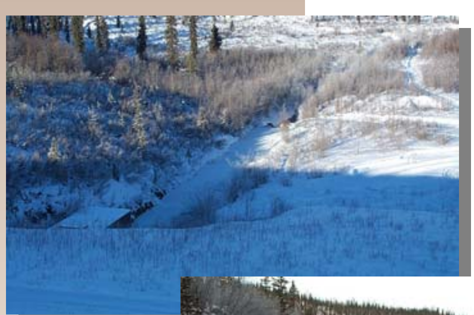
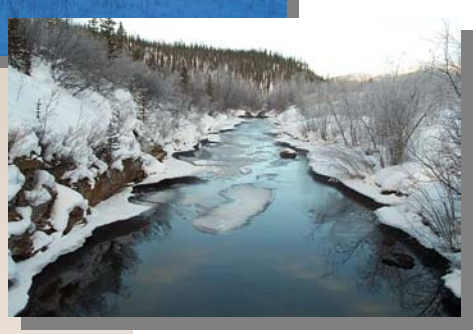
Supplement to the Preliminary Breach Design Fresh Water Supply Dam, Faro Mine

Prepared for:

DELOITTE & TOUCHE INC.
Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9





Prepared by:

SRK Consulting
Engineers and Scientists

BGC Engineering Inc.
AN APPLIED EARTH SCIENCES COMPANY

Gartner Lee Limited

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SUPPLEMENT TO THE PRELIMINARY BREACH DESIGN REPORT FRESH WATER SUPPLY DAM, FARO MINE

Prepared for:

DELOITTE & TOUCHE INC.
Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9
Canada

Prepared by:

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.
Suite 800, 1066 West Hastings St
Vancouver, B.C. V6E 3X2
Tel: (604) 681-4196 • Fax: (604) 687-5532
E-mail: vancouver@srk.com Web site: www.srk.com

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SUPPLEMENT TO THE PRELIMINARY BREACH DESIGN REPORT
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1 INTRODUCTION

The report describing the preliminary design for the breach of the Fresh Water Supply Dam (FWSD) was issued to Fisheries and Oceans Canada (DFO) on 3 February 2003, in accordance with the DFO directive to both the Interim Receiver and Indian and Northern Affairs Canada (DIAND).

At a planning meeting in Calgary on 18 February 2003, DFO and DIAND, two of the Responsible Authorities, indicated that additional information related to the proposed breach of the FWSD should be provided as a supplement to the preliminary design report noted above. Following consultation between DFO and DIAND, DIAND issued a letter on 4 March 2003 that specified the information requirements of both Responsible Authorities. The letter further noted that the combination of the Preliminary Breach Design Report and its supplement is intended to serve as an Environmental Assessment Report that will allow DFO and DIAND to complete their environmental assessment (EA) of the project. Initially, the FWSD breach project was thought to require a Comprehensive Study under the Canadian Environmental Assessment Act (CEAA), but DFO confirmed on 10 February 2003 that the EA track for this project will follow the CEAA "screening level" of review. It was noted by DIAND in their letter of 4 March that the supplementary information should reflect the change to screening level assessment.

This document, which comprises the supplement to the Preliminary Breach Design Report, is intended to provide the information requested by DFO and DIAND.

2 CUMULATIVE EFFECTS ASSESSMENT (CEA)

In order to provide a full assessment of the proposed breach of the FWSD, DFO and DIAND have requested a Cumulative Effects Assessment be completed as part of the Supplementary Information to the Preliminary Breach Design Report submitted on 3 February 2003.

A CEA is an assessment of the primary project effects (dam breach) in combination with other projects that have or will be carried out. For the purposes of an environmental assessment, not all of the potential environmental effects need to be addressed in a CEA. Only the adverse effects of the project remaining after the application of mitigation (i.e. the residual effects) are the focus of the cumulative effects assessment. To meet the requirements of the *Act*, the CEA must consider other projects or activities that have been or will be carried out. The purpose of the CEA is to determine if there are adverse effects of other projects that, in conjunction with the effects of this project will likely create significant adverse effects.

The March 4th letter from DIAND recommended that the focus of the CEA should be on fish and fish habitat. There is no reliable pre-dam information on the fish populations in the project area, therefore, changes to physical habitat will be used to address cumulative effects to fish and fish habitat that may arise from breaching the FWSD. Breaching the dam will have the following effects on fish habitat:

- Re-establishment of a natural flow regime in the South Fork of Rose Creek resulting in lower over-winter flows. This effect can extend for some distance downstream in Rose Creek
- Alteration of habitat including the loss of lake habitat and reestablishment of stream habitat in the South Fork of Rose Creek and the habitat in the freshwater channel immediately downstream of the Dam. This effect is generally confined to the existing footprint of the reservoir and immediately downstream.

The project assessment judged these effects to be neutral over the long term because the basis of assessing effects of the breach was the stream habitat that existed in the South Fork of Rose Creek prior to dam construction. However, it will take a period of years for this habitat to return to its original level of productivity provided by a seasoned stream channel and well established riparian vegetation. Therefore, a short-term residual effect of the project would be reduced productivity of the stream habitat relative to the pre-dam conditions.

The other projects that should be considered in the CEA are past, present and future projects with similar impacts as the primary project. These generally include activities associated with the operation of the Anvil Mine, the existing care and maintenance of the mine site and any future project that will proceed. The letter of 4 March 2003 from DIAND confirms that, other than the Anvil Mine, there are no other foreseeable projects for the Anvil Creek drainage that could have a cumulative effect with the dam breach. The following previous and/or ongoing activities will be considered for cumulative effects assessment:

- Development of Rose Creek diversion
- Creation of the pump house pond
- Construction and operation of the FWSD
- Construction of the mine access roads and culvert installation
- Construction of the main haul road and the use of rock drains for road crossings over streams

The full decommissioning of the Anvil Mine can be defined as a likely foreseeable project. While there is no agreement on the specific details of the decommissioning plan at this time, the decommissioning of the mine will be the subject of a CEAA Comprehensive study report and the cumulative effect of mine decommissioning and dam decommissioning will addressed at that time. Also, the Interim Receiver for the Anvil Range Mining Corporation is in the process of preparing an environmental assessment report (EAR) in order to renew and combine the current water licences for the mine site. The water licence renewal triggers a Screening under CEAA and the EAR will include an assessment of the care and maintenance activities, including cumulative effects on fish and fish habitat. Therefore, this CEA will not include the activities of mine site care and maintenance as the CEA for the water licence EAR will consider the cumulative effect of the two projects.

The temporal scope of this CEA will be up to the end of 2008. This time period has been chosen because the Interim Receiver has indicated that, by 2008, a detailed plan for closure of the mine site will have been developed, approved and closure work started. There will be a full environmental assessment of the mine closure plan including a cumulative effects assessment that will address any additional effects on fish and fish habitat in the Rose Creek drainage.

Effects of the Other Activities:

Rose Creek Diversion: This project altered approximately 6 km of Rose Creek when it was divert into a 4.8 km long constructed channel to pass the creek around the tailings facilities.

Pumphouse Pond: The creation of this pond on Rose Creek, which was used to provide water for mill operations, created a 12,500 m^2 pond and eliminated 250 m of creek habitat. This pond provides overwintering habitat for fish. A series of settling ponds were created in the channel of the North Fork upstream of the Pumphouse Pond along with a channel to divert excess flows into Rose Creek just downstream of the Pumphouse Pond (identified as the North Fork Diversion on Drawing 1). The structure used to control the flow of water through the settling ponds creates in impassable barrier to the upstream movement of fish for some of the time.

Construction of the FWSD: The FWSD created a 51.5 ha reservoir and displaced 1.7 km of stream habitat and the foot print of the dam eliminated close to 100 m of stream habitat. The spillway and dam created a barrier to fish movement from the lower reaches of Rose Creek to the upper reaches of the South Fork of Rose Creek.

Operation of the FWSD: Flows from the reservoir were unregulated once the dam reached the spillway elevation during freshet and continued unregulated through most of the summer. During winter months (November – April), the entire flow in the South Fork of Rose Creek came through the low level pipe at an average rate of 0.11 m^3/s. The reservoir normally fluctuates 6 m per year but can be as much as 10 m which likely limits the productive capacity of the reservoir. Also, the ongoing operation of the FWSD poses a risk to downstream fish and fish habitat that could occur as a result of piping with in the dam structure. Such a “sunny day” failure could result in the failure of the downstream tailings facilities and mobilizing contaminants down Rose Creek into Anvil Creek and the Pelly River.

Construction of the Access Road: Culverts that pass the South Fork of Rose Creek under the access road created a barrier to fish migration approximately 4 km upstream of the reservoir.

