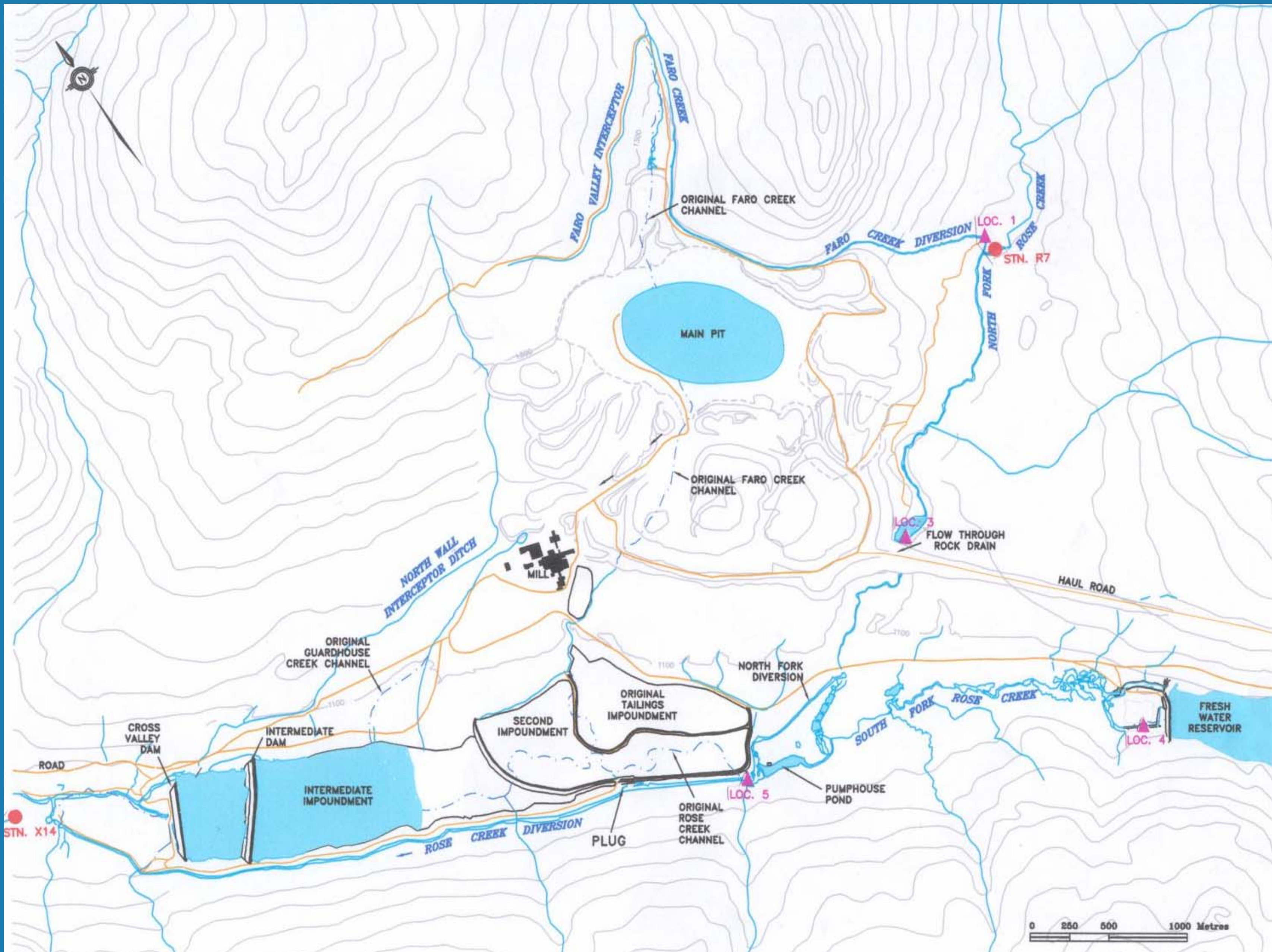
Vangorda Creek:

- Investigate discrepancies between the two data of the two gauging stations by reviewing field measurement procedures, data collection and discharge computations
- Simultaneous discharge measurements in spring of 2004 at the two gauging stations
- consider terminating discharge data collection at Vangorda Creek Sta. V8 and concentrating effort at the DIAND Sta. 29BC003

Results

Flood estimate for Mine Site sub-basins

- for return periods up to the 1000-year event
- by frequency analysis of annual flood peaks of 7 streamflow gauging stations in the Faro region
- most important data - Vangorda Creek DIAND 15-year gauge record as creek adjacent to Mine Site and small Vangorda drainage area comparable to sub-basin areas.



northwest hydraulic consultants nhc

Results

Flood estimates for Mine Site sub-basins

Mine Site Sub-basins	Drainage Area (km^2)	Flood Discharge (Instantaneous) Mean annual (m^3/s)	50-year (m^3/s)	100-year (m^3/s)	200-year (m^3/s)	500-year (m^3/s)	1000-year (m3/s)
North Fork Rose Cr. above Faro Creek Div. (Stn. R7)	95	9.2	37	45	54	67	77
Faro Creek Diversion above North Fork Rose Cr. (Loc.1)	16	1.9	7.7	9.4	11	14	16
North Fork Rose Cr. at Flow-through Rock Drain (Loc.3)	118	11	44	54	65	81	93
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67	6.8	27	33	40	49	57
Rose Creek above Rose Creek Diversion (Loc.5)	203	18	71	86	103	130	150
Rose Creek downstream of Rose Creek Div. (Stn. X 14)	230	20	79	96	115	145	167

Results

Probable Maximum Flood (PMF) Estimates for Rose Creek

- two most important inputs to PMF computations are:
  - probable maximum precipitation (PMP)
  - time to peak - time it takes for the entire watershed to contribute flow and runoff to reach a peak at the downstream location
- PMP of 200 mm adopted
- PMP based on the November 2002 PMP estimate by W.D. Hogg for the Wareham Dam spillway near Mayo
- times to peak were estimated from observation of site conditions and varied according to the drainage area raised to the power of 0.6. Adopted times varied from:
  - 3 hours for the 67 km^2 Fresh Water Supply Dam catchment, to
  - 6 hours for the 230 km^2 Rose Creek catchment downstream of the Cross Valley Dam
- time to peak estimates could be improved if short duration rainfall data were collected at the Mine site and compared with instantaneous discharge hydrographs of existing gauging stations

Results

PMF estimates for Rose Creek

Mine Site Sub-basins	Drainage Area (km^2)	PMF Peak Discharge (m^3/s)
North Fork Rose Creek at Flow-through Rock Drain (Loc.3)	118	504
Fresh Water Supply Dam (FWSD) catchment (Loc.4)	67	354
Rose Creek above Rose Creek Diversion (Loc.5)	203	690
Rose Creek downstream of Rose Creek Diversion (Sta. X 14)	230	783

Key Conclusions

- gauging station not recommended on Faro Creek
- resolve discrepancy between the data of the two Vangorda Creek gauging stations
- terminate discharge measurements at the Vangorda Creek gauging Station V8
- improve time to peak estimates by collecting short duration rainfall data at the Mine site, thereby improving PMF estimates

Status of Report

- Draft report issued to SRK / D & T
- Final report will be prepared upon receiving review comments

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Hydraulic Assessment of Rose Creek Diversion Canal

BGC Engineering Inc. (Gerry Ferris) &

Northwest Hydraulic Consultants (Gene Yaremko)

Background

- The Rose Creek Diversion Canal (RCDC) was constructed in two phases:
  - As part of the construction of the 2nd tailings impoundment [no design flood was found in available literature]
  - During construction of the Down Valley development [designed for the 1:500 flood or 160 m^3/s, 1:500 flood was updated in 2001 = 135 m^3/s]
- The Canal is a critical structure for water control in the Down Valley.
- Report provided is an early working draft.


Upper weir
Rose Creek
Lower weir


Original reach
1980 reach
Upper weir


Diversion
Dam
Original reach
Pumphouse pond

Study Questions?

- Can the canal handle the design flood?
- If it can't, why not and how can it be upgraded to handle the design flood.

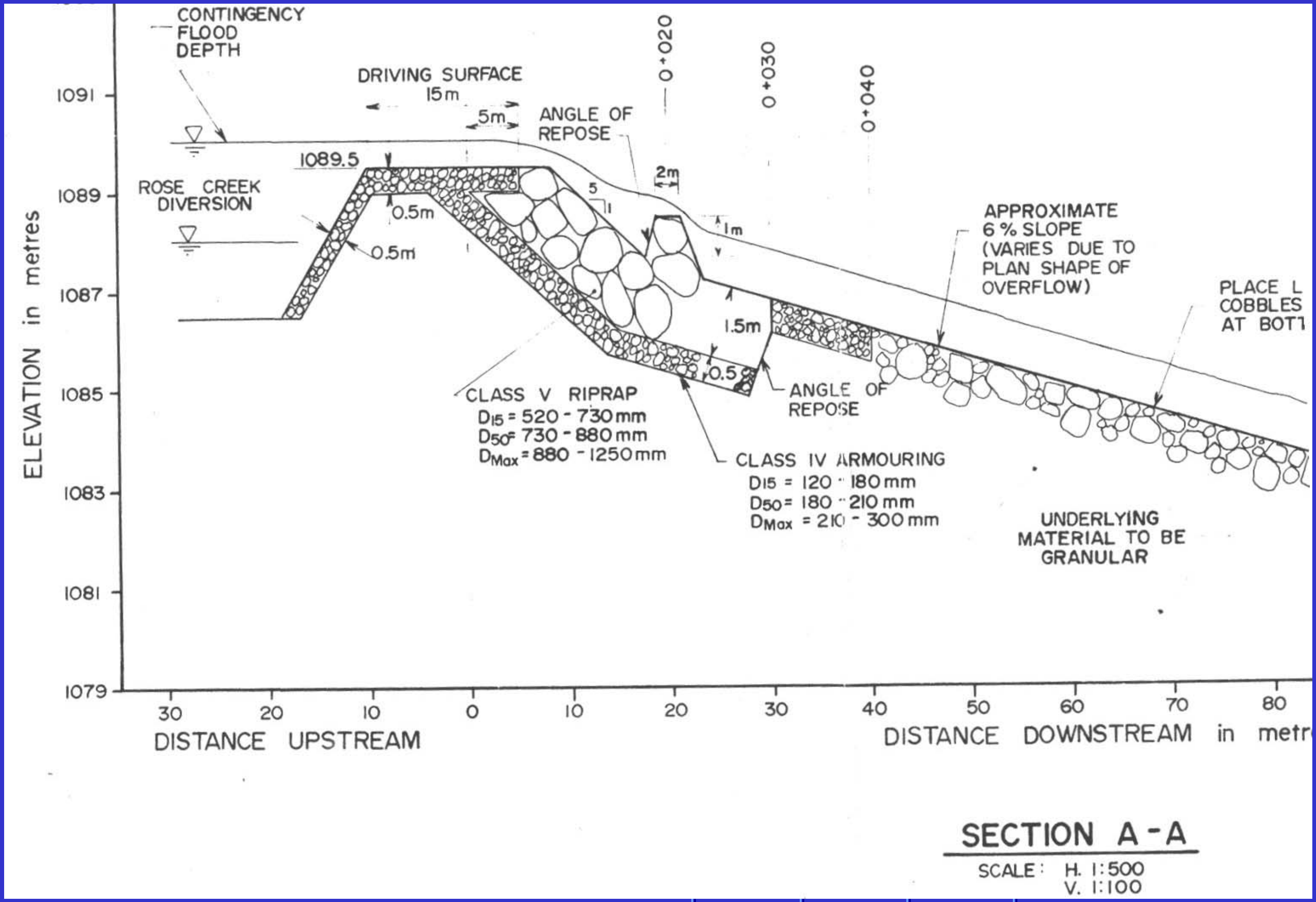
Failure Modes

- The following potential failure modes were identified for this assessment:
  - Inlet control.
  - Hydraulic capacity of the original diversion canal.
  - Erosion of the original diversion canal.
  - Overtopping/failure of the Diversion Dam.
  - Hydraulic capacity of the 1980 portion of the canal.
  - Erosion of the 1980 portion of the canal.
  - Overtopping of the weir section of the 1980 portion of the canal.

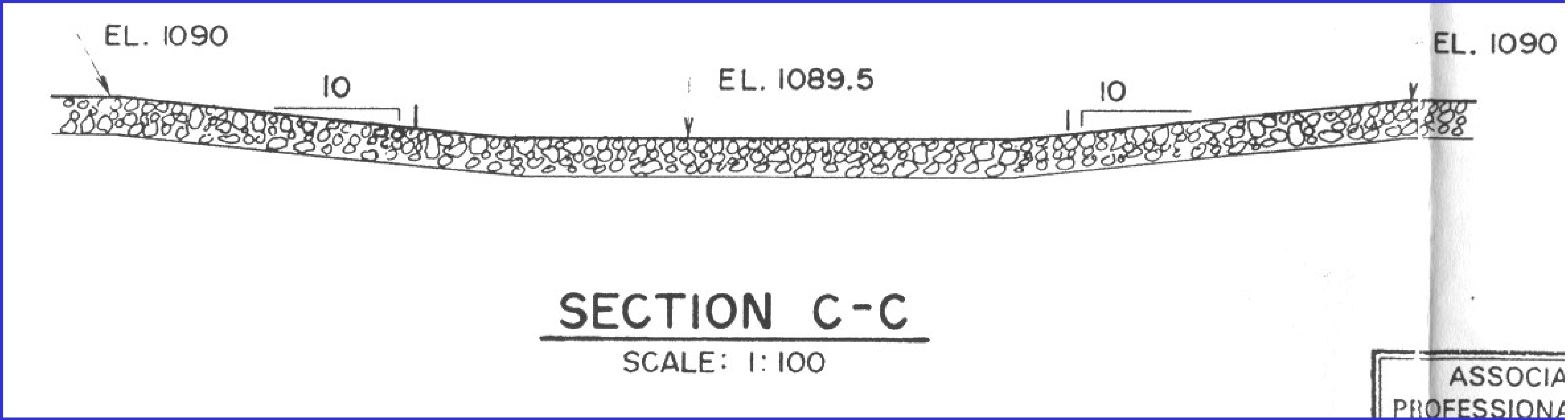
Methodology

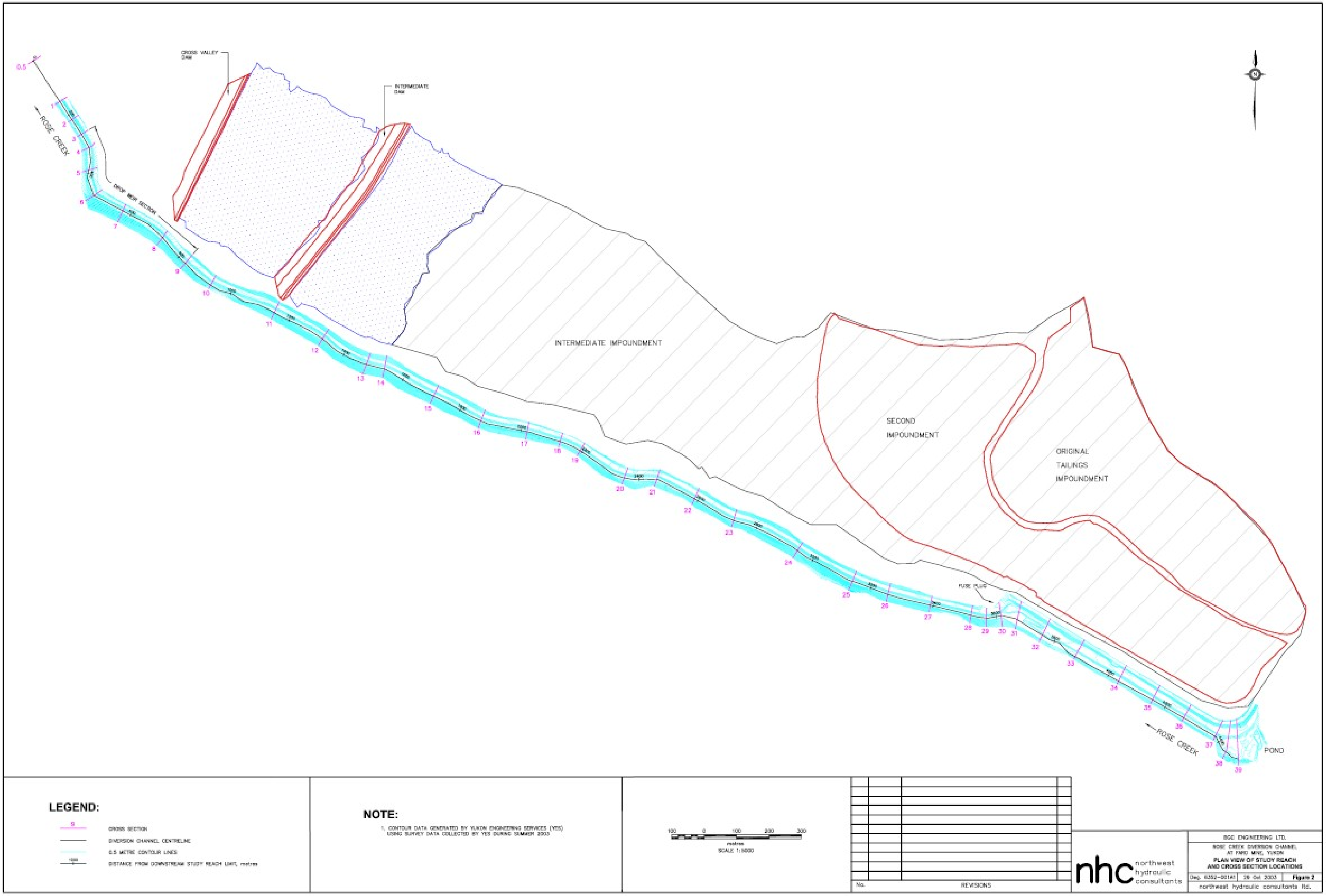
- Survey the backslope, channel and canal dike.
- Visual assessment of the Canal was performed, with specific attention paid to the condition of the channel bed and banks
- One dimensional numerical hydraulic model was constructed, HEC-RAS, using 39 cross-sections.
  - ice free model
  - 1.5 m thickness of ice blockage on base of channel