Construction of the Haul Road: A rock drain was used to pass the North Fork under this road that is a barrier 1425 m up the North Fork of Rose Creek and the footprint of the drain covers over 100 m of the creek channel. On the South Fork, a culvert approximately 40 m long is used which is approximately 500 m upstream of the access road culvert and is also a barrier to fish passage. While the culvert is a fish barrier, this reach of the south fork of Rose Creek does contain a high gradient section that is likely a natural barrier to fish movement. The haul road also crosses the North tributary of the FWS reservoir (Drawing 4 – Preliminary Dam Breach Report) however, this area of the tributary is relatively high gradient and likely does not support fish.

Harder (1991) reported that the creation of the reservoir had a beneficial impact on the productivity of the South Fork of Rose Creek and that all segments of the South Fork, and the North Fork provided the necessary elements to support Arctic Grayling. However, the formation of the reservoir, the access road and haul road have disrupted fish habitat and created barriers to fish movement. The impacts in summary include:

- Barriers on the North Fork have excluded access to over 13 km of the North Fork of Rose Creek.
- The Spillway barrier on the South Fork of Rose Creek eliminated access into the reservoir and approximately 4 km of stream habitat above the reservoir plus the short sections of accessible habitat in the North and Southeast tributaries of the reservoir.
- Habitat loss includes:
    - 1700 m of the south fork of Rose Creek within the reservoir,
    - 600 m of the tributaries to the south fork that now flow into the reservoir
    - 100 m under the foot print of the dam
    - approximately 140 m under the haul road rock drain and culvert
    - 1200 m due to diverting Rose Creek around the tailings
    - Total loss = 3800 m of stream channel
- Altered Habitat:
    - 4800 m within the Rose Creek diversion
    - 250 m within in the freshwater channel below the dam
    - Total altered = 5050 m
    - The altered channels are generally straight with limited complexity and likely not as productive as the original channels.
- Habitat Creation:
    - Short term (34 yrs) creation of reservoir habitat with a maximum surface area of 51.5 ha.

Cumulative Effects

The incremental effect of breaching the FWSD relative to the effects to fish and fish habitat affected by other project and activities in the Rose Creek Watershed will be beneficial. While the dam breach may have some short term residual effects on fish habitat relative to pre-dam conditions, the project will have the overall benefit of restoring significant lengths of stream habitat in the South Fork of Rose Creek. The breach project will undo many of the impacts of the initial dam construction including the loss of stream habitat within the reservoir area, under the footprint of the dam and immediately below the dam. The breach project will also re-establish fish passage through out the accessible sections of the South Fork of Rose Creek (up to the mine access road). The loss of the reservoir will reduce the overall habitat for adult arctic grayling but the increase in stream habitat will significantly increase the availability of suitable habitat for arctic grayling spawners and juveniles.

The re-establishment of the natural flow regime in the South Fork of Rose Creek will restore the natural hydraulic balance in the creek and is not expected to have a cumulative effect with other projects or activities. The recent risk assessment by SRK (2003) concluded that the FWSD would not substantially alter the impact of a PMF flood in the Rose Creek watershed and the associated consequences on the Rose Creek Diversion and the tailings facilities.

No significant, adverse cumulative effects are anticipated as a result of breaching the FWSD on the South Fork of Rose Creek.

3 JUSTIFICATION OF PIPE REMOVAL AND PLANS FOR PIPE DECOMMISSIONING

In correspondence dated 7 January 2003, DFO agreed to the concept of leaving the low-level pipe in place, provided that clear technical justification was provided. However, as noted in the DIAND letter of 4 March 2003, the Preliminary Breach Design Report did not articulate sufficient justification. Supplementary justification has, therefore, been requested.

DFO has concerns that groundwater flow associated with the pipe could potentially cause erosion of the residual dam above the pipe and/or tunnelling of flows through an under-dam channel. In view of these concerns, DFO is seeking an analysis of the likelihood associated with each of the following possibilities, and associated consequences should these events occur:

1. The possibility that piping may eventually occur along the exterior of the pipe;
2. The potential for long-term deterioration of the pipe walls and end caps and fate of the vertical riser at the upstream end;
3. The potential for long-term piping of the alluvium material that surrounds the pipe; and
4. The fate of water that inevitably would enter the pipe.

In addition, DFO has requested the following:

- additional details about the plans for decommissioning the low-level outlet (LLO).
- an explanation of the long-term risk(s) associated with leaving the pipe in place, including comments on the degree to which this risk is reduced and or eliminated by removal of the head created by the reservoir.

The full response to this request for additional information is contained in a memorandum which is attached as Appendix A. A brief overview of the information provided in Appendix A is provided below.

The following explanation is provided in relation to the <u>first</u> and <u>third</u> of the DFO concerns noted above:

The risk of inducing a piping failure following removal of the reservoir and its associated head is zero for all practical purposes. This conclusion is based mainly on the very low head that will be applied across the length of the LLO pipe following reservoir removal. In the absence of significant hydraulic head, the gradient will be too low for piping to occur.

The following discussion is provided in relation to the <u>second</u> DFO concern:

The estimation of the rate at which the LLO pipe will deteriorate is influenced by the following factors:

- the LLO pipe was constructed with substantial external reinforced concrete protection (the concrete around the pipe is believed to have deteriorated little over the past 30+ years);
- the water supply to the area will be removed, thereby reducing the flow of oxygenated water in contact with the LLO pipe;
- the ends of the LLO pipe will be sealed and buried, which will reduce the amount of oxygen in contact with the steel pipe, and
- the pipe is buried in an area where frozen, or at least, cold ground conditions previously existed. It is expected that following removal of the reservoir the cold ground conditions will reform (i.e. permafrost may re-form).

These factors will slow the deterioration of the pipe, potentially to the extent that significant deterioration may not occur. However, unless permafrost ingress occurs in this area, it is possible that the pipe will deteriorate in the very long term, i.e. many several tens (possibly hundreds) of years.

The preliminary design indicated that decommissioning of the LLO includes removal of the trash rack (inlet-end) and valve house (outlet-end), covering (plugging) both ends of the pipe with steel plates and burial of the remnant structures with soil. As part of final design, it is anticipated that at least one cement or cement/bentonite plug will be added to the plan. If the LLO pipe deteriorated to the point of collapse (in areas not plugged), water entering the pipe would have to first flow through the overlying soil into the pipe, and water leaving the pipe would, again, have to flow through the overlying soil. Since the creek will be offset from the pipe location and most of the pipe is covered by a significant thickness of soil comprising the residual FWSD structure, the net

> effect is that any flow through the pipe would be a very small part of the local groundwater flow. Should this occur, the potential impact on the surface flow in the South Fork of Rose Creek is expected to be inconsequential.

The following discussion is provided in relation to the <u>fourth</u> DFO concern:

> Given that at least one cement or cement/bentonite plug will be constructed inside the pipe and both ends of the pipe will be sealed with steel plates and buried, no direct flow will occur inside the pipe for many years. Water which potentially enters the pipe during this time is likely to be held in the pipe indefinitely. If, in the long term, the pipe does deteriorate to the extent that groundwater can flow into, down and then out of the pipe, water leaving the pipe would flow into the alluvial soils at the base of the valley. This water would then join the groundwater flow within the alluvial aquifer and potentially, the surface water flow within Rose Creek. The total seepage volume is expected to be orders of magnitude less than the volume of water flowing through the creek and, therefore, to have almost no effect on the water quality within the creek.

In summary, the removal of the reservoir completely eliminates the risk of piping at this location. The long term effects of non-removal of the LLO pipe are unlikely to be significant, with respect to either collapse of the pipe or deterioration of the steel pipe and concrete. It is expected that, in the short term, removal of the LLO pipe and compaction of replacement fill in the winter (to fill the void previously occupied by the LLO) would actually produce a greater risk for the development of an under dam channel than leaving the LLO in place and providing plug(s) within the pipe. Although seepage associated with non-removal of the pipe might increase in the long term, it could be less than the seepage associated with the removal of the pipe (simply due to the lineal continuity and increased area associated with the pipe removal option).

Subsequent to the preliminary design, the following details have been developed in relation to the abandonment of the LLO (note that the following list provides a general outline of the program, which may be changed as part of final design, although this programs general design intent will be maintained):

1. The inlet section of the LLO will remain in place.
2. The trash rack of the LLO will be removed, and replaced with a steel plate to cover the opening.
3. A plug of cement or cement/bentonite will be inserted near the inlet end of the LLO at a location where the LLO is within the bedrock trench.

4. The area surrounding the inlet location will be a spoil area for material taken from the breach of the dam. The spoil will be used to fill in the low area around the inlet, providing a minimum cover of 2 m over the capped inlet of the LLO.
5. The piping of the valve house and concrete valve house will be substantially removed. Waste generated from the removal will be taken to an appropriate spoil area.
6. A second plug of cement or cement/bentonite may be inserted near the outlet end of the LLO, at a location where the LLO is within a bedrock trench, in order to provide a seal of the pipe.
7. The former location of the valve house will be used as a spoil area. The capped end of the LLO will be covered by a thickness of soils greater than 2 m.

4 UPDATE ON DE-WATERING PLAN

On 13 February 2003, subsequent to the completion of the Preliminary Breach Design Report, Klohn Crippen issued to the Interim Receiver a report entitled "Low-Level Outlet Assessment." A copy of the Klohn Crippen report is contained in Appendix B. The key conclusions related to the potential use of the LLO for lowering the reservoir are as follows:

- The flow through the LLO, in its existing condition, cannot be increased to 1.5 m^3/s (20,000 Imp. Gpm) or more without absolute pressures in the outlet dropping to a level at which damaging cavitation will occur. To avoid damaging cavitation, it is estimated that the discharge should not exceed 0.4 m^3/s (5,600 Imp. Gpm).
- Assuming that the section of pipe projecting into the dissipator chamber is in a condition that will permit the welding on of a hub flange and the attachment of an orifice plate, then the outlet could be modified to permit discharges up to between an estimated 2.7 to 3.0 m^3/s (35,000 and 39,000 Imp. Gpm), depending upon the degree of energy dissipation that occurs in the dissipator chamber. To permit this discharge, the plug valve would also have to be securely bolted to the floor of the valve chamber.
- With the modifications noted above and the reservoir elevation equivalent to the intake of the LLO, the discharge through the LLO will diminish to a maximum flow rate of about 1.1 m^3/s (15,000 Imp. Gpm).
- Although not discussed in the Klohn Crippen report, there are not considered to be any other means of safely increasing the flow through the LLO.

On 26 February 2003, site personnel completed an inspection of the dissipator chamber within the valve house and concluded there are no impediments to implementing the proposed modifications. Based on this determination and further information from Klohn Crippen on 4 March concerning the specifications of the orifice plate, the machining of the orifice plate and flange system was arranged. Efforts to implement the Klohn Crippen modifications are expected to commence during the week of 10 March. The completion of the modifications is expected by 19 March, following the modified system will be tested to verify that the LLO can be operated in accordance with the design expectations.

Following completion of the performance tests on the LLO and receipt of the necessary permits, the LLO will be used to dewater the reservoir. It is expected that this will commence in the summer of 2003. The rate and specific timing of the reservoir drawdown will be optimized to account for issues such as fish removal, the upstream stability of the FWSD, flood risks and the deadline for the completion of the overall activities.

Once the low-level outlet has drawn down the reservoir to its minimum level (approximately 1082 m), a system of pumps will be used to complete the reservoir drawdown and maintain the water at suitable levels throughout the construction period. Further details are provided in the Preliminary Design Report, and these will be refined as part of final design.

5 SEDIMENT MONITORING DATA

A field program was completed between 13 and 15 February 2003 in order to collect additional information for the final design of the breach at the FWSD. The results of that field program are summarized in a memorandum attached as Appendix C. A summary of the sediment testing results are provided below. The summary focuses on determination of the quantity and quality of the sediment. Significant discrepancies between the new data and data presented in the Preliminary Breach Design Report are explained. The analysis of potential sediment effects is updated to reflect the more recent data.

Sediment samples were collected from the base of the reservoir at nine locations. An underwater camera was used to examine the base of the reservoir at these nine sample locations and at 11 additional locations that were not sampled. These observations were used to estimate the thickness of sediment in the reservoir. In deeper water locations, the sediment thickness was between 10 and 20 mm thick. In locations with shallow water, the thickness of sediment varied from about 1 to 5 mm thick.

Based on the revised sediment investigation testing presented in this memorandum, between 3,700 and 5,000 m^3 of sediment could be expected within the reservoir. These estimates were made by assuming that the reservoir had an average sediment thickness of 15 mm or 20 mm spread evenly through half of the reservoir surface area of 486,600 m^2.

Two samples of fine-grained sediments from the FWSD reservoir were collected and submitted for physical properties (grain size) and the <75 μm fraction of these samples were submitted for metal analysis by ICP.

The results indicate that the one of the sediment samples consisted of 60% sand, 30% silt and 10% clay sized particles and the other sample consisted of 19% sand, 54% silt and 27% clay.

The results of the metal analyses indicated that the FWSD samples are comparable to the range observed in the regional sediments, with the exception of copper, which was significantly higher than in the Vangorda Creek sediments. A comparison of the data to Federal Canadian Council of Ministers of the Environment (CCME) interim sediment quality guidelines (ISQG's) and probable effects levels (PEL's) indicated that copper, lead and zinc concentrations in the FWSD samples exceeded the ISQG's, and that lead in one of the samples exceeded the PEL. However, sediment samples from Vangorda Creek also exceeded the ISQG's for these and several other metals (arsenic, cadmium, and zinc), and exceeded the PEL's for lead. Elevated copper concentrations in the samples may also be due in part to the use of brass sieves during physical characterization of the samples. In conclusion, while the sediments contain some metals that exceed the applicable guidelines, they are reasonably typical of un-impacted regional sediments.

The results collected in the February field program supersede the results previously presented, for the following reasons:

1. Results of the February program conform to expectations of sediment gradations and locations. For example, the sediment collected near the head of the reservoir consists of sand with some silt, near the center of the reservoir the sediment is mostly silt with some sand and clay, and the sediment near the dam consists mostly of clay sizes with some silt. This pattern reflects the speed that sediment particles will settle within a still body of water. The results of the previous sampling, in December 2002, would indicate that sand and gravel would have floated about 2 km in still water. It is thought, therefore, that the sediment collected between the cofferdam and the FWSD in December 2002 may have been deposited as a result of the breach of the cofferdam in 1968.
2. Sediment thicknesses were estimated both by visual inspection of the base of the reservoir and through drive sampling during the February program. Sediment thickness near the dam was estimated by the divers in December 2002 by pushing a metal rod into the reservoir base. The sediment was estimated based on the rod hitting a "hard" base. The method used by the divers, does not take into account softening of the upper soil in an underwater environment. It should be noted that during the drive sampling performed in February, the sampling was stopped when a "hard" base was encountered, similar to the testing performed in December. At one sample location, the sampler was driven 483 mm (19 inches) before hitting hard material, but based on the sediment returned in the sample and visual inspections, only 2 to 5 mm of sediment were present at this location.

6 ACCIDENTS AND MALFUNCTIONS

The DIAND letter of 4 March 2003 indicated that consideration of consequences and potential mitigation should be given regarding a scenario of early snowmelt.

Table 6.1 outlines the dates of the onset of spring freshet that have been measured, at station R7 on the North Fork of Rose Creek, on site during the last five years. For planning purposes the earliest anticipated start of spring runoff was April 14. This date has been used as the final date for completion of construction activities.

Table 6.1
Start of Spring Runoff at the Faro Mine Site

Year	Date of Start of Spring Run-off
1997	April 26
1998	May 1
1999	April 21
2000	May 2
2001	May 5

The consequences and potential mitigation measures associated with an early snowmelt in 2004 depend on the status of the dewatering and breach construction process at the commencement of the freshet. Comments for a series of dewatering/construction conditions are provided below.

Case 1: The reservoir is dewatered and the base of the breach is at least a metre or so above the spillway crest.

In this case, which would be essentially the same result regardless of the extent to which the reservoir is dewatered, reservoir levels are controlled by the LLO and, if necessary, the spillway (assuming the reservoir were to rise to the level of the spillway). Consequences are expected to be minimal, unless the freshet brings flows that lead to an overtopping of the dam. In this latter case, the consequences would be catastrophic, as a failure of the FWSD will lead to an overtopping of the downstream tailings dams. In the absence of dam failure, the only consequence would be a delay of the breach schedule beyond the 2004 freshet. It would still be possible, however, to complete the breach activities as part of the 2004 calendar year.

Case 2: The reservoir is dewatered and the base of the breach is lowered below the spillway inlet.