Diversion Dam Cross-Section



Diversion Dam Crest Long. Section





Broad-based, Geotechnical | BGC | Common Sense

Original Reach

Broad-based, Geotechnical BGC Common Sense

Original Reach Riprap

Broad-based, Geotechnical BGC Common Sense

Original Section – Outside of Canal

1980 Reach

Broad-based, Geotechnical BGC Common Sense

1980 Reach

1980 Reach Riprap

Broad-based, Geotechnical BGC Common Sense

Upper Weir & Lower Section

Broad-based, Geotechnical BGC Common Sense

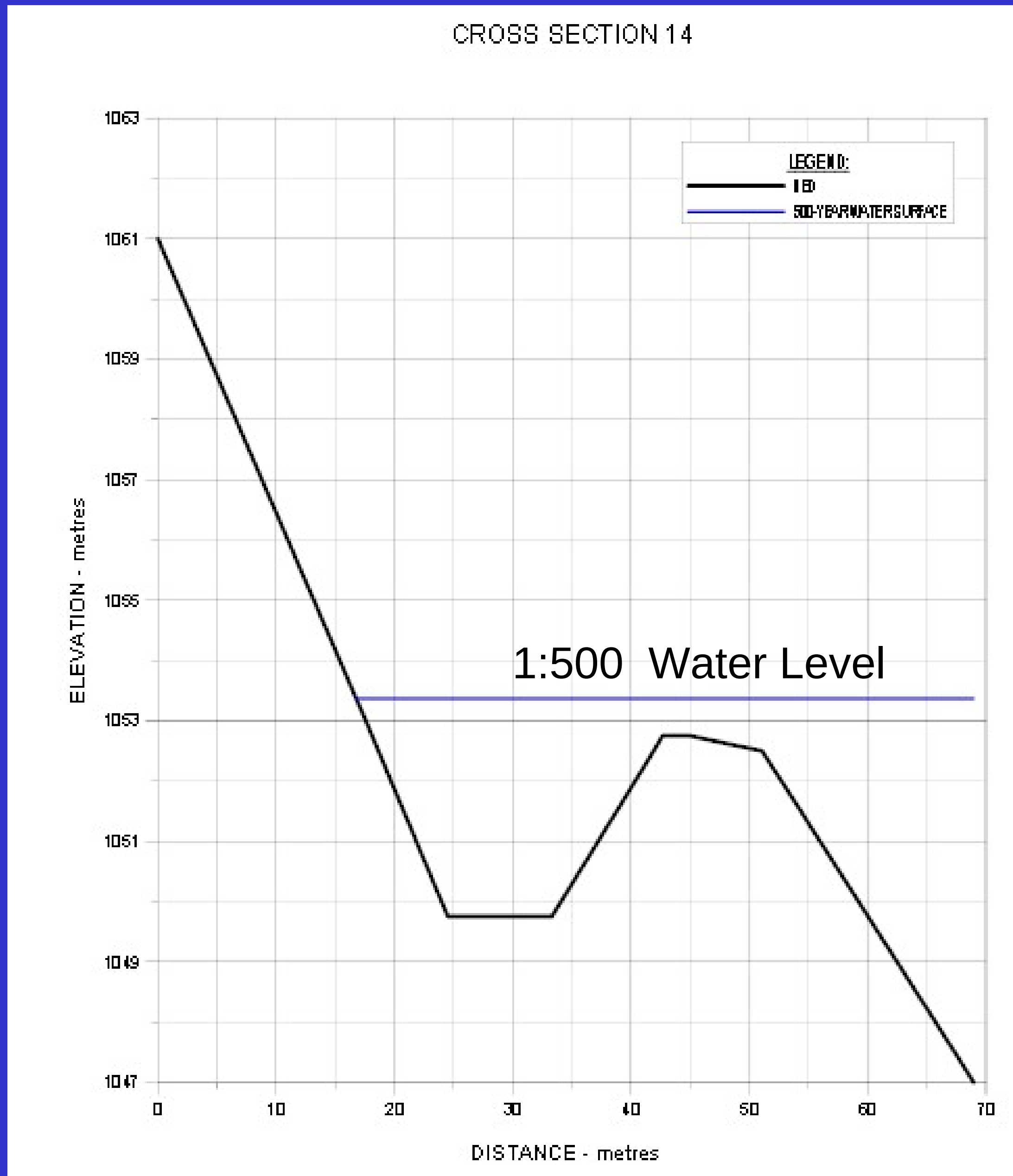
Riprap in Upper Weir

Lower Weir

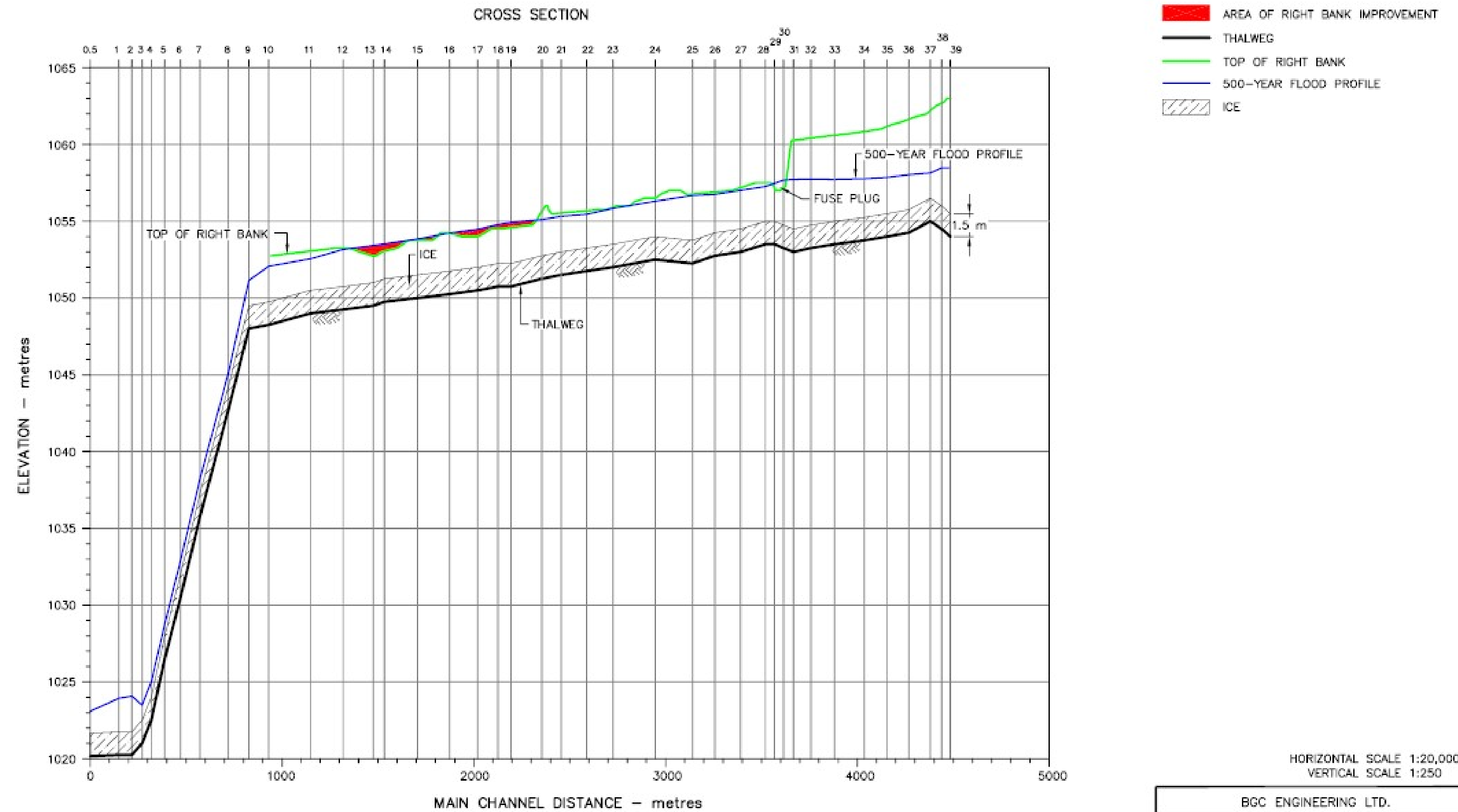
Broad-based, Geotechnical | B | G | C | Common Sense

Results

- In its present configuration the canal can not handle the 135 m^3/s design flood (1:500 year).
- The water will overtop the canal dike crest at a low point near the Intermediate Dam, prior to overtopping the Diversion Dam.
  - Ice free – 82 m^3/s, <1:100 year event
  - Ice blocked (1.5 m thickness) – 60 m^3/s, <1:50 year event



Broad-based, Geotechnical | BGC | Common Sense



BGC ENGINEERING LTD.		
ROSE CREEK DIVERSION CHANNEL AT FARO MINE, YUKON **500-YEAR FLOOD PROFILE WITH ICE IN CHANNEL**		
Dwg. 6352–002	19 Sept 2003	**Figure 4**
northwest hydraulic consultants ltd.		

Recommendations

- Raise the crest of the canal dike, by between 0.25 to 0.5 m for a length of about 1000 m (~2300 m^3 of material required)
- Place rip rap and bedding on the raised portion of the canal dike
- When bank is repaired, at 500 year flood, 12 m^3/s over Diversion Dam and 123 m^3/s down RCDC (clear channel conditions).
- Assess the bed size in the original canal reach, it is considered likely that erosion will occur in the original reach at the design flood; potential rip rap upgrade needed.

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Closure Planning for Faro Mine Site Area
Rose Creek Diversion
Hydrotechnical Studies

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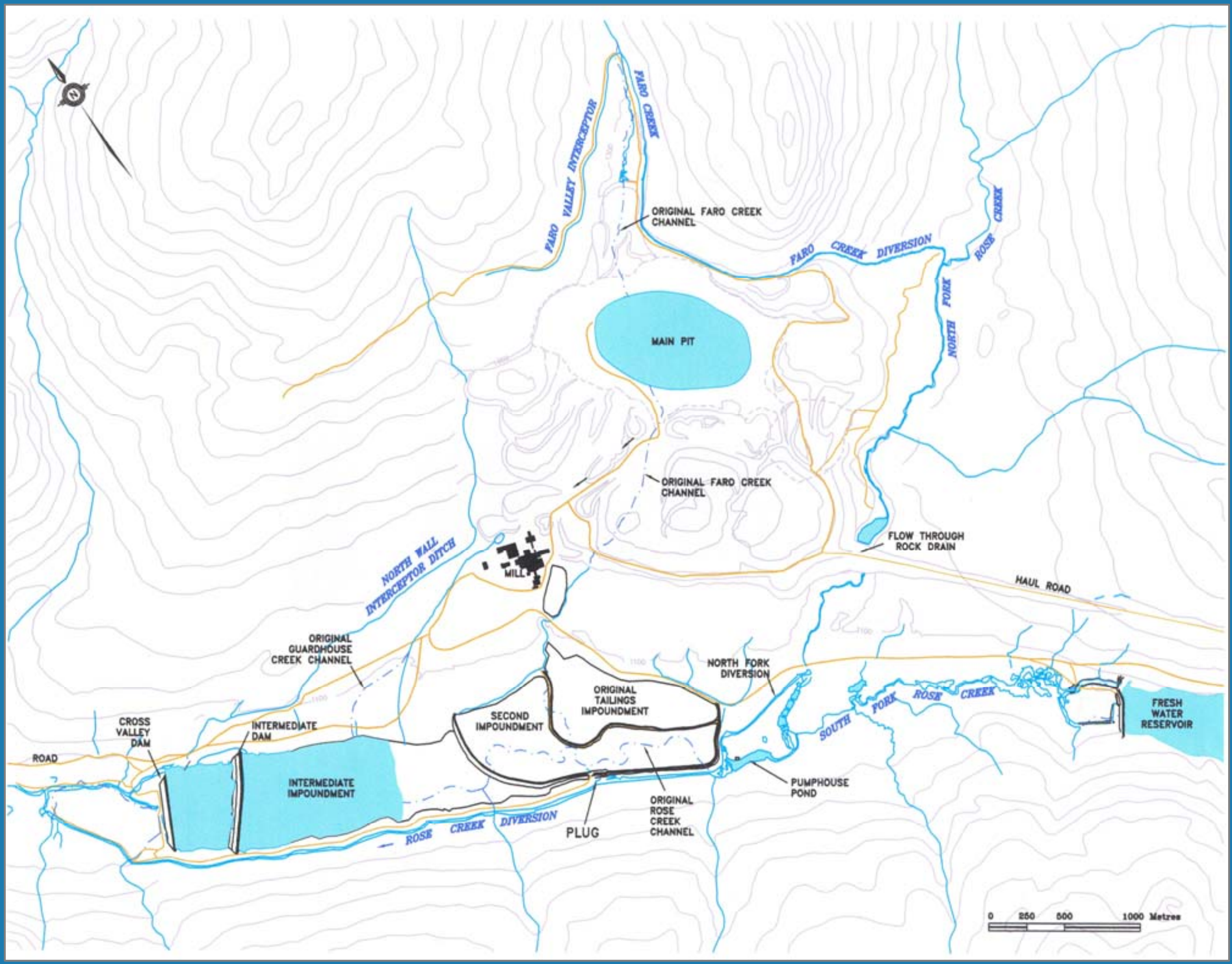
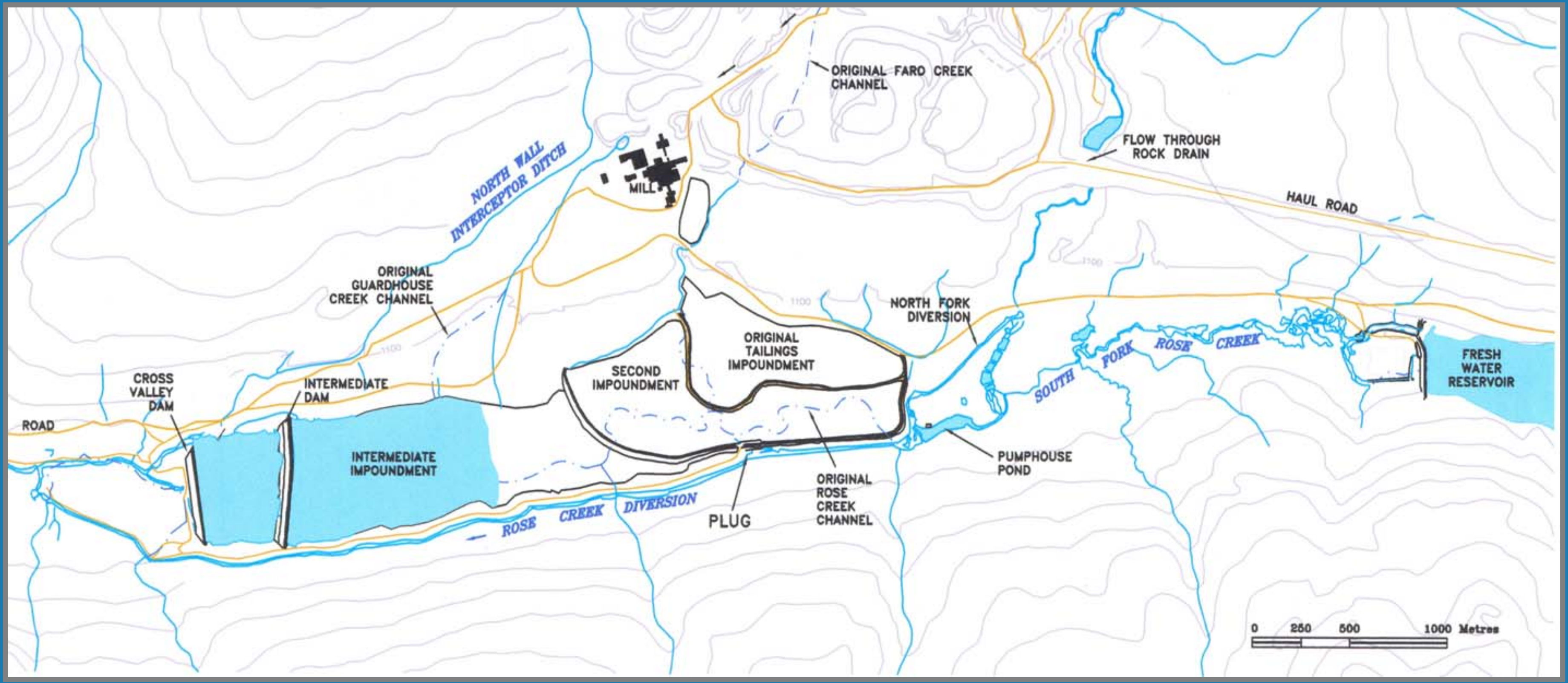


Presentation Topics

- Study Objective
- Scope of Work
- Hydrology
- Hydraulics

Study Objective

To safely pass extreme flood flows around or over the tailings impoundments and into Rose Creek downstream of the Cross Valley Dam.

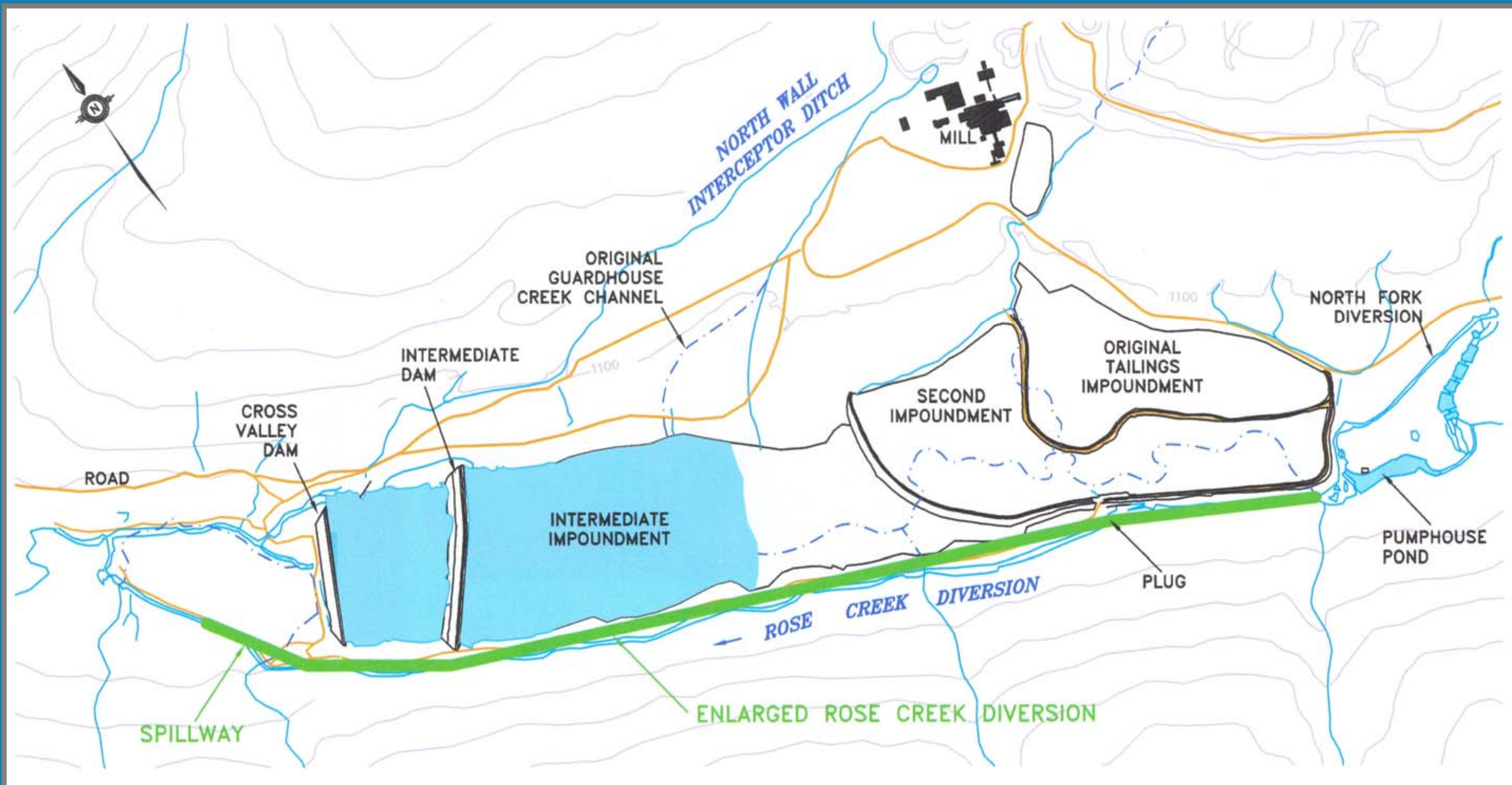


Scope of Work

- Update Probable Maximum Flood (PMF) estimates for Rose Creek.
- Develop preliminary designs and costs estimates for passing extreme floods up to the PMF round the tailings impoundments. Three options were assessed.

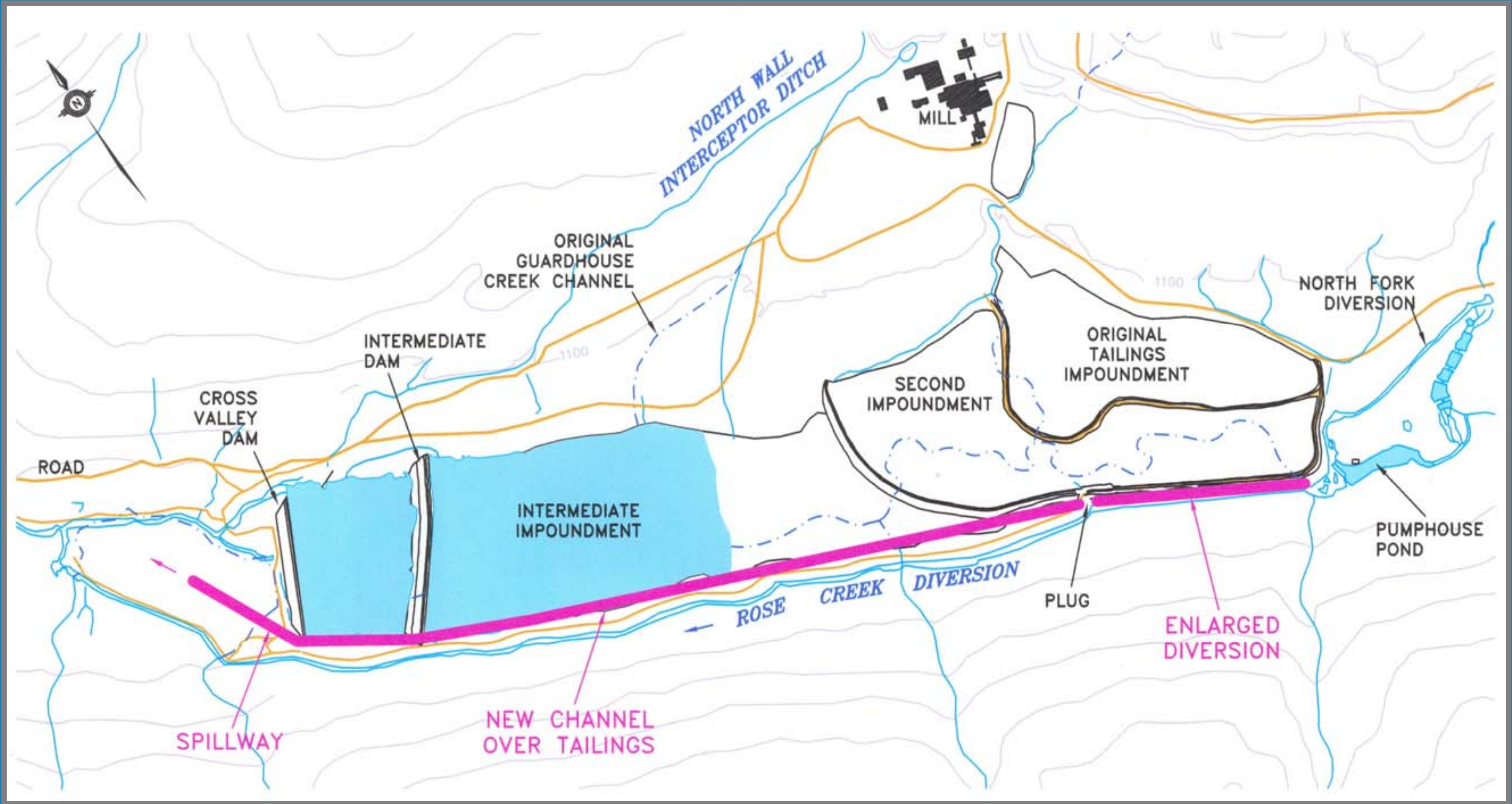
Option 1

- **Increase the size of the Rose Creek diversion channel along the south side of the tailings impoundments to convey the PMF.**



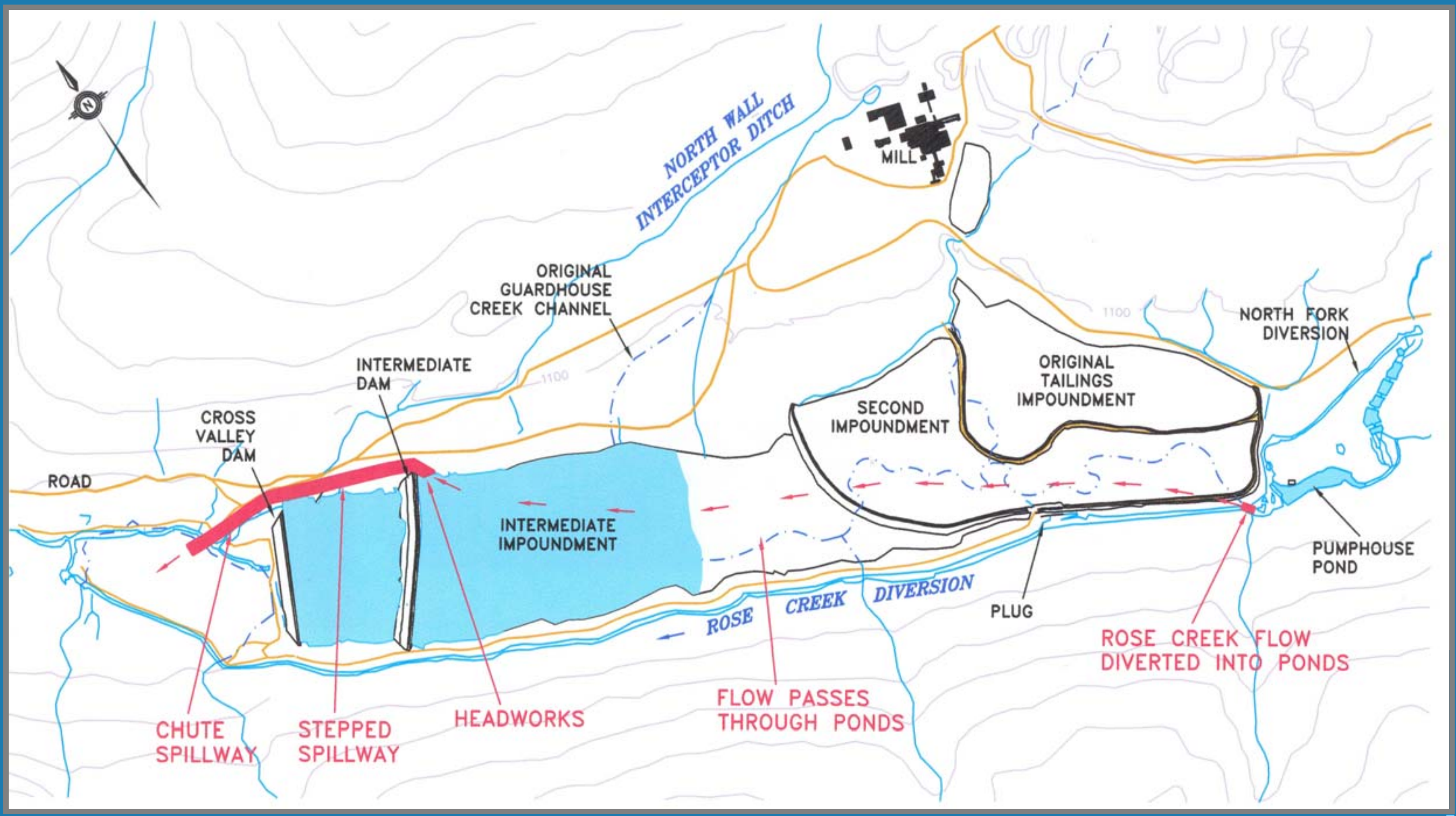
Option 2

- **Abandon the Rose Creek diversion channel downstream of the plug.**
- **From the plug, convey the PMF over the tailings to a new spillway by-passing the Intermediate and Cross Valley Dams.**



Option 3

- Remove tailings from the original, second and intermediate impoundments to el. 1042 m.
- Rose Creek flow to enter the impoundment area.
- Attenuated PMF to pass over a spillway located at the Intermediate Dam.



Hydrology

Design flood used for Rose Creek diversion:

- Probable Maximum Flood (PMF) of 730 m^3/s

PMF computed from:

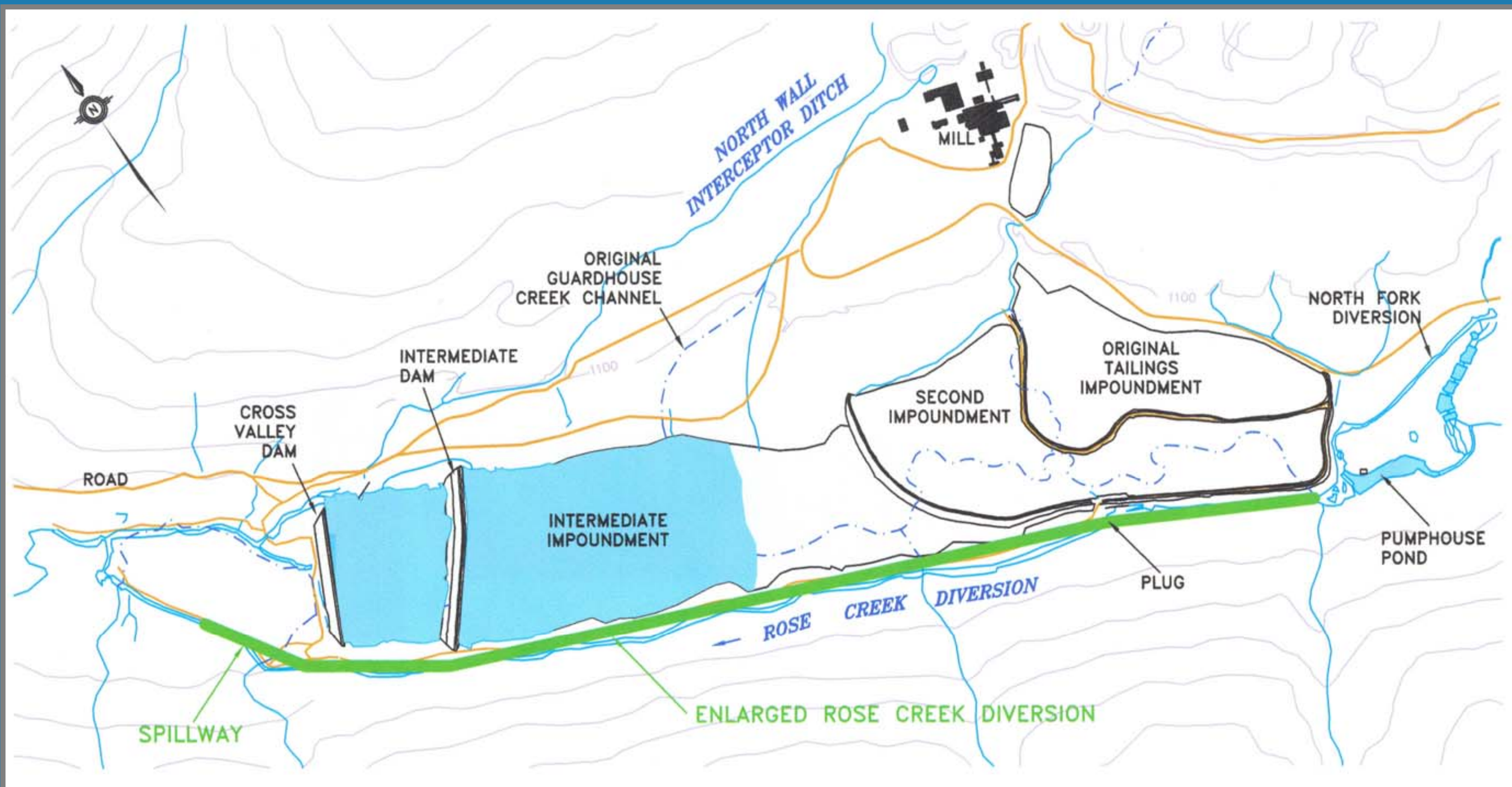
- Probable Maximum Precipitation (PMP) of 200 mm

and was based on the November 2002 PMP estimate for the Wareham Dam spillway near Mayo.

Hydraulics

Option 1

- Increase the size of the Rose Creek diversion channel along the south side of the tailings impoundments to convey the PMF.



Hydraulics

Design Summary - Option 1:

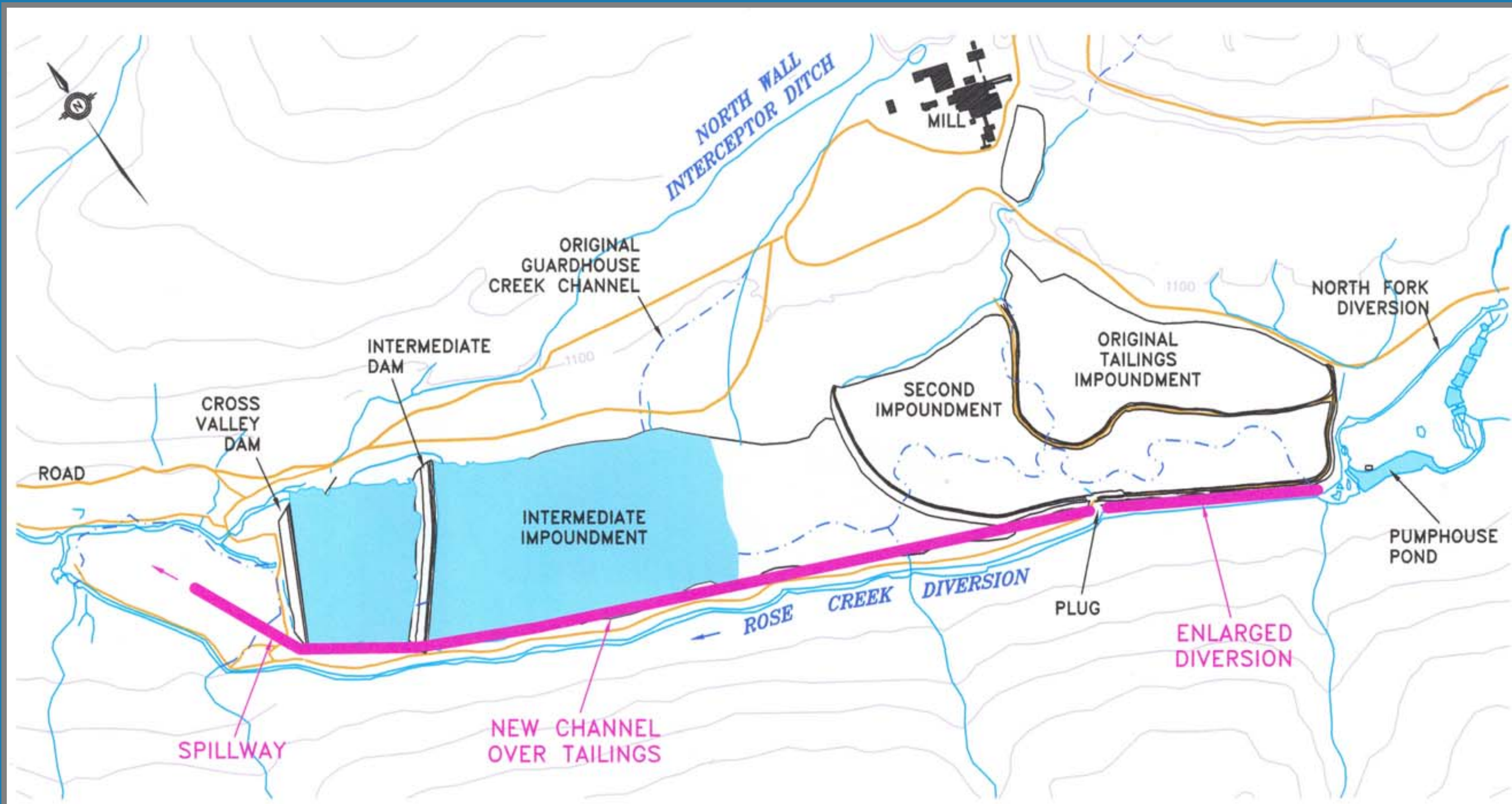
- right bank dike raised to accommodate PMF.
- channel boundary protected with rock riprap.
- flow conveyed in a concrete spillway down the steeply sloped section downstream of the Cross Valley Dam.
  - spillway chute width 30 m.
  - spillway length 300 m.
  - spillway slope 13.6:1 (horiz:vert).
  - stilling basin length 45 m.
- basin outflow into enlarged channel.
- 550 m long fish by-pass provided around the spillway.

Capital cost estimate: $32,100,000.

Hydraulics

Option 2

- Abandon the Rose Creek diversion channel downstream of the plug.
- From the plug, convey the PMF over the tailings to a new spillway by-passing the Intermediate and Cross Valley Dams.