In this case, water levels are controlled by the LLO only. The spillway cannot be used because the dam will overtop before the reservoir level reaches the spillway. If the freshet occurs when the breach level is high, the consequences are likely to be severe. In particular, the higher the breach level is when it is overtopped, the larger is the volume of impounded water that will wash downstream and, therefore, the risk of a failure of the downstream tailings facilities is also higher. Conversely, when the dam is low, the consequences are likely to be much less severe. A lower dam impounds less water which means there is less of a chance of problems with the downstream tailings facilities. Any repairs and the remaining breach activities would have to be completed as part of the 2004 calendar year.

The mitigation measures associated with this case are as follows:

- The breach excavation must not start unless there is sufficient time for the dam breach activities to be completed. This will include an adequate safety factor in relation to the data base of previous freshets records.
- In the unlikely event that the dam breach activities are not completed before the onset of the freshet, emergency measures should be implemented to lower the breach as quickly as possible.

Case 3: The dam has been breached, but the fish habitat works within the floodplain are still under construction.

In this case, water levels are controlled by the breach. No significant downstream impacts are expected, other than the cost of reconstructing any of the fish habitat works that were damaged by the freshet. These repairs and any remaining breach activities would have to be completed as part of the 2004 calendar year.

The mitigation measures associated with this case are simply that breach excavation must not start unless there is sufficient time for the dam breach activities to be completed. This will include an adequate safety factor in relation to the data base of previous freshets records.

7 CONCLUSIONS

The information contained in this supplement is based on data acquisition completed to date, as well as the current status of the final design of the FWSD breach. It is included here with the sole intent of fulfilling the requests contained in the DIAND letter of 4 March 2003.

Additional data will be gathered later in this year, post-freshet, in relation to fisheries and vegetation issues. Furthermore, the final design is ongoing with an expected completion date of 1 April 2003.

It is anticipated that elaboration and/or consideration of other aspects arising from the review of this document by the Regulatory Authorities can be addressed as part of the final design.

This report "**Supplement to the Preliminary Breach Design Report, Fresh Water Supply Dam, Faro Mine**" has been prepared by:

STEFFEN ROBERTSON & KIRSTEN (CANADA) INC.

Gerry Ferris, P.Eng.
BGC Engineering Inc.

Cam Scott, P.Eng.
SRK Consulting Inc.

Bruce Ford, R.P.Bio.
Gartner Lee Limited

Peter Healey, P.Eng.
SRK Consulting Inc.

Appendix A

Justification of Pipe Removal and Plans for Pipe Decommissioning

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
1605, 840 – 7 Avenue S.W. , Calgary, Alberta, Canada. T2P 3G2
Phone (403) 250-5185 Fax (403) 250-5330

PROJECT MEMORANDUM

To:	**File**	**Fax No.:**	
Attention:	**1CD001.22**	**CC:**	
From:	**Gerry Ferris / Cam Scott**	**Date:**	**March 13, 2003**
Subject:	**Justification of Pipe Removal and Plans for Pipe Decommissioning – FWSD Breach Project**		
No. of Pages (including this page): 7		**Project No:**	**0257-012-06**

This memorandum regarding the low level outlet (LLO) pipe has been prepared in partial response to a letter received from Indian and Northern Affairs (DIAND) and Fisheries and Oceans (DFO), dated March 4, 2003. It is expected that this memorandum forms a portion of the response (information request number 2) to the request for supplementary information and therefore will form a portion of the Environmental Assessment report that will allow DIAND and DFO to complete their environmental assessment of the project.

Background

This memorandum offers the following summary with respect to the LLO.

In a letter dated November 15, 2002 DFO required that "Practical engineering plans and costs to conduct a full breach of the Faro Freshwater Supply Dam and low level outlet pipe removal for fall-spring 2003-2004". Following discussions in a meeting on December 3, 2002 DIAND and the Interim receiver requested clarification on the issue of removal of the LLO.

In the January 7, 2003 response letter from DFO, the following clarification was provided: "DFO's requirement for plans regarding removal of the low-level pipe was made prior to recent information surrounding the construction of the low-level pipe. DFO's intention again is the long-term reduction of risks to downstream fisheries resources. You have indicated that as-built records identifying that the low-level pipe and the original channel do not coincide. In light of this new information and that the pipe removal may be an expensive and redundant endeavour, the DFO is prepared to consider pipe decommissioning alternatives that satisfactorily mitigate the risk imposed on the downstream environment without excavation of the pipe, provided clear technical justification is provided."

Section 3.6 of the Preliminary Breach Design[1] report provided a discussion regarding the reasoning for leaving the LLO in place. Following a review of the preliminary breach design report, DFO indicated that the information provided in Section 3.6 did not articulate sufficient justification for the non removal of the pipe. Therefore, as indicated in the February 18, 2003 meeting and discussed in the March 4, 2003 letter, supplementary justification regarding the decision to leave the LLO in place has been requested.

Request for Clarifications

The initial directive (November 15, 2002) from DFO directed the removal of the low-level pipe. A subsequent clarification (January 7, 2003) confirmed that the removal of this pipe was not a requirement, provided clear technical justification for leaving it in place is provided.

It is understood that the basis of the original pipe removal requirement was that leaving the pipe in place produced a risk to the long term fisheries resources downstream of the dam breach. Specifically, DFO has indicated (part of a DIAND letter dated March 4, 2003) that they have outstanding concerns with the potential for groundwater flow associated with the pipe. The concerns are with respect to the potential to cause erosion of the residual dam above the pipe and/or tunnelling of flows through an under-dam channel. Specifically, the concerns are related to:

1. The possibility that piping may eventually occur along the exterior of the pipe.
2. The potential for long-term deterioration of the pipe walls and end caps and fate of the vertical riser at the upstream end.
3. The potential for long-term piping of the alluvium material that surrounds the pipe.
4. The fate of water that inevitably would enter the pipe.

DFO notes that they are seeking an analysis of the likelihood associated with the above possibilities, and associated consequences should the events occur.

The supplement should provide clear explanations about the long-term risks associated with leaving the pipe in place. The degree to which this risk is reduced and or eliminated by removal of the head created by the reservoir should be discussed.

The information should provide additional details about the plans for decommissioning the low-level outlet.

[1] SRK Consulting Inc., BGC Engineering Inc. & Gartner Lee Limited. 2003. Preliminary Breach Design, Fresh Water Supply Dam, Faro Mine. Report submitted to Deloitte & Touche Inc., February 3.

Supplementary Information Regarding the LLO

The following key information is highlighted with respect to LLO. This information is used to address the specific concerns raised by DFO.

- The LLO pipe (according to as-built records and construction photos) was surrounded in 0.38 m (1.25 feet) of re-enforced concrete, with the base of the concrete founded on bedrock.
- The general trench backfill of the excavation required to install the LLO consisted of compacted fill between re-enforced concrete seepage cut-off collars placed 6 m on center along the alignment of the LLO. The seepage cut-off collars extended from bedrock to 1.3 m (4.25 feet) above the obvert of the LLO. These details are illustrated on as-built drawing D-1575-058-010 (attached).
- The LLO pipe was constructed in a section of the valley that was permafrost prior to the construction of the FWSD.
- The inlet elevation of the LLO is 1082 m amsl and the spring line of the LLO, at the inlet, is 1077.8 m amsl.
- The elevation of the LLO at the valve house is 1077.5 m amsl. Given the elevation at the inlet, this indicates that the LLO is nearly flat.
- The proposed elevation of the channel through the dam breach (near the inlet of the LLO) is 1080 m amsl.
- For the design flood, 500 year return period, and the 20 m width of the floodplain in the breach section, resulted in a depth of flow of about 1 m of water. Meaning that for the design flood the maximum water level will be 1081 m amsl, or 1 m below the inlet elevation of the LLO.
- The water elevation of the outlet of the breach section is 1077 m amsl.

With respect to the first and third concerns:
The risk of inducing a piping failure following removal of the reservoir and its associated head is zero for all practical purposes. This conclusion is based mainly on the very low head that will be applied across the length of the LLO pipe following reservoir removal. In the absence of significant hydraulic head, the gradient will be too low for piping to occur.

The assessment that the possibility of a piping failure was zero was made the very low applied head across the length of the LLO pipe and that the alluvium material in the base of the valley has a much greater permeability than the material surround the pipe.

As noted, the permeability of the alluvial (consisting of cobbles, gravel and sand) deposit in the bottom of the valley is much higher than the compacted fill and concrete seepage collars. This means that seepage will preferentially concentrate within the alluvial material as compared to the area surrounding the LLO.

With respect to the second concern, the following discussion is provided:
The deterioration of the steel pipe is possible in the long term, but the deterioration is expected to be very slow due to the limited supply of water and oxygen to the LLO following completion of the breach project.