Hydraulics

Design Summary - Option 2:

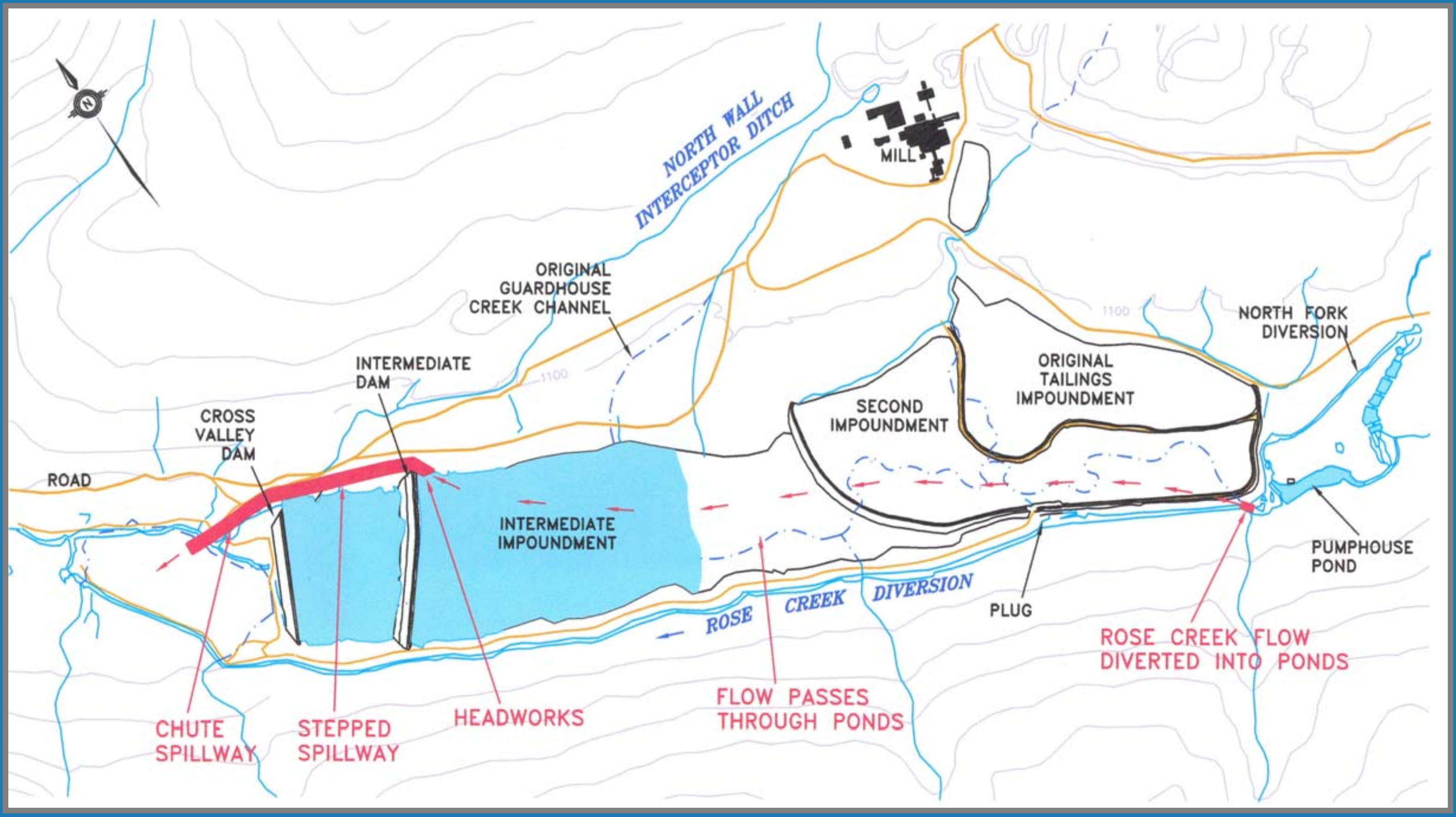
- right bank dike raised down to the plug to accommodate PMF.
- from plug, PMF diverted into a channel over the tailings to the Intermediate Dam.
  - channel length 2400 m; bed width 80 m.
- flow passes into spillway approach channel.
  - approach length 445 m; bed width 30 m
- at the Cross Valley Dam flow enters concrete spillway.
  - spillway length 120 m.
  - spillway slope 5:1 (horiz:vert).
  - stilling basin length 42 m.
- basin outflow into downstream Rose Creek valley.
- 900 m long fish by-pass provided around the spillway.

Capital cost estimate: $59,900,000.

Hydraulics

Option 3

- Remove tailings from the original, second and intermediate impoundments to el. 1042 m.
- Rose Creek flow to enter the impoundment area.
- Attenuated PMF to pass over a spillway located at the Intermediate Dam.



Hydraulics

Design Summary - Option 3:

- Rose Creek PMF flow enters the dredged impoundment ponds at the Pumphouse Pond.
- Attenuated flow exits impoundment ponds at the north abutment of the Intermediate Dam at spillway headworks.
  - headworks weir width 55 m
  - stepped spillway length 480 m; chute width 30 m
  - chute spillway length 50 m
  - spillway slope 5:1 (horiz:vert)
  - stilling basin length 32 m
- basin outflow into downstream Rose Creek valley.
- 900 m long fish by-pass provided around the spillway.

Capital cost estimate: $32,600,000.

RCDC Scoping of Closure Options - Geotechnical

Home

- Holger Hartmaier with NHC
- Objectives
- Scope of Work
- Results
- Key Conclusions
- Status of Report

Study Objectives

- Provide geotechnical input for conceptual design of 3 closure scenarios to handle PMF flows down Rose Creek Diversion Channel (RCDC).
- Preliminary cost estimates.
- Recommend best option.

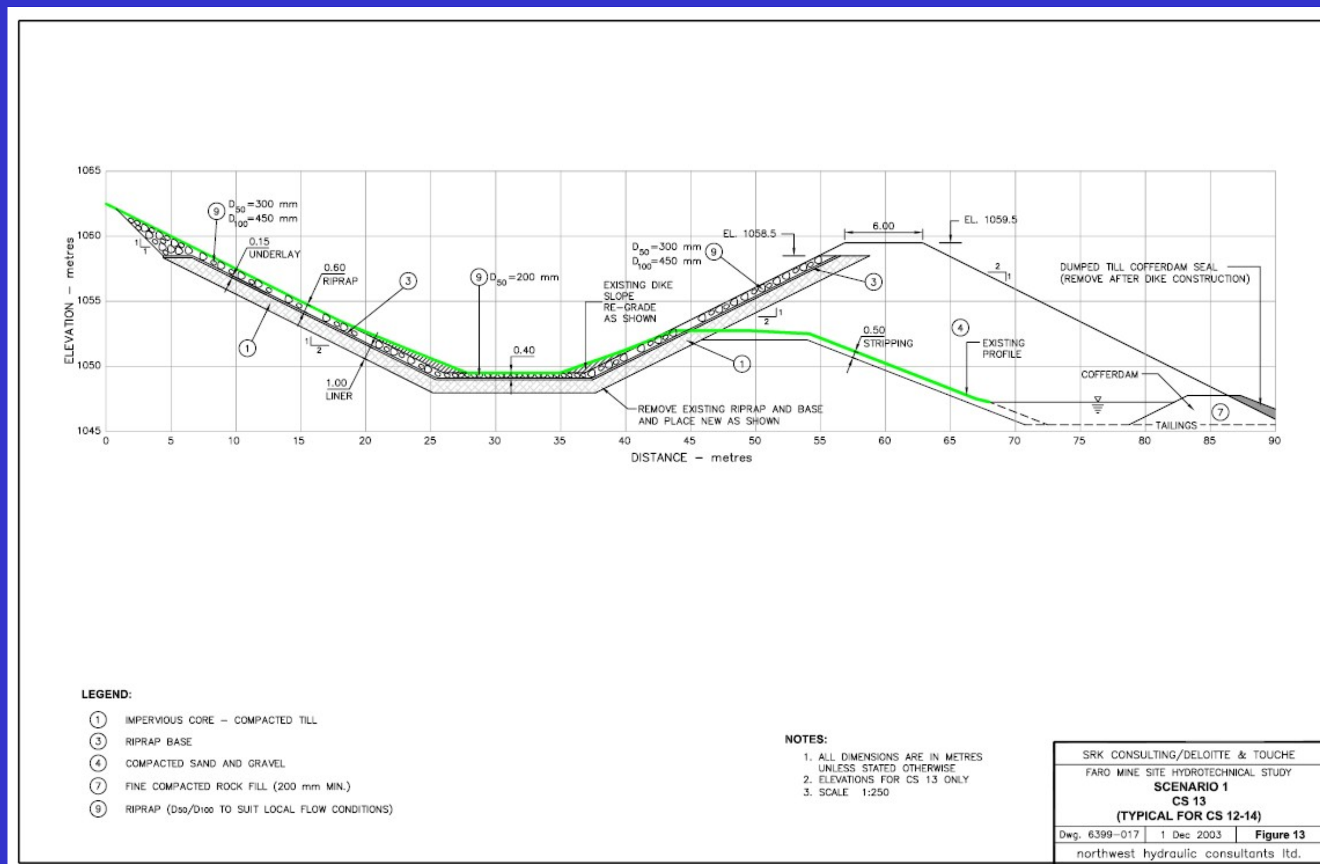
Scope of work

- Desk top study- review of existing geotechnical data.
- Develop conceptual cross-sections based on hydraulic/hydrology parameters provided by NHC.
- Estimate quantities and capital costs for each Scenario.

Results

- Considered 3 scenarios plus 2 variants.
- Compiled data on existing canal and dike design and current conditions.
- Compiled data on tailings disposal facility, including tailings properties, hydrogeology, thermal conditions.
- Prepared conceptual cross-section drawings.
- Estimated quantities and costs for earthworks components.

Scenario 1: Increase existing capacity of canal by raising dike.



Scenario 1- Geotechnical issues

- Existing vegetation on left bank will be left.
- Extend existing dike slope to minimize increasing footprint of dike.
- No "as-built" information available on existing dike.
- An impervious liner will be constructed on new dike. Extent of liner depends on local seepage conditions.

Cost Estimate

- Capital cost $16.1 million (for earthworks).
- All estimates exclude mobilization/demobilization, escalation and extra work allowances.
- Final engineering and construction supervision not included.
- This Scenario requires a concrete lined spillway in drop weir section- Scenario 1b.

Scenario 1a - Widen existing channel by 5 m

- Expand channel width by 5 m into left (south bank.
- Side slopes cut at 2 H : 1 V.
- Volume of excavation 124,000 m^3
- Clearing and grubbing of left bank required.
- Still requires dike extension on right to pass PMF flows.

Scenario 1a- Cost Estimate

- $15 million for earthworks component.
- Still requires a concrete spillway in drop weir section.
- No allowance for additional excavation and placing of thermal protection on left bank slopes.
- This Scenario offers no cost advantage over Scenario 1.

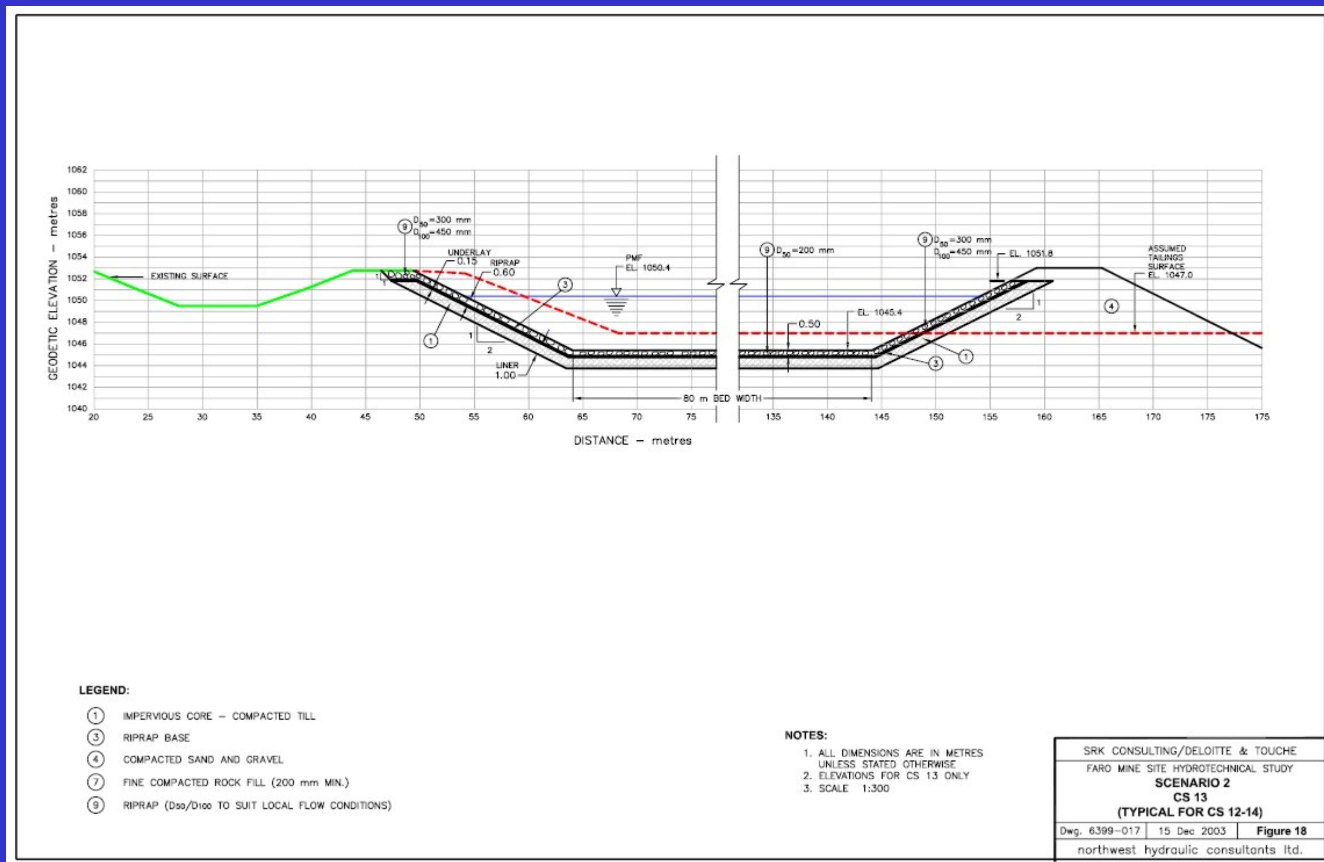
Scenario 1b- Raise dike and construct spillway

- Raise dike as in Scenario 1.
- Replace rock drop weir section with concrete spillway and chute.
- Incorporates a fish by-pass channel.

Scenario 1b- Cost Estimate

- Earthworks component: $ 13.4 million.
- Spillway structure: $ 17.4 million.
- Outlet channel: $ 0.4 million
- Fish by-pass: $ 0.9 million
- Total: $32.1 million

Scenario 2- Route PMF over engineered cover on Intermediate Impoundment



Scenario 2- Geotechnical Issues

- Routing PMF flood on top of dry tailings cover contradicts philosophy of dry cover.
- Increases potential for infiltration of oxygen rich water.
- Portion of new channel constructed on tailings will need to be fully lined.
- A Geogrid layer is included at the base of the new dike to minimize deformation of the cover.

Geotechnical Issues- continued

- Assumed that Intermediate Pond will be drained for construction of dry cover.
- Channel excavation requires removal of cap and underlying tailings, that may be saturated.
- Additional drainage/dewatering of tailings may be required in advance of construction.

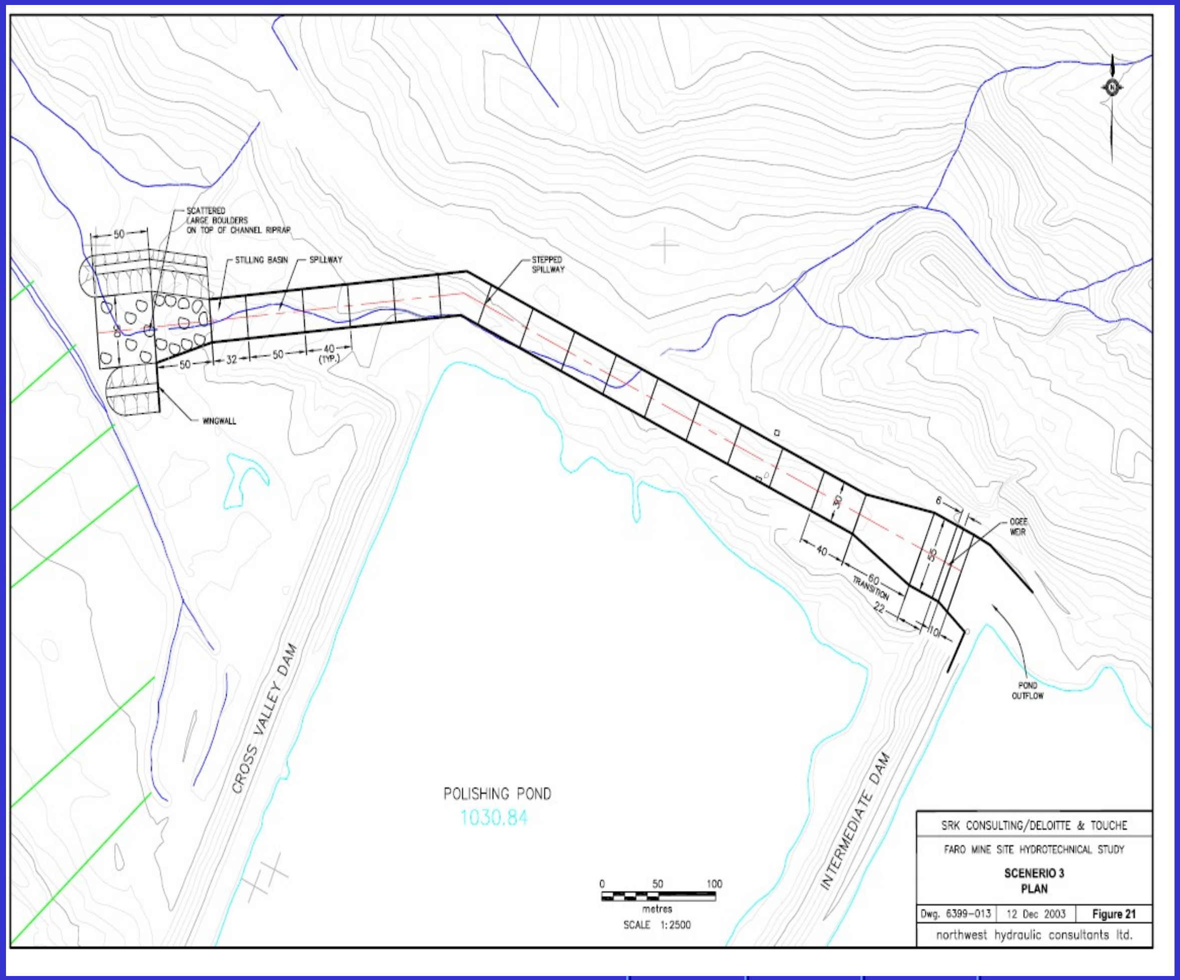
Scenario 2- Cost Estimate

- Earthworks component: $29.5 million.
- Spillway structure: $28.7 million.
- Outlet Channel: $0.4 million.
- Fish by-pass: $1.4 million.
- Total: $59.9 million

Scenario 3- Excavate tailings and route PMF into water cover.

- Removal of tailings by others to el 1042 m.
- Construct new headwall at Pumphouse Pond.
- Flood will be routed over lowered tailings with water cover.
- RCDC downstream of fuse plug dam will be used as fish by-pass.
- New spillway on north side of Intermediate Dam

Scenario 3


SCATTERED LARGE BOULDERS ON TOP OF CHANNEL RIPRAP
STILLING BASIN
SPILLWAY
STEPPED SPILLWAY
WINGWALL
OGEE WEIR
TRANSITION
POND OUTFLOW
CROSS VALLEY DAM
INTERMEDIATE DAM
POLISHING POND
1030.84
0 50 100
metres
SCALE 1:2500
SRK CONSULTING/DELOITTE & TOUCHE
FARO MINE SITE HYDROTECHNICAL STUDY
SCENERIO 3
PLAN
Dwg. 6399-013
12 Dec 2003
Figure 21
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Scenario 3- Geotechnical issues:

- Favourable topographic and foundation conditions for spillway on north side.
- Intermediate Dam will require a seismic upgrade (common to all Scenarios).
- Minimal additional earthwork components required for this Scenario.

Scenario 3- Cost estimate

- No earthworks component.
- Upstream headwall: $ 0.2 million
- Spillway structure: $31.1 million
- Outlet channel: $0.4 million
- Fish by-pass: $0.9 million
- Total: $32.6 million

Cost Estimate Summary

- **Option 1 (Scenario 1b)- $32.1 million**
- Option 2- $59.9 million
- **Option 3- $32.6 million**

(Options 1 and 3 are identical within the accuracy of the cost estimate. Option 1 has a higher risk of cost increase than Option 3 due to the amount of work involved)

Recommendation

Option 3 is favoured because:

- Removal of significant volume of tailings.
- Seismic upgrading will be required in any case.
- No increase in existing mine disturbed footprint. Upgraded spillway is located within existing spillway.
- Minimal new information required for design.

Key Conclusions

- Scenario 1b is the only viable option to increase capacity of existing RCDC.
- Scenario 2 incompatible with dry cover and too expensive.
- Scenario 3 is lowest risk cost option overall for routing of PMF flow (assuming tailings removal by others).
- Seismic upgrading required in any case.

Status of report

- Draft report issued to NHC/SRK/D&T.
- Final report will be prepared following receipt of comments.

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Tailings Relocation Hydraulic Method

Literature Research & Evaluation

Literature Research

- 2 searches of international scientific and engineering data bases
- Truck and shovel common
  - Arid settings, small deposits, unconfined deposits
- Hydraulic methods
  - Very few references

Case Histories

- Pinto Valley, EPA project, 38 million tons
- Eastmaque Gold, Kirkland Lake, Ont.
- Giant Mine, Yellowknife, 2.3 million tons
- ERG Project, Timmins, Ont., < 1 million ? tons
- South Africa, 8 sites, through put 0.2 to 1.8 million tons <u>per month</u>

Case Histories

- Hydraulic mining is not common in N.A.,
- S.A. experience suggests that it is a viable technology – arid working conditions

Hydraulic Re-mining At Faro

Three independent steps

1. Liberate the tailings
2. Get the tailings into the pipe
3. Transport the material to the pit

Process must be continuous

Hydraulic Re-mining At Faro

- Monitors must be continuously moved
- Mining in horizontal slices, up to 10 m high
- Sumps near to monitors
  - Dredge type or submersible type pumps
  - Variable density
  - Debris
  - Original ground (rocks, vegetation, etc)

Hydraulic Re-mining At Faro

- Pumping to pit
  - Moving tailings once in the pipe is standard technology
  - Common approach is low slurry density, < 20% solids

Hydraulic Re-mining At Faro

Low density slurry	High density slurry
■ Large volume of circulating water ■ Water management & energy cost ■ Typical equipment does not handle debris very well	■ About half the volume of water ■ Equipment can process debris ■ Booster needed to lift slurry up to pit

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Task 18a
Tailings Relocation Methods

Presented by Cam Scott, SRK

Content of Presentation

- Brief background on key contributors to study
- Issues and objectives
- Two options (total and partial relocation)
- Three methods (dredge, monitor, mechanical)
- For each method:
  - Contractor's scope
  - Recommended equipment
  - Mine plan
- Comparison of methods (risks and costs)
- Conclusions

Contributors

- Ernie Zuccolin, FRPD/EZC
  - Over 30 years of dredging & marine construction experience
- David Jansson, ECPM
  - Over 30 years of hydraulic monitoring experience, including South Africa and Chile with Fraser Alexander
- Keith Byram, Pelly Construction
  - Over 40 years of earthworks construction experience, including numerous projects at Faro & Vangorda Plateau since 1969, i.e.
- Pat Bryan, SRK Associate
- John Chapman, SRK

Issues

- There are risks associated with the Rose Creek tailings impoundment:
  - Physical stability
  - Geochemical stability

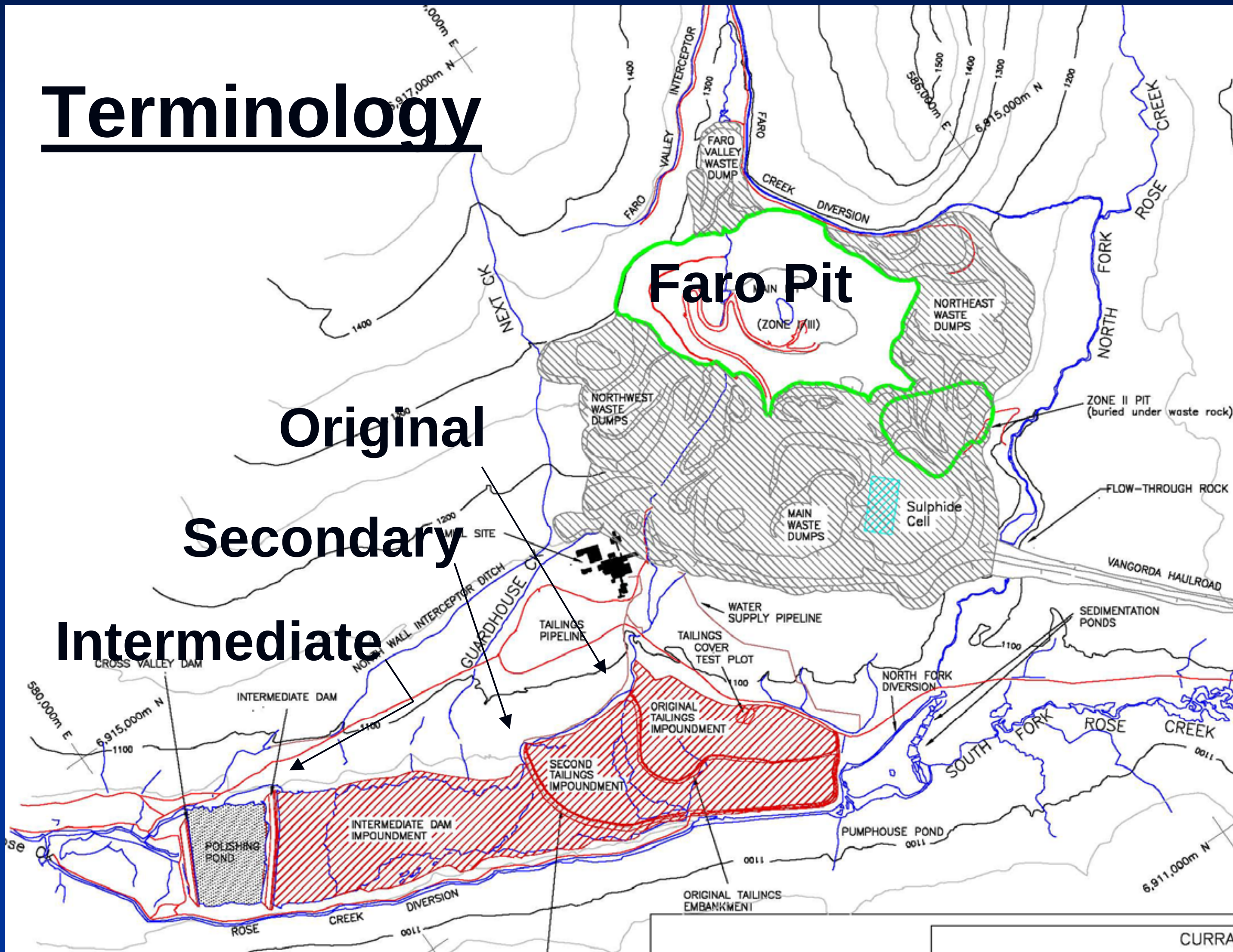
- Should all or part of the tailings be relocated?
- And, if so, how and at what cost?

Study Objectives

- Develop conceptual designs and preliminary costs for various systems to relocate all or a portion of the tailings to the Faro Pit.
  - Dredging
  - Hydraulic monitoring
  - Mechanical methods

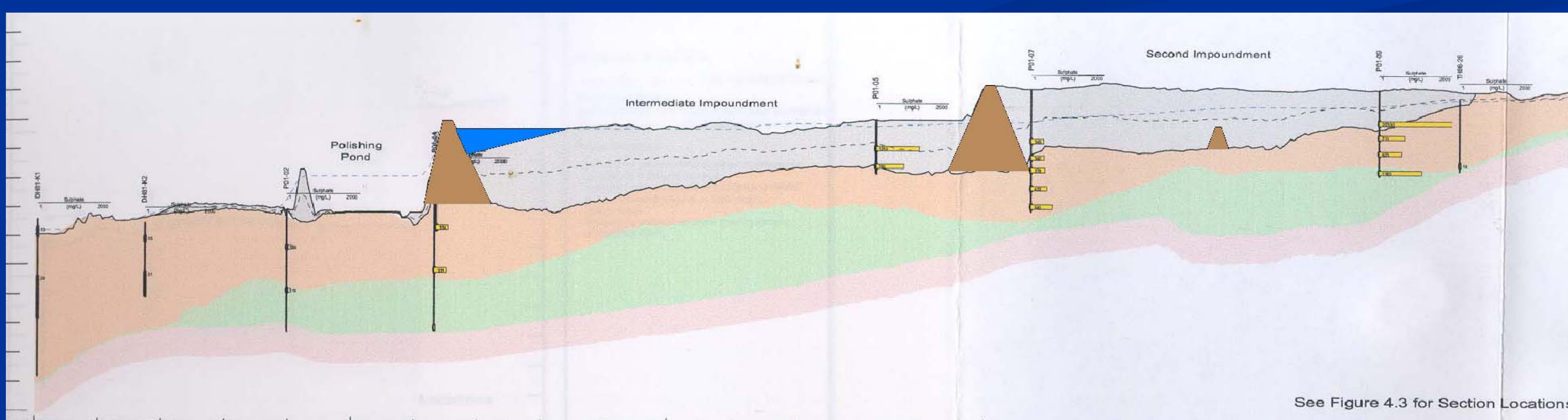
- Consider water management and water treatment issues.

Terminology



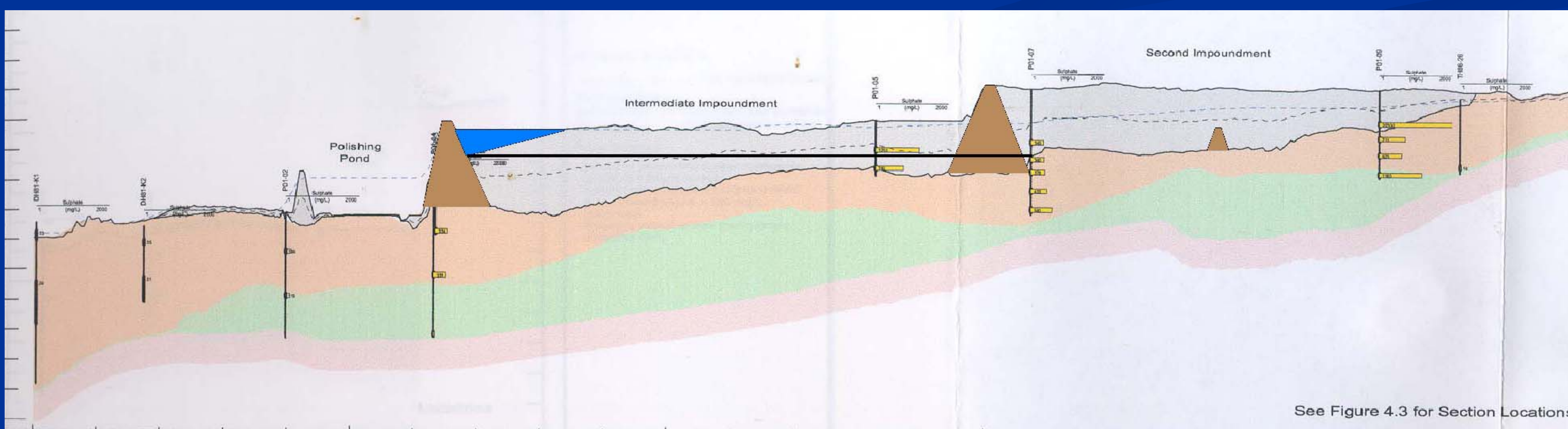
Two Relocation Options

- Total tailings relocation (57 million tonnes)
  - Relocate all tailings to the Faro Pit
  - Remove all or part of original and secondary dams (and breach the Intermediate Dam & CV Dam)



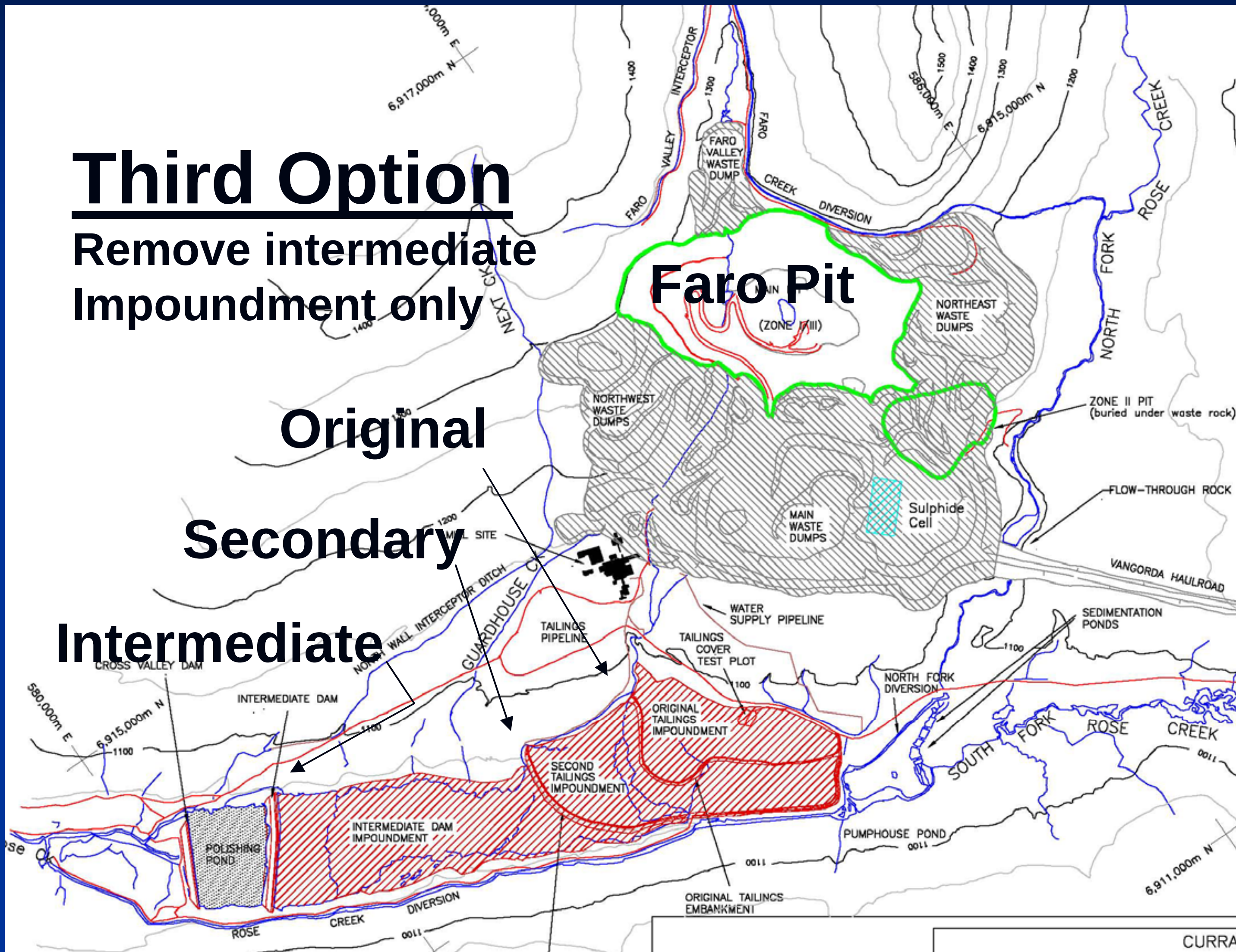
Two Relocation Options

- Partial tailings relocation (43 million tonnes) to el. 1042 m
  - Relocate tailings above elev. 1042 m
  - Remove most of the tailings from the original and secondary impoundments
  - Close with 3 m water cover; freeboard is adequate, so a raise of the Intermediate Dam is not required.



Third Option

Remove intermediate Impoundment only



Dredging Method

Dredging - Scope

- Site visit and data review
- Select dredge plant and support equipment
- Provide recommendations on the overall power requirements, crewing, training, maintenance and pipelines
- Cost estimates for both diesel & electric power options
- Prepare a draft summary report

Dredging – Main Equipment

- Portable suction dredge
- Cables and winches to raise/lower suction pipe
- Centrifugal main pump powered by diesel or electric drive motors
- Two spud system
- Portable pontoons
- Floating discharge pipeline
- Support boats

Typical Dredge Arrangement

Typical Dredge Arrangement

Dredge – Mine Plan

- Excavate starter pit in original impoundment
- Float the dredge
- Cut in 1 to 2 m lifts until original and secondary impoundments are gone
- Use mechanical equipment as necessary to remove dams
- Repeat the process at the Intermediate impoundment

Dredge – Mine Plan

Concern at Secondary Dam

Dredge - Mine Plan

- Operating season assumed to be 7 months/year
- Time to complete:
  - For total relocation: 5 years
  - For partial relocation: 5 years

Hydraulic Monitoring Method

Hydraulic Monitoring - Scope

- Data review
  - The 1991 report by Kilborn & A.S. Webster
  - The 2003 dredge report by Ernie Zuccolin (similarities with respect to pumping issues)
- Select hydraulic monitoring equipment and pumping system
- Cost estimates
- Prepare a draft summary report

Hydraulic Monitoring – Equipment

- Six operating hydraulic monitoring guns with four spares
  - Skid-mounted
  - Electrically operated from a weatherproof cabin
- The cabin will be on wheels and elevated to ± 2 metres above ground level, thereby allowing the operator full visibility of the operation
- Sump with various screen sizes and a pump/pipeline system to deliver the tailings to the Faro Pit

Typical Monitoring System

Typical Monitoring System

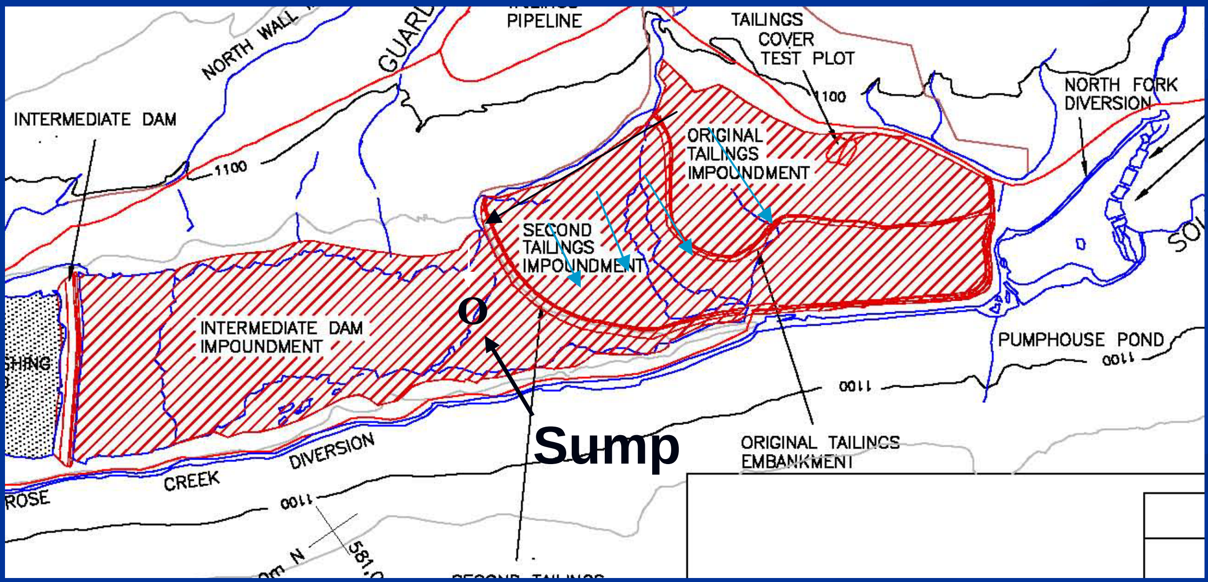
Typical Monitoring System

Typical Monitoring System

- Natural mountainside is brown coloured.
- Tailings are grey.