According to the results of sonic testing of the LLO pipe in 2001, it has experienced up to a 54% reduction in its thickness, since installation in 1968. This reduction in the wall thickness was noted at one location. The thickness reduction occurred under conditions of constant contact with running water (and thereby an oxygen source to drive the oxidation process).

Completion of the breach of the dam will have three main effects on the LLO. The first is to remove the source of water through the pipe, thereby changing the source of water to the concrete and steel from reservoir water to groundwater. This will reduce the amount of oxygenated water that is in contact with the concrete and steel, which reduces the deterioration rate. The placement of soil cover on the inlet and outlet areas will reduce the amount of oxygen in contact with the steel pipe, which will further reduce the deterioration rates. Thirdly, although less significant that the previous two, removal of the reservoir removes a heat source from the area, which will result in a general ground cooling, which reduces the rate of chemical reactions.

The removal of the reservoir and its associated heat source will allow the establishment of a new temperature equilibrium in this area. Prior to the construction of the dam, this was an area of discontinuous permafrost. Following removal of the reservoir, permafrost may develop in this area, although it is expected to be a long term process (i.e. many decades). The expected cooling of the ground in the area will reduce the rates of chemical reactions which control the deterioration rates. Although the deterioration rates of the concrete and the steel of the LLO pipe are expected to be very slow, it is possible that the LLO pipe could deteriorate over time.

The preliminary design indicated that decommissioning of the LLO includes removal of the trash rack (inlet-end) and valve house (outlet-end), covering (plugging) both ends of the pipe with steel plates and burial of the remnant structures with soil. As part of final design, it is anticipated that at least one cement or cement/bentonite plug will be added to the plan. If the LLO pipe deteriorated to the point of rupture or collapse (in areas not plugged), water entering the pipe would have to first flow through the overlying soil into the pipe, and water leaving the pipe would, again, have to flow through the overlying soil. Since the creek will be offset from the pipe location and most of the pipe is covered by a significant thickness of soil comprising the FWSD residual structure, the net effect is that any flow through the pipe would be a very small part of the local groundwater flow.

Given the very low rates of chemical reaction and the low rates of groundwater flow through the bedrock, the collapse of the pipe is not expected, but should it occur, the potential impact on the surface flow in the South Fork of Rose Creek is expected to be inconsequential.

With respect to the fourth concern, the following discussion is provided:
Given that at least one cement or cement/bentonite plug will be constructed inside the pipe and both ends of the pipe will be sealed with steel plates and buried, no direct flow will occur inside the pipe for many years. Water which potentially enters the pipe during this time is likely to be held in the pipe indefinitely. If, in the long term, the pipe does deteriorate to the extent that groundwater can flow into, down and then out of the pipe, water leaving the pipe would flow into the alluvial soils at the base of the valley. This water would then join the groundwater flow within the alluvial aquifer and potentially, the surface water flow within Rose Creek. The total seepage volume is expected to be orders of magnitude less than the volume of water flowing through the creek and, therefore, to have almost no effect on the water quality within the creek.

The ultimate fate of water will depend on the final temperature of the ground in the area of the pipe. As noted previously, this area was previously permafrost and the removal of the reservoir removes a heat source which has been keeping the ground warm. If permafrost does not form, then the description presented in the previous paragraph is applicable. If permafrost does reform in this area, the water within the pipe would freeze which would limit groundwater flow to nearly imperceptible levels.

The breach project has been ordered complete prior to the onset of the 2004 spring freshet. Given various constraints on the project, the construction period is likely to be throughout the winter of 2003/2004. If the LLO pipe were to be removed, given its embedment in concrete (attached as-built drawing D-1575-058-010), its removal would be performed through blasting which would further increase the permeability of the local bedrock. More importantly, the material placed into the trench created by the removal of the LLO pipe would have to be placed in the winter. Winter placement of fill would result in variable properties of the fill material (both strength and permeability), and likely result in a worse situation with respect to the creation of a under dam channel than leaving the LLO pipe in place.

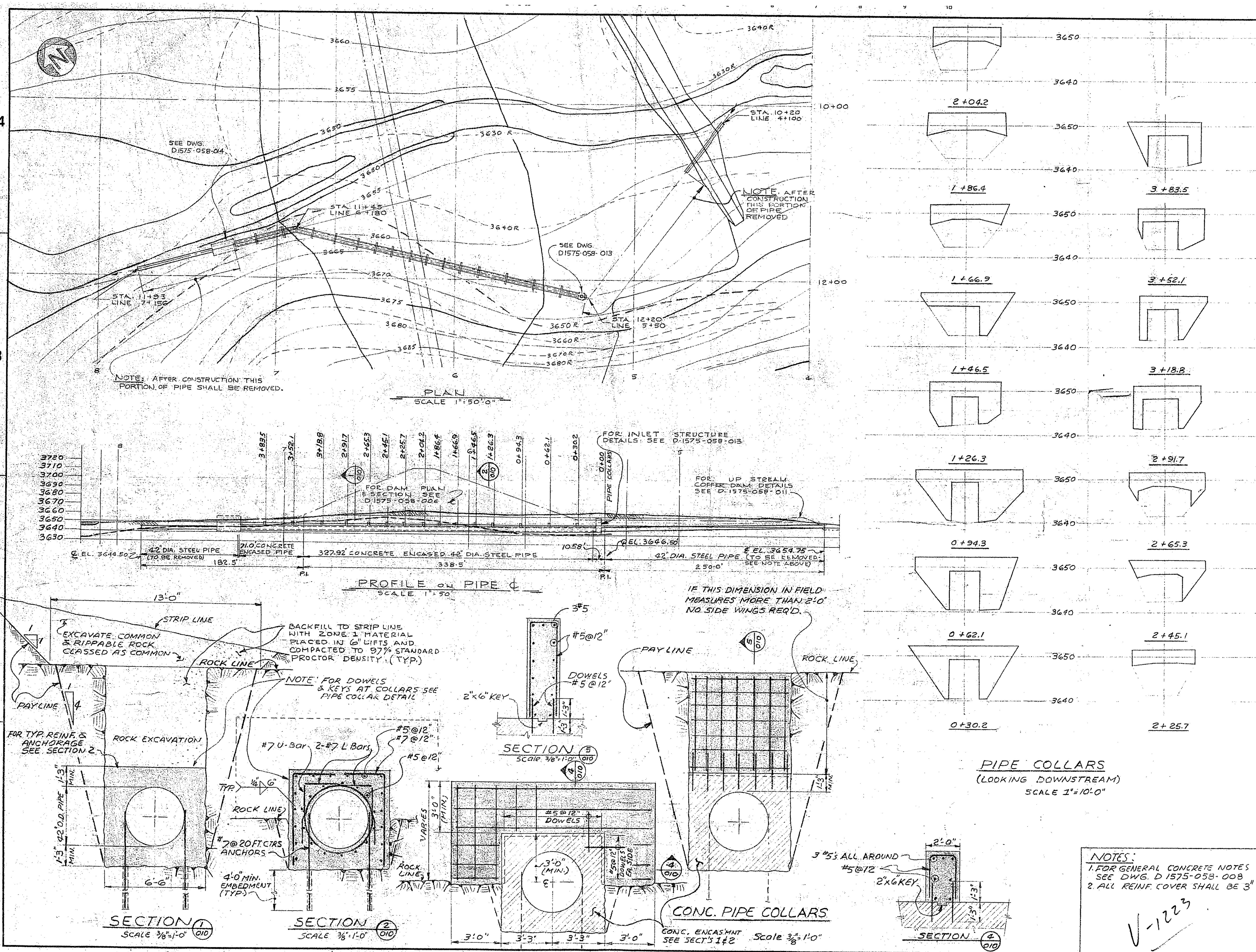
In summary, the removal of the reservoir completely eliminates the risk of piping at this location. The long-term effects of non-removal of the LLO pipe do not appear to be significant, with respect to either collapse of the pipe or deterioration of the steel pipe and concrete. It is expected that compaction of fill in the winter would actually produce a greater risk for the development of an under dam channel than leaving the LLO in place and providing plug(s) within the pipe.

Decommissioning Plans for the LLO Pipe

Section 5.2.8 of the preliminary breach design report outlined that the inlet of the LLO would be capped with a metal plate and the remainder of the structure buried and the ground surface shaped over the inlet. Abandonment of the valve house was to consist of removal of the piping, the concrete valve house, plugging the end of the LLO and burial of the exposed footprint.

Subsequent to the preliminary design, the following details have been developed in relation to the abandonment of the LLO (note that the following list provides a general outline of the program, which may be changed as part of final design, although this programs general design intent will be maintained):

1. The inlet section of the LLO will remain in place.
2. The trash rack of the LLO will be removed, and replaced with a steel plate to cover the opening.
3. A plug of cement or cement/bentonite will be inserted near the inlet end of the LLO at a location where the LLO is within the bedrock trench.
4. The area surrounding the inlet location will be a spoil area for material taken from the breach of the dam. The spoil will be used to fill in the low area around the inlet, providing a minimum cover of 2 m over the capped inlet of the LLO.
5. The piping of the valve house and concrete valve house will be removed. Waste generated from the removal will be taken to an appropriate spoil area.
6. A second plug of cement or cement/bentonite may be inserted near the outlet end of the LLO, at a location where the LLO is within a bedrock trench, in order to provide a seal of the pipe.
7. The former location of the valve house will be used as a spoil area. The capped end of the LLO will be covered by a thickness of soils greater than 2 m.



NOTES:
1. FOR GENERAL CONCRETE NOTES SEE DWG. D 1575-058-008
2. ALL REINF. COVER SHALL BE 3"

DWG. ISSUED TO VENDOR	PURCHASE ORDER NUMBER	DESCRIPTION

REQ'D FOR CONTR.	ASSOCIATED DRAWINGS	
	D-1575-058-006	PLAN & SECTION
	-008	SPILLWAY STRUCTURE CONCRETE OUTLINE
	-011	UPSTREAM COFFER DAM
	-012	DOWNSTREAM COFFER DAM
	-013	INLET STRUCTURE CONCRETE OUTLINE
	-016	42" DIA. DIVERSION PIPE STEEL DETAILS
	-014	OUTLET STRUCTURE CONCRETE OUTLINE

ISSUE NO.	D/M/Y	ISSUE	DR	CH	APP
06	31/10/68	PIPE COLLAR LOCATIONS ADDED. AS BUILT			
05	AUG 15 1968	SECTIONS REVISED SHOWING NEW PAYLINES AS PER FIELDMEETING & AGREEMENT OF AUGUST 2, 1968			
04	23/7/68	ISSUE FOR CONSTRUCTION			
03		42" DIA. DIVERSION PIPE WAS 7'-0" DIA. MULTI PLATE			
02	29/5/68	REDRAWN & ISSUED FOR TENDER			

CERTIFIED FOR CONSTRUCTION
SCALE AS NOTED

PARSONS – JURDEN CORPORATION
ANVIL MINES PROJECT — YUKON TERRITORY

H. A. SIMONS (INTERNATIONAL) LIMITED
CONSULTING ENGINEERS
VANCOUVER, B.C. — CANADA

AREA: WATER STORAGE DAM
SUBJECT: DIVERSION STRUCTURE
HAS DRAWING No: D-1575-058-010
REV: 06

Appendix B

Low Level Outlet Assessment

ANVIL RANGE MINE
WATER SUPPLY DAM

LOW-LEVEL OUTLET ASSESSMENT

Prepared for:

DELOITTE & TOUCHE INC

and

SRK CONSULTING

By:

KLOHN CRIPPEN

A3003-03-01 February 2003

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DISCLAIMER

This report was prepared by Klohn Crippen for the sole use of Deloitte & Touche Inc. and SRK Consulting in connection with the decommissioning of the Water Supply Dam at Anvil Range Mine, near Faro, Yukon. All other parties are third parties.

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1. INTRODUCTION

This report presents the findings of an assessment of the capability of the low-level outlet of the water supply dam at the Anvil Range Mine with regard to its use to draw down the reservoir in preparation for the proposed breaching and decommissioning of the dam.

The assessment was requested by Cam Scott of SRK Consulting (SRK), Vancouver and was performed as a separate task under an existing Klohn Crippen project assignment for Deloitte & Touche Inc. The Terms of Reference (TOR) for the assessment were prepared by SRK, with minor amendments by Klohn Crippen.

2. PROJECT DESCRIPTION

The mine and water supply dam are situated 22 km by road from Faro, Yukon, which is situated approximately 344 km by road from Whitehorse. The dam is a zoned earthfill embankment.

The low-level outlet is situated on the left side of the original river valley and according to "as-built" drawings consists of:

- an inlet structure formed by a vertical concrete-encased section of 42-in-diameter steel pipe, 12.5 ft high, equipped on top with four vertical trashrack panels forming a square and covered by a steel plate;
- a concrete-encased 42-in-diameter steel pipeline founded on rock passing under the dam; and
- a reinforced concrete outlet structure at the downstream toe of the dam housing a 42-in to 24-in- diameter eccentric reducer, a 24-in-diameter gate valve, a 24-in-diameter plug valve and associated 24-in-diameter pipe work (H.A. Simons International Drawing D1575-058-014 Rev. 05).

Flow from the outlet pipe discharges into a reinforced concrete dissipator chamber at the downstream end of the outlet structure, flows over a weir in the right side of the chamber, and thence through a rectangular opening at the bottom of the right side wall of the outlet structure into the discharge channel.

The steel pipeline was part of the temporary diversion system used during construction of the dam. The vertical inlet pipe formed a Tee in the temporary diversion pipeline. After construction, the section of pipeline upstream of the Tee was removed and the pipe was closed with a blind flange.

In recent years, flows through the low-level outlet have been restricted to about 5,500 Imp. gpm due to safety concerns.

3. SCOPE OF WORK

In accordance with the TOR, the objectives of the assessment were:

- to assess whether the flow through the system in its current condition can be safely increased to 20,000 Imp. gpm or more;
- if not, identify what measures, if any, would need to be implemented to increase the flow capacity of the current system to 20,000 Imp. gpm or more; and
- consider and identify other means of increasing the flow through the low-level pipe system, such as installing a valve system on the upstream end of the low-level pipe.

The scope of work consisted of:

- a review of background reports provided by SRK, and construction drawings prepared by H. A. Simons (International) Ltd., issued with the annotation "As Built";
- a site visit, inspection and survey of pipe wall thickness;
- a hydraulic evaluation of the low-level outlet system;
- a structural evaluation of the critical buckling pressure of the pipe, and of the strength of the outlet dissipation chamber; and
- the preparation of this report.

In view of the need for early results, and in the absence of information from the plug valve manufacturer, a draft of this report was prepared based on a hydraulic evaluation using valve characteristics developed from information in the technical literature. The draft was submitted and on 15 January 2003. Information was subsequently received from the original valve manufacturer's current corporate parent company and the hydraulic evaluation was updated.

4. SITE VISIT

4.1 General

Chris Wilson P.Eng. flew to Whitehorse on Friday 20 December 2002, and drove to Faro, arriving at the townsite late in the afternoon, where he was met by Mike Bryson. The inspection and survey were conducted on Saturday 21 December and Mr. Wilson returned to Whitehorse late that night, and flew back to Vancouver on Sunday 22 December. The sky was overcast throughout and temperatures hovered close to -20ºC. Light snow fell during the return drive to Whitehorse.

Mr. Bryson had arranged for the valve chamber to be pumped dry, and only a thin sheet of ice remained on the floor of the chamber. Mr. Bryson provided an assistant with a portable generator and lighting. Divers were also on site on the 21 December to re-install the trashrack on the low-level outlet intake that had been removed by other divers during an internal inspection and survey of the pipeline under the dam in September 2001.

Several photographs were taken during the visit and a selection are included in Appendix A.

4.2 Observations and Measurements

The components of the pipe work within the low-level outlet structure valve chamber differ from the details shown on the "as-built" drawings. The principal difference is the presence of a 24-in-diameter spool piece 14.5 in long between the gate valve and the plug valve (Photos. 1 and 2). The spool piece previously housed a flow meter. Mr. Bryson reported that the tappings in the left and right wall of the pipe that housed the meter sensor leaked badly. The sensor was removed and the tappings were replaced and capped. The type of meter has not been established, but was probably either a vortex or positive displacement type, although it is not known how power was supplied to provide the 4 mA signal current required by the Moore Industries Inc. Linear Integrator mounted in a box on the wall of the chamber entrance vestibule. In addition to the two sensor tappings, there are two small shutoff cocks and a plugged tapping in the top of the spool piece.

The dimensions of the other components upstream of the spool piece are essentially the same as indicated on the drawings. Consequently, the presence of the spool piece means that the plug valve and the downstream section of 24-in-diameter pipe with the Smith-Blair flexible coupling are a commensurate distance further downstream than shown on the drawings. The dissipator chamber was full of water, and the outlet passage was flooded by tailwater, and neither could be inspected. Consequently, it is not known whether the section of pipe protruding into the dissipator chamber section of the outlet structure was reduced in length to compensate for the presence of the spool piece.