Hydraulic Monitoring – Mine Plan

- Plan not defined as part of current study
- 1991 study defined a plan for an equivalent to the partial relocation option



Hydraulic Monitoring - Mine Plan

- Operating season assumed to be 6 months/year
- Time to complete (current information):
  - For total relocation: 12 years
  - For partial relocation: 9 years
- Can presumably be done faster using more monitoring guns (?)

Mechanical Method

Mechanical - Scope

- Data review
- Develop concept for mechanical excavation
- Cost estimates
- Prepare a draft summary report

Mechanical – Equipment

- Cat 776, 135 tonne wagons
- D11 size dozer
- Large capacity belt loader

Mechanical - Mine Plan

- Improve roads for hauling (grades and alignment)
- Tailings pushed to the belt loader, which loads the trucks
- Trucks haul to the pit.
- **Entire approach is based on the equipment being able to traffic on the tailings**

Mechanical - Mine Plan

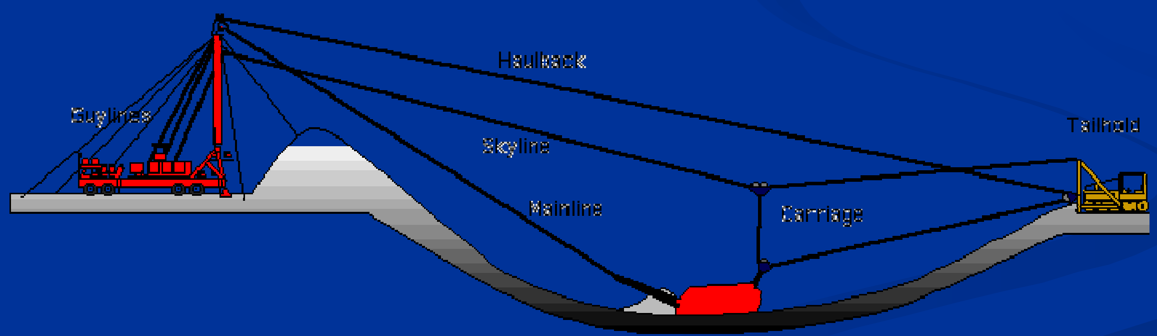
- Operating season assumed to be 7 months/year
- Time to complete (current information):
  - For total relocation: 7 years
  - For partial relocation: 5.4 years

Comparison - Risks

- Dredge
  - Large pond leads to increased seepage losses and increased risk of failure of the secondary dam
  - Must be complemented by mechanical methods to remove coarse granular portion of dams
- Hydraulic Monitoring
  - Seepage losses expected to be less than dredging
  - Less risk of dam failure, but slope failure in tailings is possible

Comparison - Risks

- Mechanical
  - Approach depends on the equipment being able to traffic on the tailings – significant technical risk
  - Needed to complement select aspects of the other methods, i.e. removal of waste rock starter dam
  - Alternatives such as draglines and Sauerman/Cresent drag scraper limited by materials and/or width of area



Comparison - Costs

	Total Relocation	Partial Relocation
Dredging		
Total Cost	$115 - $130 M	$103 - $108 M
Cost/tonne	$2.01 to $2.27	$2.38 to $2.51
Hyd. Monitoring		
Total Cost	$27 M	$20 M
Cost/tonne	$0.47	$0.47
Mechanical		
Total Cost	$92 M	$70 M
Cost/tonne	$1.61	$1.63

Costs not in Table

- Water treatment (about \$3 million)
- Excavation of old dams (up to \$5 million)
- In the case of dredging, incremental cost of removing 1 m of natural soil (\$5 to \$10 million)

Conclusions

- Water balance and water treatment issues are similar for all options, except dredging (seepage)
- Environmental risks seem to be highest with the dredging method.
- There is a significant technical risk with the mechanical method (trafficability).
- The hydraulic monitoring method appears to be the least expensive method, i.e. in the order of $2.

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Waste Rock Pile and Tailings Covers for the Anvil Range Mining Complex

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Projects 16(a) & 18(b)

Presented by:

Maritz Rykaart

SRK Consulting

Project Objectives

- At a conceptual level, what can be achieved with soil covers at the ARMC, both at the Rose Creek tailings and the waste rock piles

- This study does not present a cover solution (design), but illustrates the issues that should be taken into consideration when deciding whether covers should be used at ARMC

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Waste Issues Driving Cover

- No benign waste at ARMC
- Primary problem is oxidizing waste, with associated low pH leachate and mobilization of metals – results in poor quality surface and groundwater
- Secondary problem on tailings is wind erosion
- Environmentally and socially probably most desirable to remove or isolate all the waste

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Basic Cover Concepts

- Cover systems must be site specific
- Cover must fulfill specific objectives – the most common being:
  - Dust and erosion control
  - Chemical stabilization
  - Containment release control
  - Providing growth medium
  - Access & aesthetics

Generic Cover Types

- Generic cover types:
  - Water covers
  - “Low Permeability” covers
  - Capillary Barrier covers
  - Store-and-Release covers
  - Reactive covers
- Cover functionality determined by:
  - Objective
  - Climate
  - Cover material type/availability

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Sample ARMC Cover Objectives

- Isolate waste to prevent direct contact with human and wildlife (this includes preventing dust and shedding clean runoff)
- Ensure long-term stability of all facilities
- Re-vegetate
- Minimize leachate (accepting that in all likelihood any poor quality leachate will have to be collected and treated) – this includes shedding clean runoff
- It may not be useful to try and limit or even minimize further oxidation

Project Components

- Reviewed cover related site literature
- Characterized the potential cover materials
- Documented site specific constructability issues that would affect any cover design decision
- Conducted scoping level numerical modeling to estimate cover performance

Historic Cover Research

- ARMC tailings test covers
- Partial Vangorda waste rock pile cover
- Vangorda waste rock pile starter berm
- Overburden dump re-sloping & vegetation trial

ARMC Tailings Test Cover Trial

- Constructed 1997 – operated 5 years
- 6 cells and 1 in-situ tailings area
- Located in Original Impoundment
- Results somewhat inconclusive

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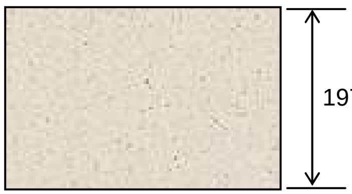
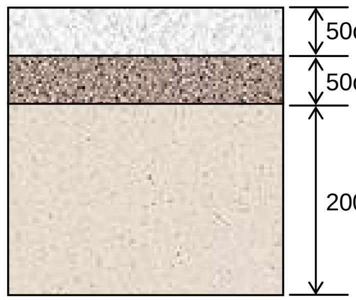
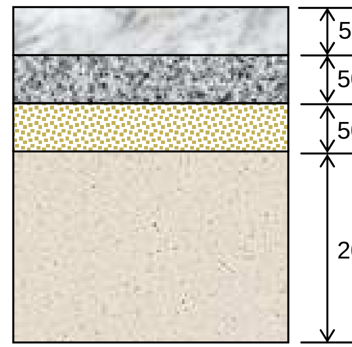
ARMC Tailings Test Cover Trial



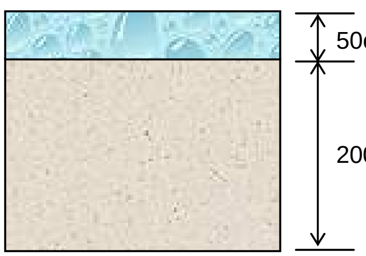
Test Pit #3
(Control)



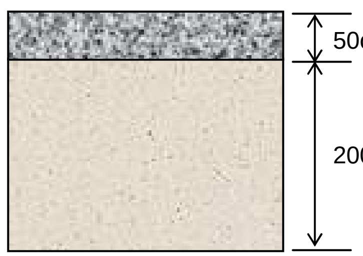
Test Pit #2
(Organic Cover)



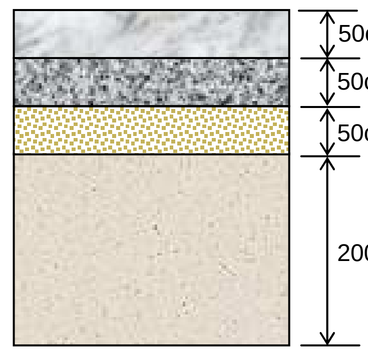
Test Pit #1
(Composite Cover)
saturated



Test Pit #6
(Water Cover)



Test Pit #5
(Till Cover)



Test Pit #4
(Composite cover)
unsaturated

Partial Vangorda Waste Rock Pile Cover

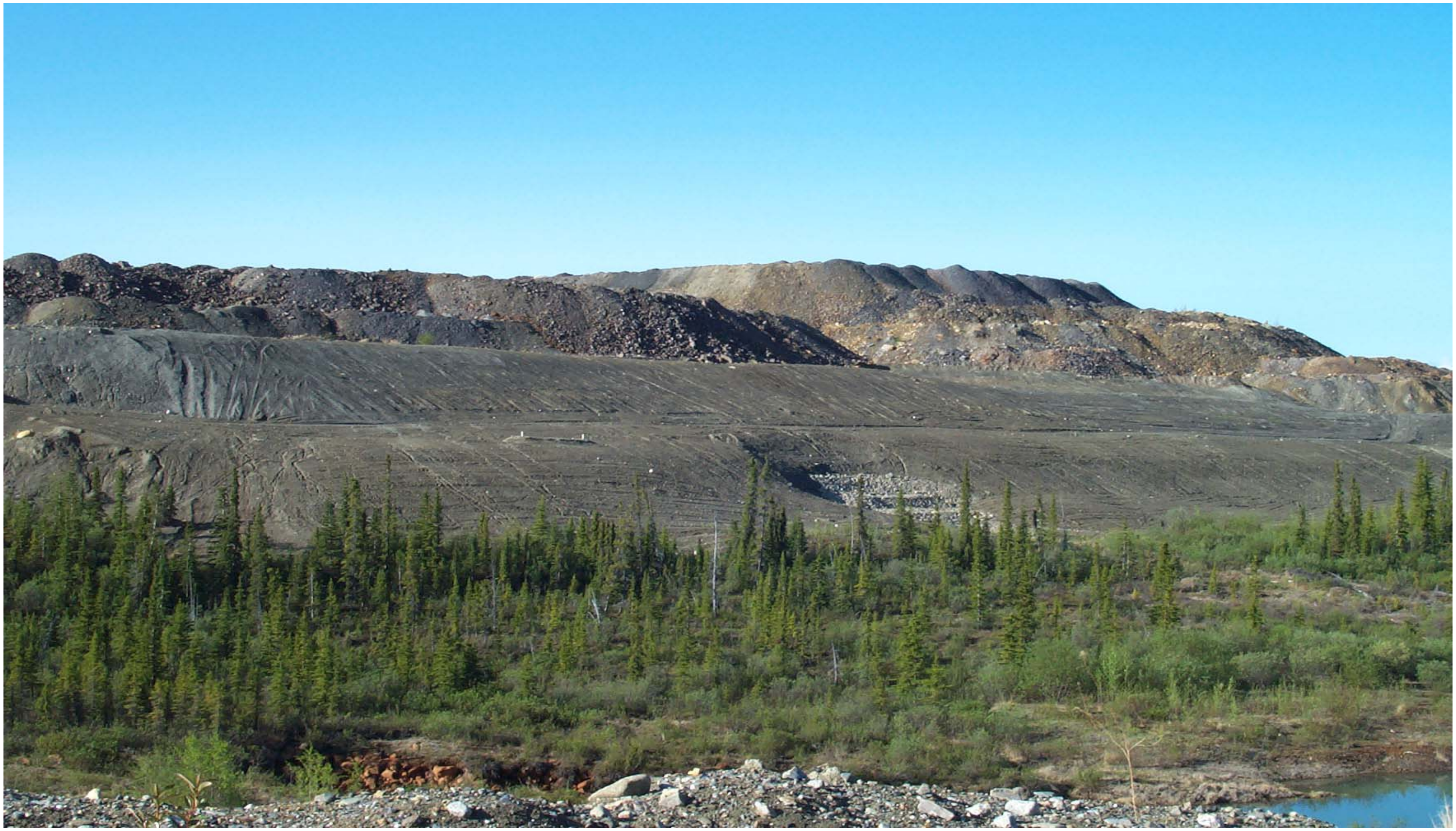
- 10-Year old cover
- 2 m thick cover (1 m loosely compacted till over 1 m highly compacted till)
- Constant 2.5H:1V slope
- Not vegetated

Partial Vangorda Waste Rock Pile Cover

Partial Vangorda Waste Rock Pile Cover

Partial Vangorda Waste Rock Pile Cover

Vangorda Waste Rock Pile Starter Dyke



Overburden Dump Re-Sloping & Vegetation Trial

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Cover Materials

- What is available?
  - Till – 11.62 million m^3
  - Glaciofluvial – 2.8 million m^3
  - Organics – 0.2 million m^3
- Approximate haul distances
  - Till – 3.8 to 21.9 km
  - Glaciofluvial – 2.8 to 22.8 km
  - Organics – 4.3 to 22.2 km

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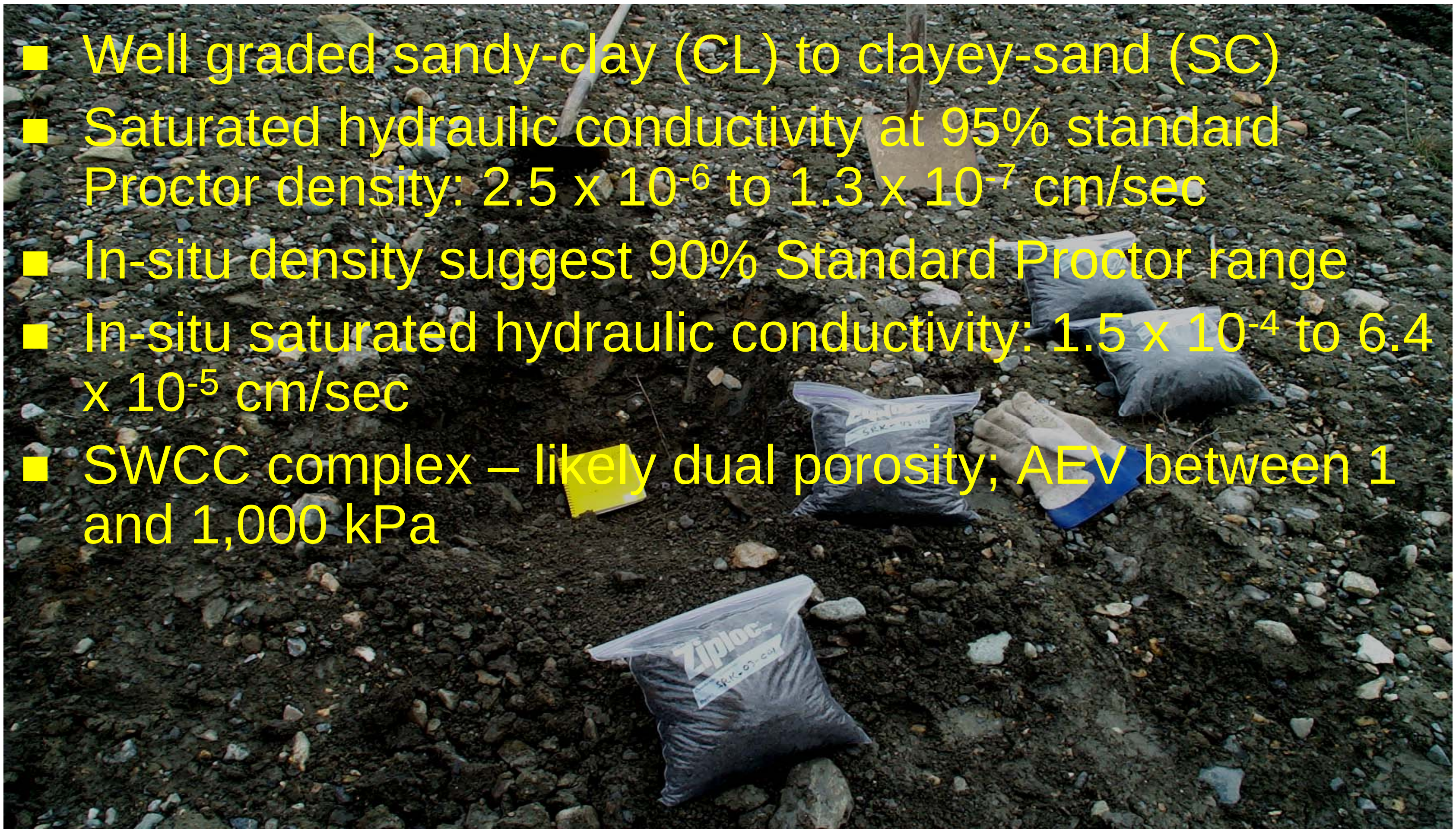
Test Program

- **Laboratory Testing**
  - Limits
  - Specific gravity
  - Particle size distribution
  - Compaction
  - Consolidation
  - Saturated hydraulic conductivity
  - SWCC
- **In-Situ Testing**
  - Saturated hydraulic conductivity (ring infiltrometer & Guelph)
  - Density
  - Conductivity & pH
  - Moisture content
  - Thermistors

Till



- Well graded sandy-clay (CL) to clayey-sand (SC)
- Saturated hydraulic conductivity at 95% standard Proctor density: 2.5×10^{-6} to 1.3×10^{-7} cm/sec
- In-situ density suggest 90% Standard Proctor range
- In-situ saturated hydraulic conductivity: 1.5×10^{-4} to 6.4×10^{-5} cm/sec
- SWCC complex – likely dual porosity; AEV between 1 and 1,000 kPa

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Glaciofluvial

- Poorly graded gravel-sand mixtures with an abundance of gravel and sands and virtually no fines
- Saturated hydraulic conductivity at 95% standard Proctor density: 1.1 x 10^{-3} to 5 x 10^{-5} cm/sec
- In-situ density suggest 90% Standard Proctor range (excluding surface compacted layers)
- In-situ saturated hydraulic conductivity: 9.9 x 10^{-5} cm/sec for compacted surface layers; 2.8 x 10^{-3} for loose layers
- AEV between 1 and 10 kPa

Tailings

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Waste Rock

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Thermistors

- 16 shallow thermistors
- Placed in till, glaciofluvial & tailings
- Assist in determining active layer depth

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Infiltration tests

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Constructability Issues

- Vegetation (season length and species)
- Tailings trafficability (access and settlement)
- Frost penetration depth
- Evaporites (presence & vegetation uptake)
- Re-sloping
- Volume of cover material

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Re-Sloping

- Re-slope areas steeper than 2.5H:1V on side slopes – only outer slopes considered
- Faro Waste Rock Pile
  - 3.1 million m^3 of 129 million m^3 (2.4%)
- Grum Waste Rock Pile
  - 0.42 million m^3 of 23.6 million m^3 (1.8%)
- Vangorda Waste Rock Pile
  - 0.6 million m^3 of 32.5 million m^3 (1.8%)

Cover Material Volumes

- Total re-sloped waste rock pile area of 602 ha.
- Rose Creek tailings surface area is 196 ha.
- If all waste was covered with till only – maximum cover thickness would be 150 cm
- If all waste was covered with glaciofluvial only – maximum cover thickness would be 35 cm.