The three flanged joints between the eccentric reducer and the gate valve, between the gate valve and the spool piece, and between the spool piece and the plug valve, have small concrete plinths under them. However, the four sides of each plinth have formed finishes, and the pedestals are so small that it would not have been possible to get concrete into them with the pipe work in place. Hence, it appears that the plinths were cast before the pipe work was installed, contrary the specification on the drawing that the supports be poured after the installation. The flanges do not appear to be attached to the plinths, and hence they only provide vertical support after the deflection of the pipe work. Furthermore, the downstream flange of the 3,500 lb plug valve does not rest on a plinth and is apparently unsupported except for what appeared to be a piece of timber. The net result is that the pipe work acts, in effect, as a poorly supported beam cantilevered from the upstream wall of the chamber and the concrete surround upstream of the wall.

Forty measurements of the thickness of the steel components were made with an ultrasonic tester. The results are shown in Table 4.1. Despite the heavily corroded exterior of the pipe work the measurements indicate that the pipe work is in much better condition than the buried section of pipeline surveyed by the divers in 2001. The smallest reading was a thickness of 0.300 in (80% of original) on the left spring line of the stub of the 42-in-diameter pipe adjacent to its exit from the upstream wall of the chamber. A reading was obtained on the underside of the 42-in-diameter stub, but a reading could not be obtained on the underside of the eccentric reducer, despite several attempts in different areas. The cause of the failure to get a reading has not been determined. The test areas were severely pitted, but the areas were well covered with couplant, and readings were obtained immediately the sensor was placed on a previously tested section or on the calibration test pieces.

Despite the external appearance, the pipe work appears to be in relatively good condition.

The Rockwell-Nordstrom Fig. 4169 plug valve installed in the valve chamber is no longer manufactured, and neither the current Canadian distributor of Nordstrom valves nor the Nordstrom Audco office in the US were able to provide any information. It had been hoped to obtain a Bill of Material and a Serial Number from the valve to assist in inquiries, but the only plate found on the valve did not contain the information. However, the original manufacturer's current parent company Flowserve in Texas was ultimately able to provide information on the characteristics of the valve.

5. HYDRAULIC EVALUATION

5.1 General

The principal concerns with regard to the prolonged operation of the outlet at large discharge are the potential for damage resulting from cavitation, and from vibration caused by cavitation and by turbulence. In addition, the plug valve is a source of vibration at partial openings because the discharge from the opening in the plug is directed against one wall of the downstream pipe. Any vibration will be accentuated by the absence of proper support, particularly lateral restraint, and the turbulence produced by the eccentric reducer immediately upstream.

With regard to cavitation, four stages are commonly recognized (Ref. 1):

- incipient cavitation, which represents the onset of cavitation where the noise consists of light intermittent popping sounds and has been suggested for use where noise, damage and vibration cannot be tolerated;
- critical cavitation, which is characterized by light steady cavitation noise ("similar to frying bacon") and is a condition considered light enough to preclude any but minor damage in a reasonably long period of time;
- incipient damage, which represents the onset of pitting of solid boundaries caused by implosion of the vapour cavities on or near the boundaries and may produce objectionable noise and some vibration, but damage should be minor; and
- choking cavitation, which is the condition where the mean pressure at or just downstream of the control reaches the vapour pressure of the fluid, and there is no further increase in discharge with decrease in downstream pressure with constant upstream pressure.

Once the choking condition is reached, further increase in upstream pressure or decrease in downstream pressure moves the vapour pressure pocket downstream to induce supercavitation. Near choking the cavitation reaches its maximum intensity and is accompanied by excessive noise and vibration. Heavy damage in a control is likely. If the level is advanced to supercavitation, the cavity collapses further downstream to other parts of the system where damage, intense noise and vibration may occur.

5.2 Methodology

A spreadsheet numerical model was developed to evaluate the hydraulic system. The model was based on the dimensions shown on the "as-built" drawings, as amended by observations during the site visit. Measurements taken by the divers in 2001 (Ref. 2) based on markings on their umbilical, indicate the distance from the top of the inlet of the 42-in-diameter pipeline to the gate valve to be about 15 m less than indicated on the drawings. In addition to the length of the outlet pipe, there are a number of other unknowns concerning the hydraulic losses in the system, particularly, the friction coefficient of the corroded and growth encrusted 42-in-diameter pipe, and the degree of energy dissipation provided by the chamber into which the 24-in-diameter pipe discharges. These losses were based on judgement. Friction losses were calculated using a Manning "n" value of 0.0165 for the 42-in-diameter pipe, a relatively high value for steel, equivalent to a roughness height of 6.6 mm and a Darcy "f" value of 0.0344 for the assumed water temperature of 10^{o}C and resulting Reynolds number. (A roughness height of 6.1 mm represents the maximum quoted in the literature for severely tuberculated pipe.) A somewhat lower Manning "n" value of 0.0145 was assumed for the 24-in-diameter pipe. In the case of the degree of energy dissipation, this was assumed to be equal to the "expansion" loss represented by the square of the difference in velocity between the jet from the pipe and the mean velocity through the chamber outlet, which amounted to approximately 75% of the velocity head of the pipe jet.

Other losses and hydraulic characteristics were based on values in the literature. The hydraulics of the outlet structure are complicated by the close proximity of the rectangular outlet from the dissipator chamber and the rectangular orifice at the base of the outlet structure that discharges to the tailrace channel. The rectangular outlet from the dissipator chamber behaves as a weir until the water level reaches the roof of the chamber, and thereafter behaves more like a submerged orifice. The discharge characteristics of the chamber outlet are also affected by the degree of submergence resulting from the discharge characteristics of the rectangular opening (orifice) at the bottom of the side wall of the outlet structure, which are in turn a function of the hydraulic characteristics of the tailrace channel. These hydraulic characteristics are not readily amenable to reliable calculation, and for an important outlet would customarily be determined in a hydraulic model test. In the absence of such data, the characteristics were estimated based on values in the literature and on judgement.

Flowserve provided the necessary data to calculate the discharges through the plug valve that would cause incipient cavitation, damaging cavitation, and choking cavitation at valve openings from 10% to 100% in 10% increments. These data were incorporated in the spreadsheet model and the cavitation characteristics of the assumed existing conditions were evaluated for a range of valve openings and reservoir levels.

In view of the results of the evaluation of the existing conditions, a modified version of the outlet was evaluated. The modification consisted of the addition of an orifice plate on the downstream end of the 24-in-diameter pipe in the dissipator chamber. The modified outlet was also evaluated with several different degrees of assumed energy dissipation in the chamber.

5.3 1984 Test

A test of the low-level outlet was conducted in October 1984 (Ref. 3), and it had been expected that the test, which included flow measurements, would afford some basis for calibrating the numerical spreadsheet model. However, calculations based on the reported flows and the tailwater levels scaled from photographs in the test report, together with the early results of the numerical modeling, showed a significant discrepancy with respect to the reported conditions.

Firstly, with the guard valve (gate valve) and the control valve (plug valve) fully open, the discharge should have been more than three times the reported discharge of 12,000 gpm (whether Imperial or US units was not reported). Secondly, at the time of the test, a constriction/weir existed in the tailrace channel some distance downstream from the valve chamber. The constriction was formed by earth-filled timber cribs on each bank. The dimensions of the opening between the cribs is not known. It is also not known whether there was a weir plate at the bottom of the opening, i.e. whether the structure behaved as a sharp-crested weir, or whether as a simple channel contraction. Calculations based on the difference in scaled water levels at the outlet chamber at reported discharges of 1,000 gpm and 12,000 gpm indicate that the discharge range should have been somewhat larger than reported, regardless of the characteristics of the constriction/weir.

The discrepancies suggest that the flow measurements were in error, and/or that the guard valve (gate valve) was not fully open.

5.4 Evaluation Results

The evaluation of the assumed existing conditions indicated that, with the reservoir at the normal full supply level (El. 3705 ft), the pressure drop through the plug valve would result in incipient cavitation at all valve openings, would result in absolute pressures dropping to damaging cavitation levels at valve openings of 20% and greater, and choking would occur at valve openings greater than 70%. The pressure drop for openings greater than 20% increased steadily until at 80% opening the drop was more than twice the amount required to initiate damaging cavitation. Assuming that the outlet would be in use for several months (say 2000 hrs), the possibility exists for serious cavitation damage to the 24-in-diameter outlet pipe, and to the plug valve itself. To avoid absolute pressures in the existing outlet dropping to a damaging cavitation level, the plug valve opening would have to be restricted to less than 20%, and a maximum discharge in the order of 5,600 Imp. gpm.