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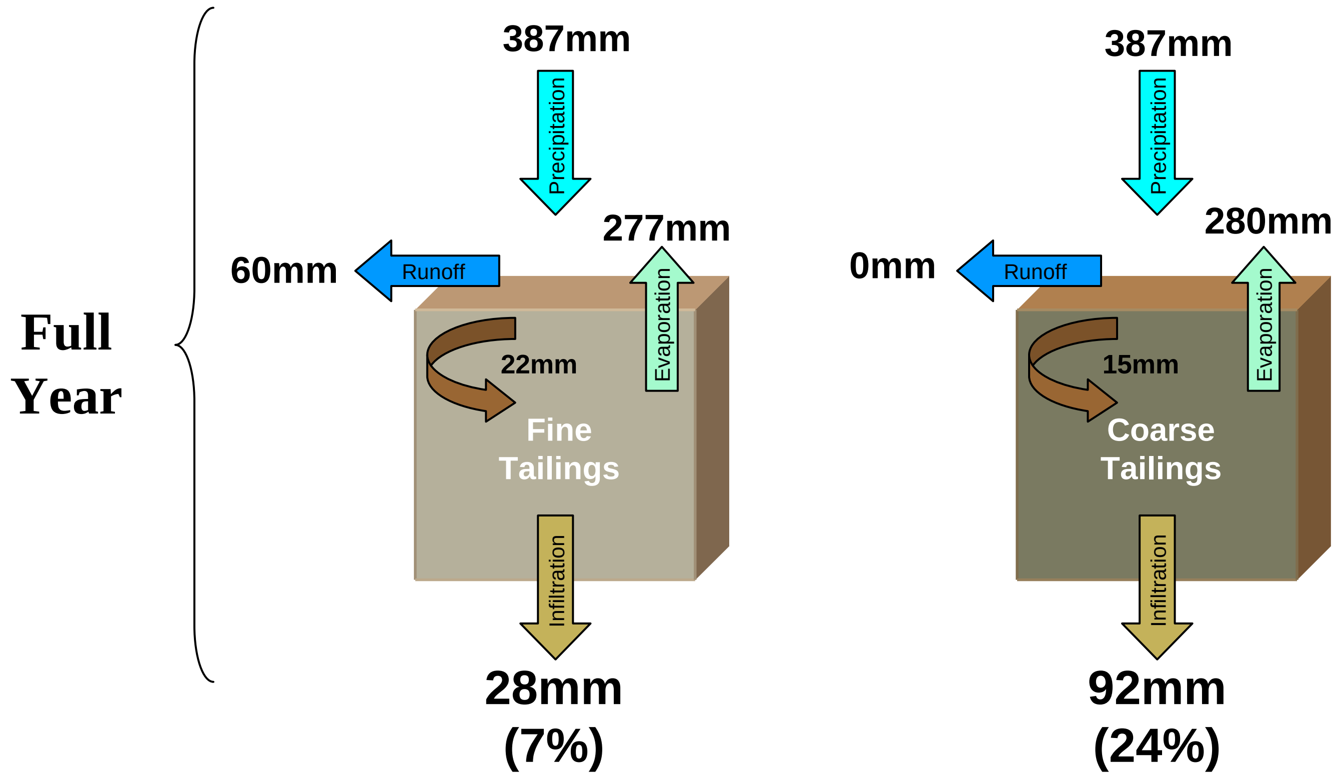
Scoping Level Numerical Modeling

- Un-calibrated cover performance predictions
- SoilCover model
- Single season setup – average climatic year
- Basic set of material properties reflecting field and in-situ data
- Set up uncovered case to compare cover performance against
- Not refined for slope, aspect etc.
- Actual reported numbers not absolute – comparative information important

Numerical Modeling – Uncovered Tailings



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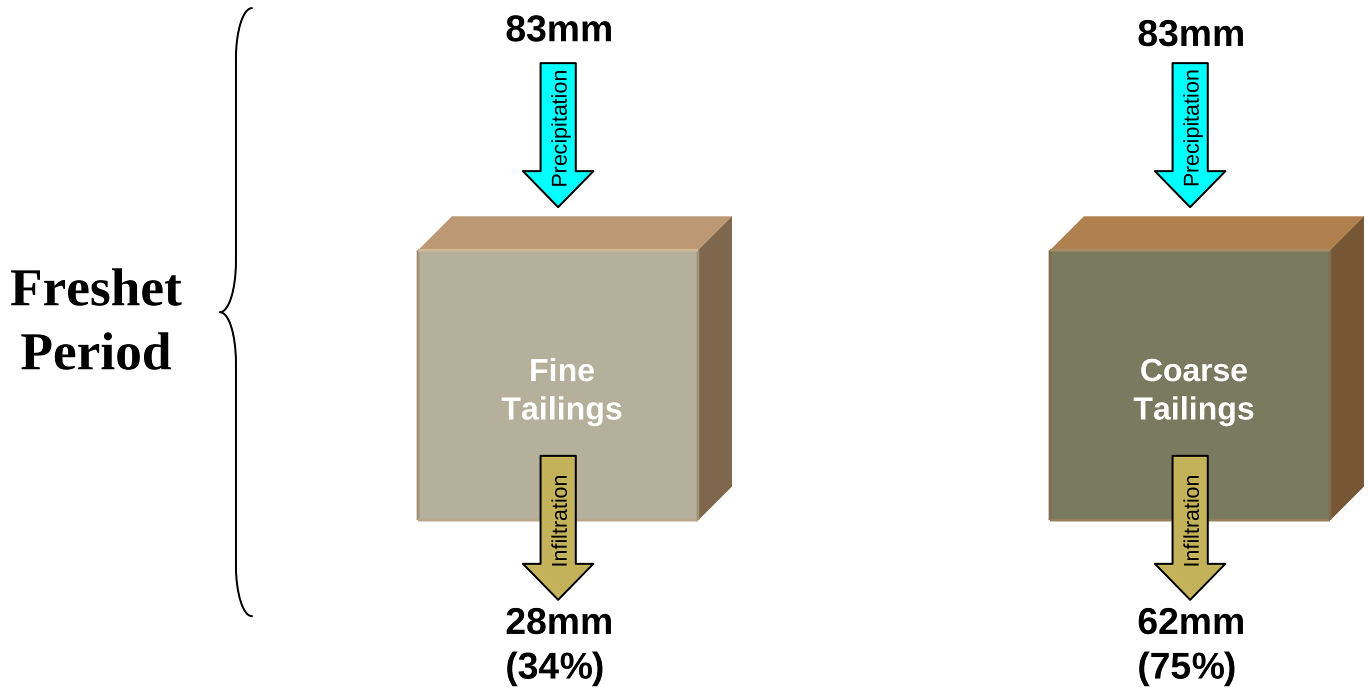
Numerical Modeling – Uncovered Tailings



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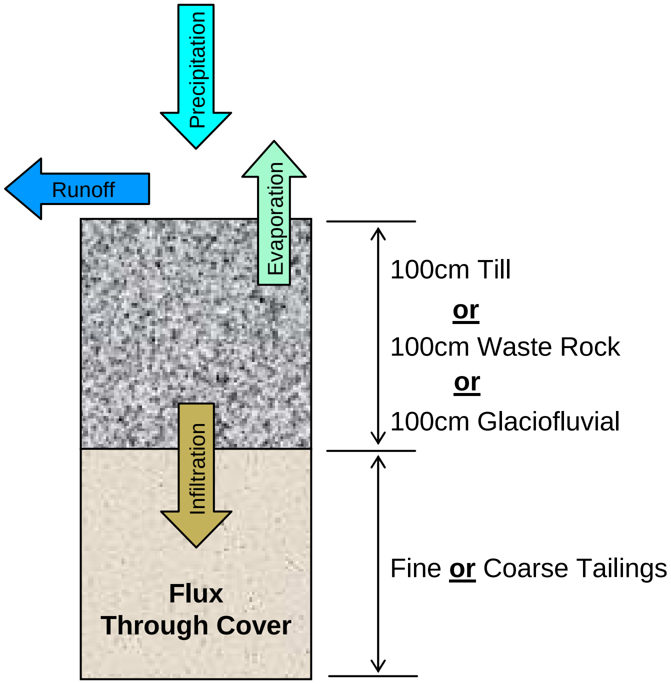
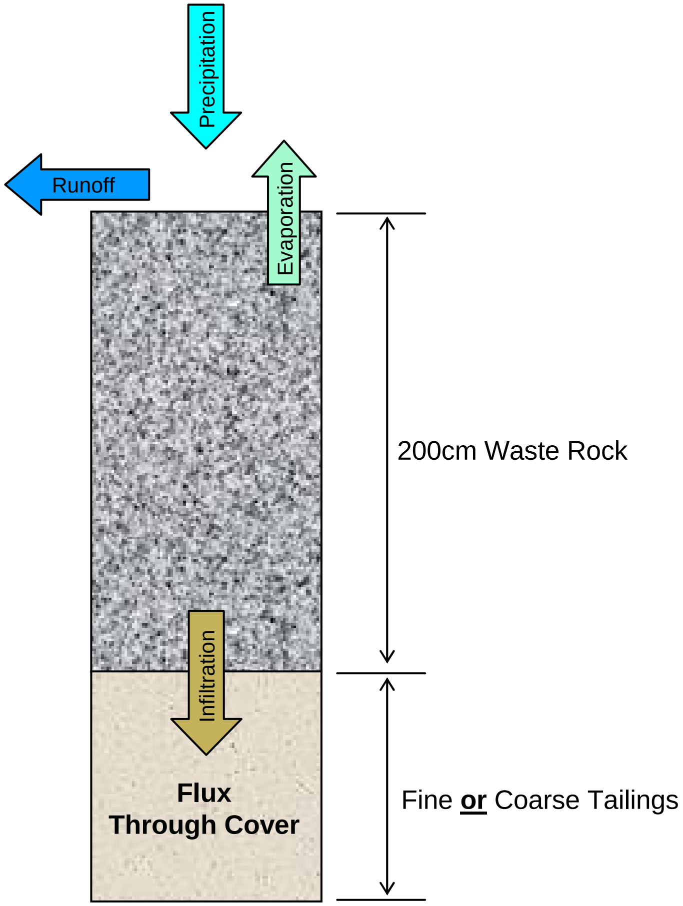
Tailings Profiles - Single-layer Covers

Thicker is better





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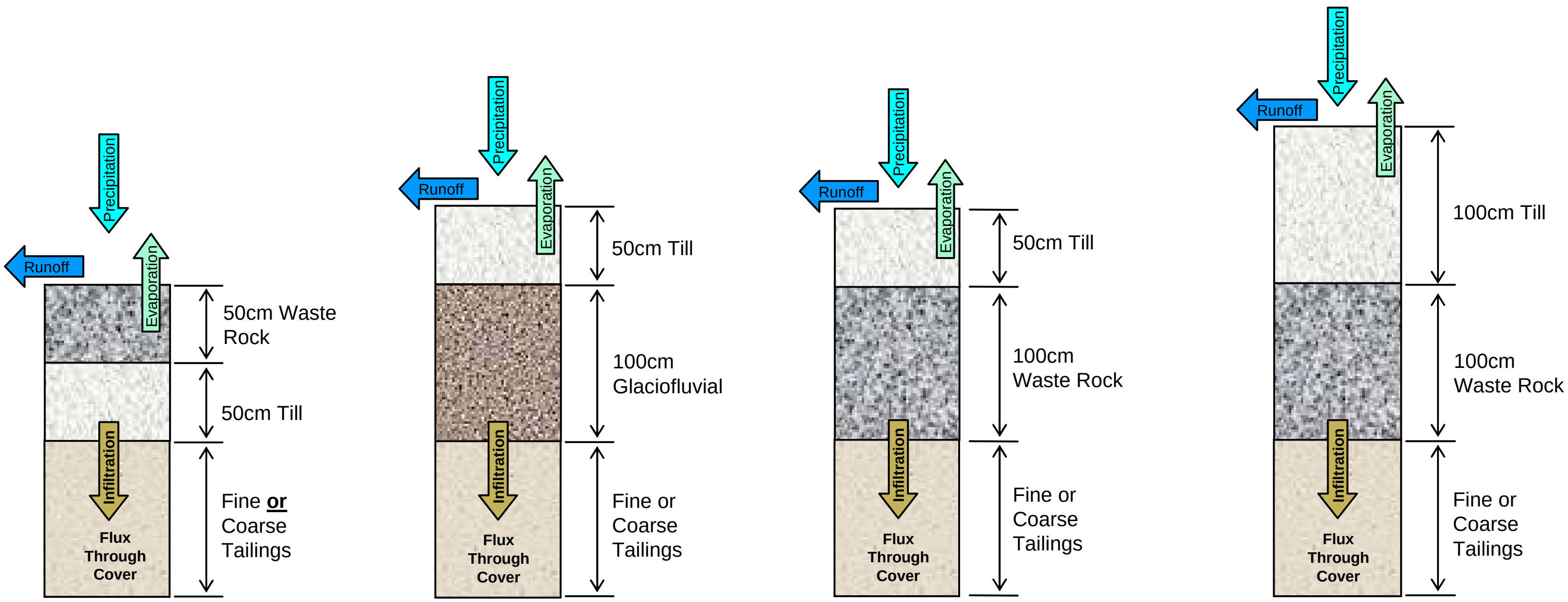
Tailings Profiles - Two-layer Covers



10% Flux

Till over waste rock of glaciofluvial results in low flux

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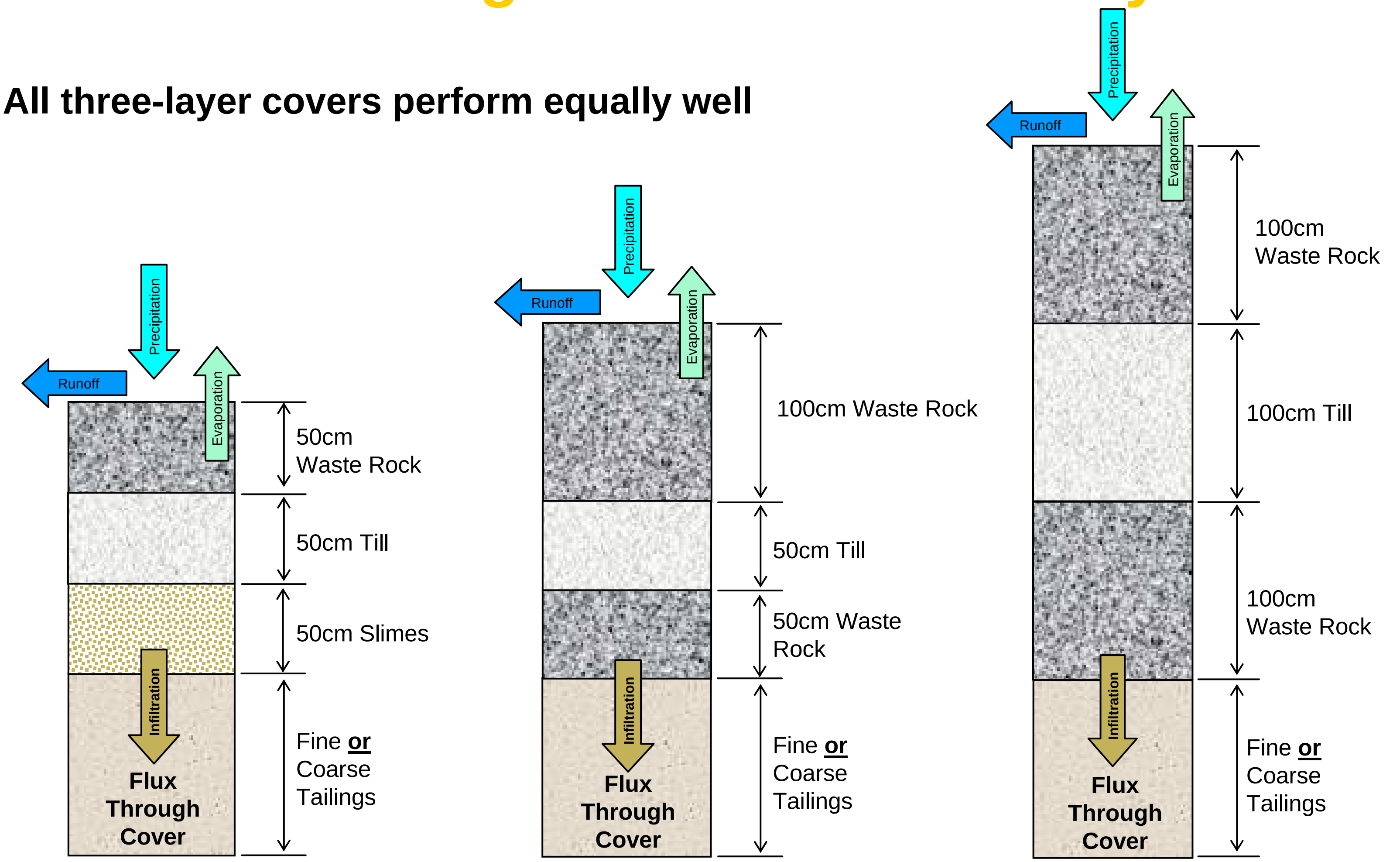
Tailings Profiles - Three-layer Covers

All three-layer covers perform equally well



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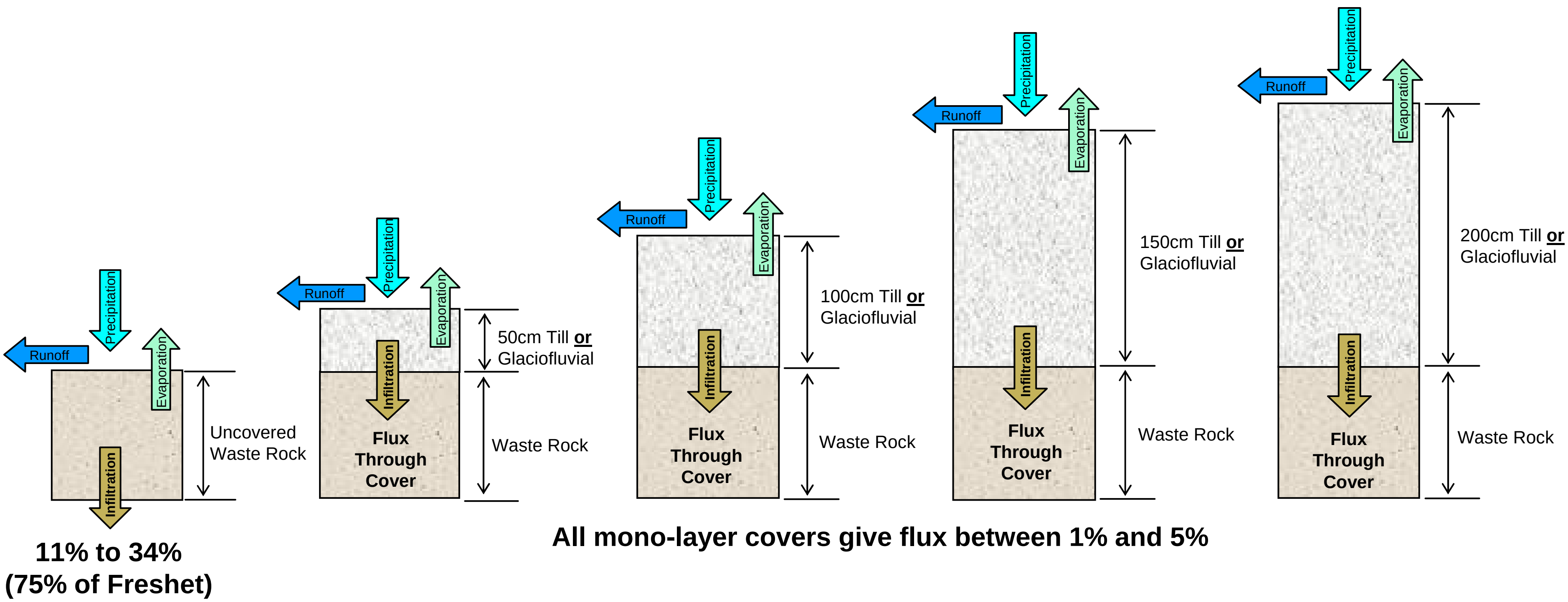
Waste Rock Cover Profiles



All mono-layer covers give flux between 1% and 5%

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Conclusions

- Soil covers can be practically constructed at the ARMC
- The soil covers can be infiltration barriers, but are unlikely to be good as oxygen barriers
- Natural re-vegetation is unlikely to occur, at least not in the short to medium term timeframe
- Selective covering of “hotspots” on the waste rock piles might be worth considering
- Covering the tailings remains a physical challenge due to access and settlement

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Discussion Items

- Initiate a re-vegetation study
- Conduct tailings settlement test (two test pads) – March 2004
- Construct full-scale test cover cells to determine optimum cover thickness for waste rock piles – Summer 2004
- Focused follow-up numerical modeling

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Rose Creek Tailings

	Cover	Add Re-grading
50cm WR/50cm Till	$ 9,306,236	$ 10,776,236
50cm WR/100cm Till	$ 13,579,630	$ 15,049,630
100cm WR/50cm Till	$ 13,977,867	$ 15,447,867
100cm WR/100cm Till	$ 18,251,261	$ 19,721,261
50cm WR/50cm GF	$ 9,829,994	$ 11,299,994
50cm WR/100cm GF	$ 17,135,312	$ 18,605,312
100cm WR/50cm GF	$ 14,501,624	$ 15,971,624
100cm WR/100cm GF	$ 21,806,942	$ 23,276,942

Faro Waste Rock Pile

Source	50cm Till	100cm Till	150cm Till	200cm Till
Cover Only	$ 10,875,173	$ 25,962,982	$45,795,764	$65,628,545
Incl. WR re-grading	$ 15,525,173	$ 30,612,982	$50,445,764	$70,278,545

Grum Waste Rock Pile

Source	50cm Till	100cm Till	150cm Till	200cm Till
Cover Only	$ 3,143,623	$ 6,287,245	$ 9,430,868	$12,574,491
Incl. WR re-grading	$ 3,773,623	$ 6,917,245	$10,060,868	$13,204,491

Vangorda Waste Rock Pile

Source	50cm Till	100cm Till	150cm Till	200cm Till
Cover Only	$ 1,099,842	$ 2,398,352	$ 3,778,133	$ 5,157,915
Incl. WR re-grading	$ 1,999,842	$ 3,298,352	$ 4,678,133	$ 6,057,915

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Faro In-Pit Plug Dam Conceptual Design

- Holger Hartmaier and Grant Bonin
- Study Objectives
- Scope of Work
- Results
- Key Conclusions
- Status of Report

PLUG DAM CONCEPTUAL DESIGN

Objective:

To retain pit water and tailings solids/waste rock within the Faro Pit and prevent any overflow or seepage from entering the adjacent Zone II Pit.

Scope of Work

- Compile topographic and geological data.
- Site reconnaissance.
- Conceptual design.
- Additional site investigations required.
- Prepare draft and final report.
- Early draft provided, not yet internally reviewed.

Study Results

- Rockfill dam with central impervious core using local materials.
- Crest elevation 1176 m.
- Faro Pit level 1173 m.
- Requires grout curtain down to elevation 1137 m
- Capital cost $2 million (excluding, mob/demob, escalation and extra work).

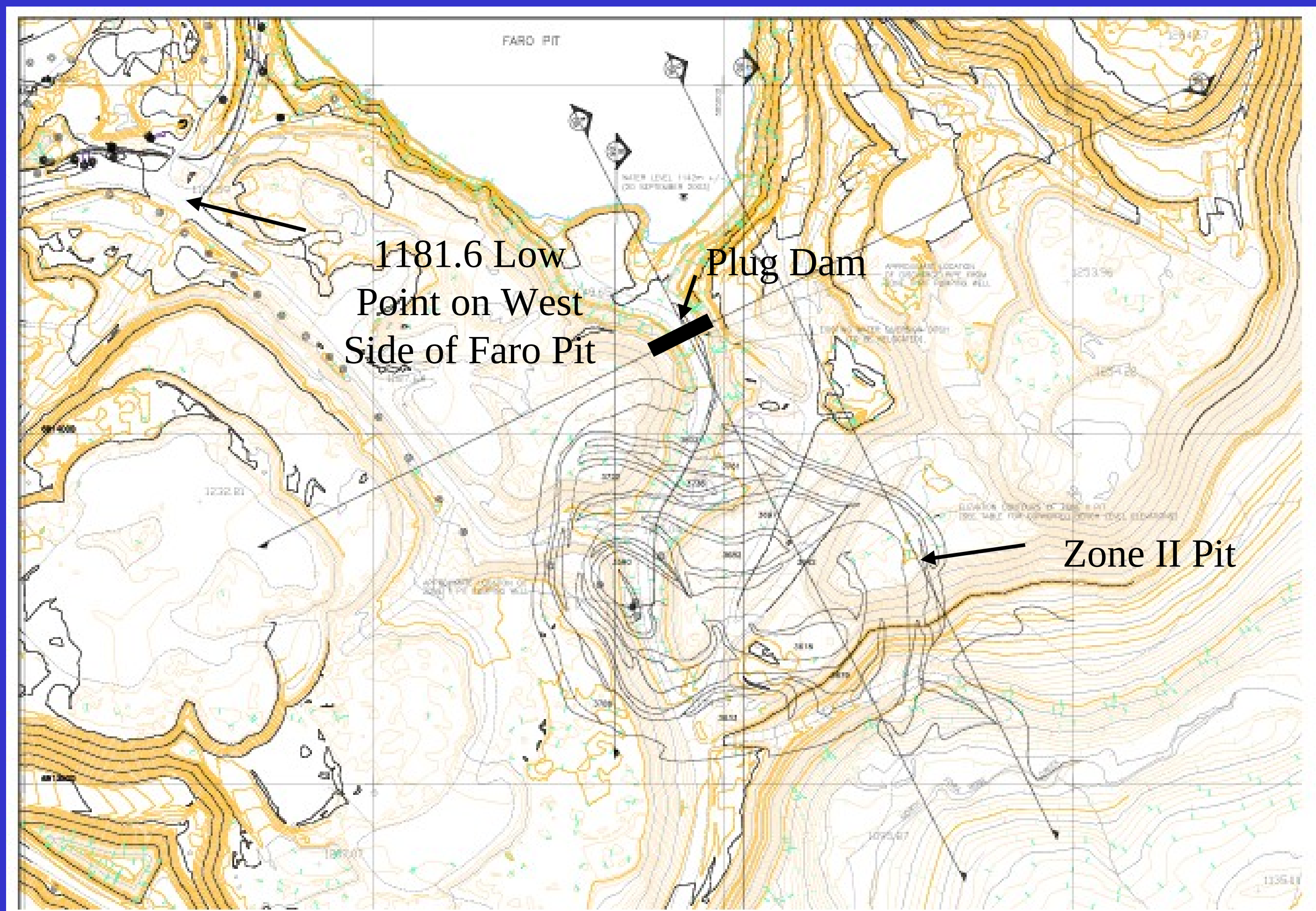
Key Conclusions

- Further assessment required of seepage zone on west side of Faro Pit (former Faro Creek area).
- Core drilling and water pressure testing required to confirm depth and extent of grout curtain.
- Geophysical surveys required to confirm bedrock topography under right bank waste dump piles in pillar area between Faro Pit and Zone II Pit.

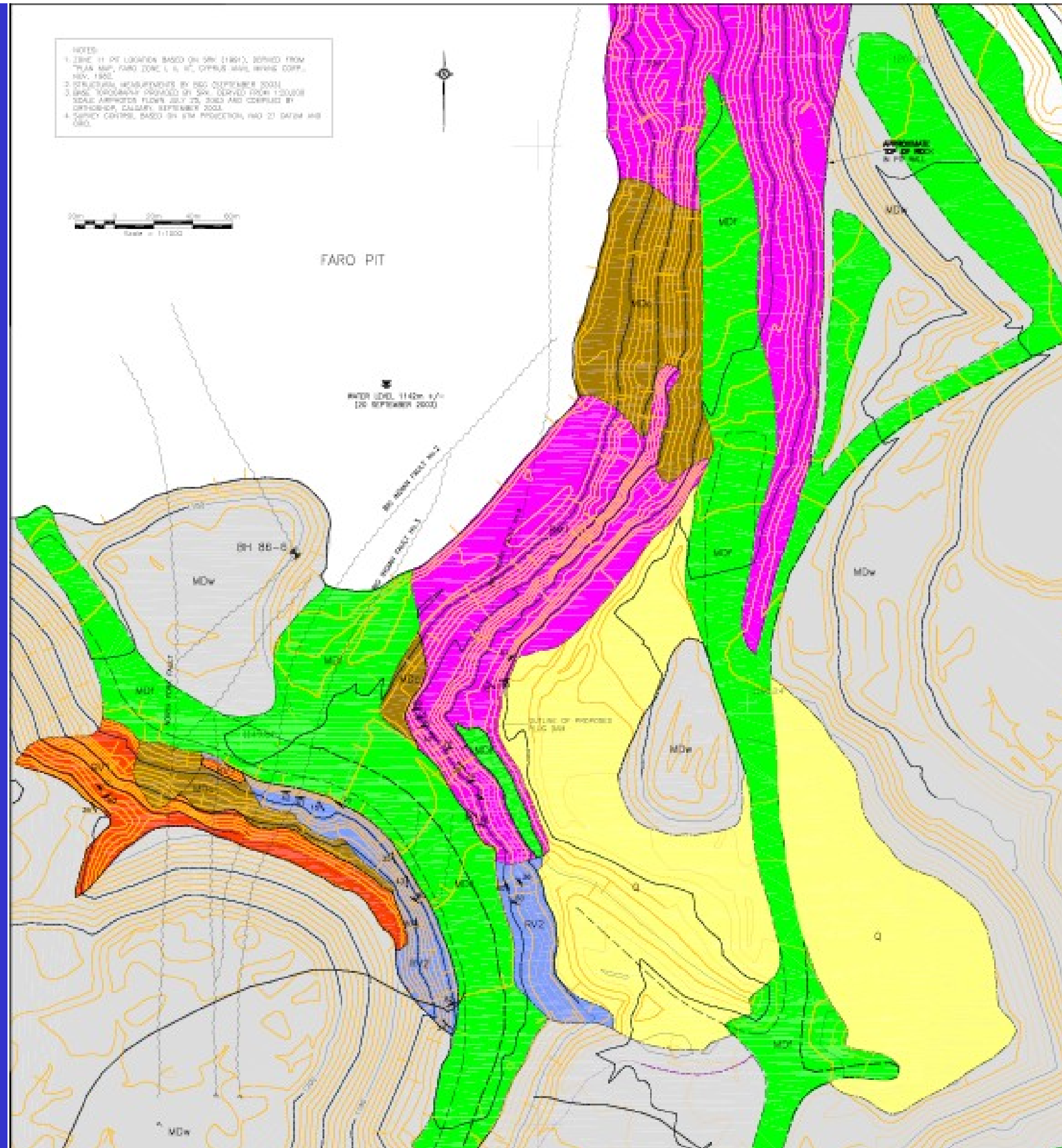
Status of Report

- Early draft report sent to SRK/Deloitte.
- Needs to be reviewed internally by BGC.
- Costs need to be reviewed.
- Final report will be prepared upon receipt of comments.

Plug Dam- Dam Site Topography



Plug Dam- Geology



FIELD RECONNAISSANCE

- Structural and geological mapping.
- Assessment of site conditions.

RECONNAISSANCE- PHOTOS

View of Plug Dam site from top of right abutment, looking downstream.

Plug Dam site looking downstream along haul road.

Looking upstream along toe of right abutment.

Looking upstream along toe of left abutment.

RECONNAISSANCE- PHOTOS

View of right abutment from top of left abutment.

Looking upstream along top of left abutment. Diversion ditch and berm on bench.

Edge of bedrock on right abutment at edge fo Zone II pit filled with waste rock.

Small - scale wedge failure in left abutment has breached diversion ditch and liner on upper bench

RECONNAISSANCE-PHOTOS

Exposure of Quaternary colluvial material in left abutment.

Toe of waste rock dump on top of bedrock in right abutment.

View of right bank bedrock pillar separating Faro Pit from Zone II Pit.

CONCEPTUAL DAM DESIGN

- Design Criteria
- Embankment Section
- Seepage Assessment and Cut-off Elements
- Construction Quantities and Cost Estimate

DAM DESIGN- Criteria

- Lowest bedrock elevation on west side of pit at elevation 1158 m.
- Lowest natural ground surface on west side of pit at elevation 1173 m. Now covered by waste rock to elevation 1181.
- Dam length increases significantly above elevation 1180 m on left abutment.

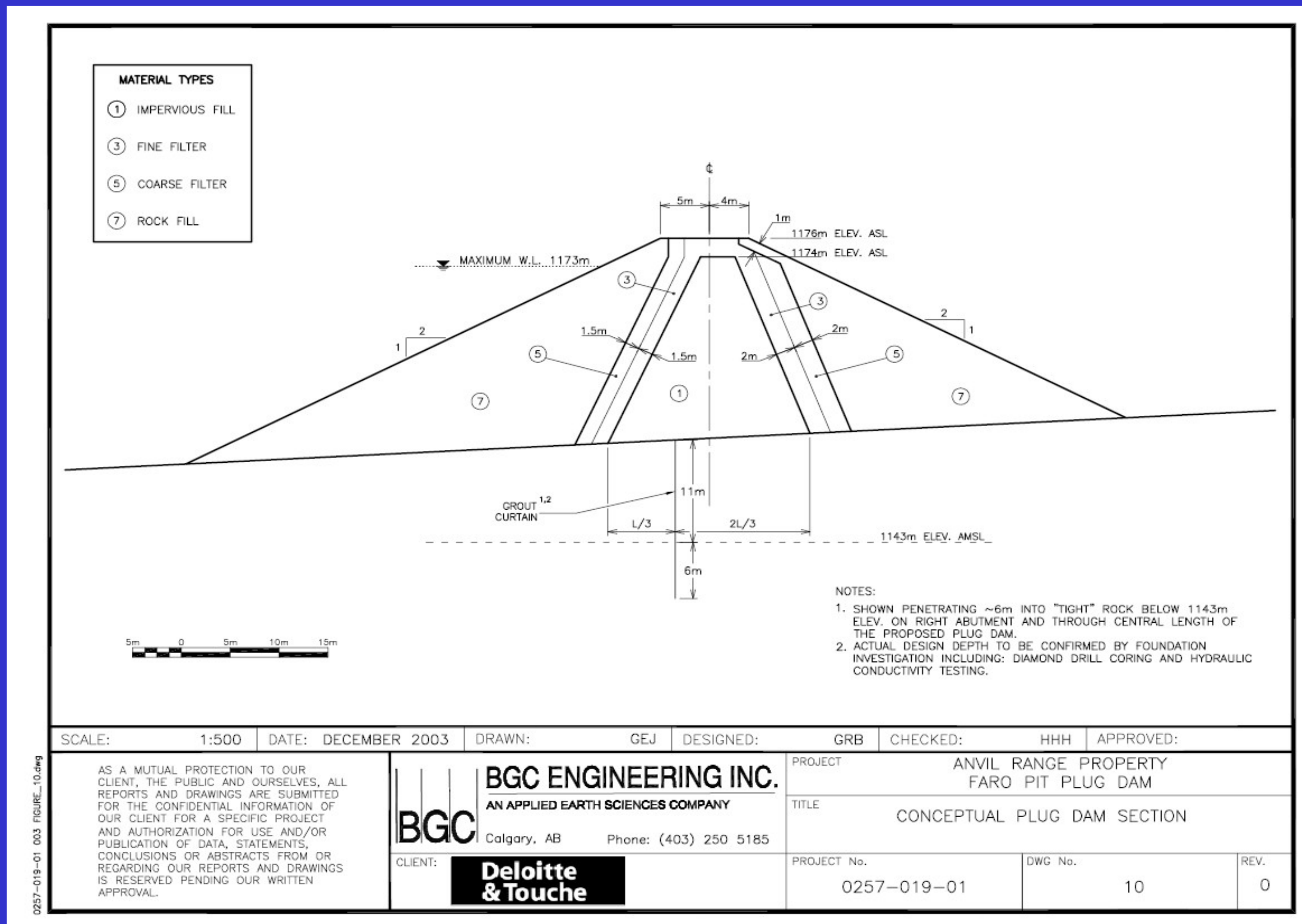
DESIGN CRITERIA- cont'd

- Maximum retained water level to be at 1173 m.- assumes some seepage through overburden in west side of pit.
- Top of core 1 m above maximum water level, (el.1174 m)
- Top of crest 2 m above top of core (el. 1176 m)

DESIGN CRITERIA- Dam Stability

- Design flood and design earthquake to be based on Consequence Classification.
- Bedrock foundation and abutments- pseudo-static methods are acceptable.
- Upstream and downstream slopes must meet minimum required factors of safety for prescribed loading conditions as per CDA guidelines.

DAM DESIGN- Embankment Section



DAM DESIGN- Seepage and Cut-off

- Potential seepage path through right abutment pillar between Faro and Zone II Pit.
- Zone II Pit acts as a local drain.
- In left abutment, gradient is small to North Fork Rose Creek.
- Previous pit hydrogeology studies found relatively lower permeable rock below el.1143 m.

DAM DESIGN- Seepage Cut-off

- Single line grout curtain to tie-in to zone of lower permeability rock.
- Bottom of grout curtain at el. 1137.
- Grout curtain extends from left abutment dam crest to right abutment crest, then along pillar between Zone II and Faro Pit for another 120 m (approx.)

CONSTRUCTION QUANTITIES AND COST ESTIMATE

MAJOR WORK ITEMS INCLUDE:

- Bulk excavation and stripping.
- Core trench rock excavation
- Foundation preparation
- Foundation grouting
- Construction materials excavating, hauling and placing

COST ESTIMATE (Needs to be Validated)

- Estimated capital cost- **$2 million (approx.)**
- Excludes mobilization, demobilization, escalation and extra work allowances.
- Excludes permitting and regulatory costs, contingencies, final design engineering and construction supervision and instrumentation.
- Excludes costs of additional access roads required by contractor.

PROPOSED SITE INVESTIGATIONS

- Bedrock core drilling and water pressure testing in abutments and foundation of dam.
- Geophysical surveys to delineate bedrock topography under right bank waste dump
- Test pitting to assess quality of construction materials on left bank and geotechnical laboratory testing.
- Estimated Cost: **$280k**. (Includes engineering supervision and reporting

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