Installing a restricting orifice plate on the downstream end of the outlet pipe in the energy dissipator would increase upstream pressures within the system such that the pressure drop through the plug valve would not result in absolute pressures dropping to damaging cavitation levels. A 20-in-diameter orifice was evaluated over the range of reservoir levels from full supply level (El. 3705 ft) down to El. 3660 ft, approximately 1 ft above the top of the inlet pipe, at which point air would almost certainly be entrained. The evaluation also considered several degrees of energy dissipation in the outlet chamber. The results are shown by the rating curves on Figure 5.1.

Figure 5.1 shows that for the initially assumed level of energy dissipation of 75% of the velocity head of the jet from the 20-in-diameter orifice, and with the plug valve fully open, the discharge would vary from an estimated maximum of approximately 35,000 Imp. gpm with the reservoir at the fully supply level down to a minimum of approximately 15,000 Imp. gpm. Absolute pressures in the pipe system would remain above damaging cavitation levels at all reservoir levels.

If the degree of energy dissipation is only 50% of the velocity head of the orifice jet, then the discharges would range from an estimated maximum of approximately 39,000 Imp. gpm down to a minimum of approximately 17,000 Imp. gpm. Absolute pressures in the pipe system would still remain above damaging cavitation levels at all reservoir levels. However, further evaluation showed that if the energy dissipation was only slightly less (47.8% of the jet velocity head) then absolute pressures would just drop to the damaging cavitation level with the reservoir level at the normal full supply level. The estimated maximum discharge would increase slightly to about 39,500 Imp. gpm.

The margin of safety against damaging cavitation was evaluated at progressively lower reservoir levels, and it was found that the degree of dissipation required to avoid damaging cavitation decreased steadily until, at the minimum level considered (El. 3660 ft), the degree required was estimated to be only about 4% of the orifice jet velocity head. A decrease in the energy dissipation would result in an increase in the estimated discharge as shown by the blue curve on Figure 5.1.

The rating curve for a dissipator loss of 75% of the jet velocity would be the appropriate one to use for an evaluation of the reservoir drawdown.

Depending upon the degree of energy dissipation, the orifice plate might reach choking conditions, but the resulting cavitation would occur in the dissipator chamber. In view of the possibility of cavitation vapour pockets collapsing on the downstream wall of the chamber and causing damage, the length of the pipe projecting into the chamber should probably be reduced to move the plate further upstream. As mentioned earlier, the actual length of the projection is not known.

5.5 Required Modifications

Installation of an orifice plate would require:

- watertight sealing of the rectangular opening at the bottom of the right side wall of the outlet structure with an appropriately stiffened plywood or timber panel attached to the outside of the wall;

- dewatering of the space upstream of the rectangular opening and dewatering of the dissipator chamber;
- cutting of the projecting 24-in-diameter outlet pipe and preparation of the end and outside of the pipe to an acceptable standard for welding;
- welding of a hub flange onto the end of the pipe (a slip flange is unlikely to be suitable if the pipe is badly corroded);
- fabricating a suitably dimensioned and machined orifice plate and bolting it to the hub flange on the pipe; and
- welding a thrust collar onto the 24-in-diameter pipe immediately against the upstream side of the downstream wall of the valve chamber.

To inhibit vibration, the plug valve would need to be restrained and supported by a suitably dimensioned bracket bolted to the downstream flange of the valve and bolted to the floor of the chamber.

The right side crib forming the constriction in the downstream channel observed in 1984 photographs has been destroyed and the opening now contains a steel V-notch weir plate (Photo. 6). Flow bypasses the plate on the right side, and will bypass the plate on the left side when the water level exceeds the top of the remaining timber crib. With the water level at the top of the weir plate and excluding bypass flows, the maximum discharge of the V-notch plate is estimated to be about 7,600 Imp. gpm. Hence, even allowing for the bypassing flows, the weir plate would probably have to be removed to permit the outlet to discharge 35,000 Imp. gpm without the flow overtopping the upstream banks of the discharge channel.

There may be other constraints on discharge capacity further downstream in the channel, but these were not part of the scope of this assessement.

The dissipator chamber should be dewatered and the condition of the outlet pipe determined before proceeding to design and implement the modifications, particularly if it is intended to call for fixed-price tenders to do the work.

6. STRUCTURAL EVALUATION

6.1 Critical Buckling Pressure

The reduced wall thickness of the pipe under the dam recorded by the divers and the possibility that water under reservoir pressure is present between the outer wall of the pipe and the concrete surround led to a concern that the pipe might buckle due to excessive differential pressure during dewatering of the reservoir. However, calculation of the critical buckling pressure for the thinnest measured section of pipe, approximately 2 m downstream of the 90º inlet bend (Tee-junction), indicates that the pipe still has adequate buckling resistance. Nevertheless, in view of the possibility that more severely corroded areas were not detected by the divers' survey, care should be taken during dewatering to ensure that excessive differential pressures do not occur.

6.2 Dissipator Chamber

Although relatively lightly reinforced, it is estimated that the roof of the dissipator chamber, the weakest component, has the strength necessary to withstand the internal water pressure resulting from the hydrostatic head estimated to be required to pass the maximum discharge of 39,000 Imp. gpm through the rectangular opening at the top of the chamber side wall.

It is also estimated that the end wall of the dissipator has sufficient strength to withstand the force of the impact of the jet from the orifice plate, assuming a moderate total divergence angle of the jet of at least 4 degrees (2 degrees all around) beyond the point of maximum contraction (vena contracta) before impinging on the wall. The vena contracta was assumed to occur 4 ft from the wall. To increase the flare of the jet, and reduce the potential for cavitation damage to the wall, the length of the pipe projecting into the chamber should be reduced to an amount that will just permit satisfactory welding of the upstream end of the hub flange.

7. CONCLUSIONS

The flow through the low-level outlet in its existing condition cannot be increased to 20,000 Imp. gpm or more without absolute pressures in the outlet dropping to a level at which damaging cavitation will occur. To avoid damaging cavitation, it is estimated that the discharge should not exceed 5,600 Imp. gpm.

Assuming that the section of pipe projecting into the dissipator chamber is in a condition that will permit the welding on of a hub flange and the attachment of an orifice plate, then the outlet could be modified to permit discharges up to between an estimated 35,000 and 39,000 Imp. gpm, depending upon the degree of energy dissipation that occurs in the dissipator chamber. To permit this discharge, the plug valve would also have to be securely bolted to the floor of the valve chamber.

Although not discussed in this report, there are not considered to be any other means of safely increasing the flow through the low-level outlet.

Prepared By: Reviewed By:

C. J. Wilson, P.Eng.
Senior Civil/Hydrotechnical Engineer

N. N. Heidstra, P.Eng.(B.C.)
Chief Engineer

REFERENCES

1. Ball, J.W. et al. "Predicting Cavitation in Sudden Enlargements", Journal of the Hydraulics Division ASCE, HY7, July 1975
2. Diving Dynamics. "Anvil Range Mine, Yukon, Water Storage Dam, Internal Pipe Inspection, September 2001
3. Dome Petroleum Ltd. "Rose Creek Water Supply Dam, Feasibility Study of Raising the Height of the Existing Dam, Site Visit Report", October 1984. (In association with Acres Consulting Services Ltd.)
4. H.A Simons International Ltd. Various construction drawings annotated "As-Built", October 1968.

LIST OF TABLES

Table No.

Table 4.1

Results of Outlet Pipe Ultrasonic Measurements

Location		Wall Thickness (in)	Location		Wall Thickness (in)
42 in pipe stub	Top Left	0.375	42 in-24 in reducer	90º R #1	0.370
	45º Left	0.350		90º R #2	0.375
	90º Left	0.300		90º R #3	0.365
	Bottom L	0.365		90º R #4	0.350
	Top Right	0.345		90º R #5	0.355
	45º Right	0.360		90º R #6	0.355
	90º Right	0.360	24 in spool piece	Top U/S	0.365
42 in-24 in reducer 6 points in line U/S to D/S	Top #1	0.365		Top D/S	0.370
	Top #2	0.360		90º L U/S	0.355
	Top #3	0.340		90º L D/S	0.375
	Top #4	0.355		90º R U/S	0.375
	Top #5	0.360		90º R D/S	0.375
	Top #6	0.345	24 in pipe stub	Top U/S	0.355
	90º L #1	0.360		Top D/S	0.365
	90º L #2	0.375		90º L U/S	***0.375***
	90º L #3	0.370		90º L D/S	0.360
	90º L #4	0.355		90º R U/S	0.365
	90º L #5	***0.375***		90º R D/S	0.355
	90º L #6	0.325	24 in exit pipe	Top	0.345
				90º Left	0.360
				90º Right	0.350

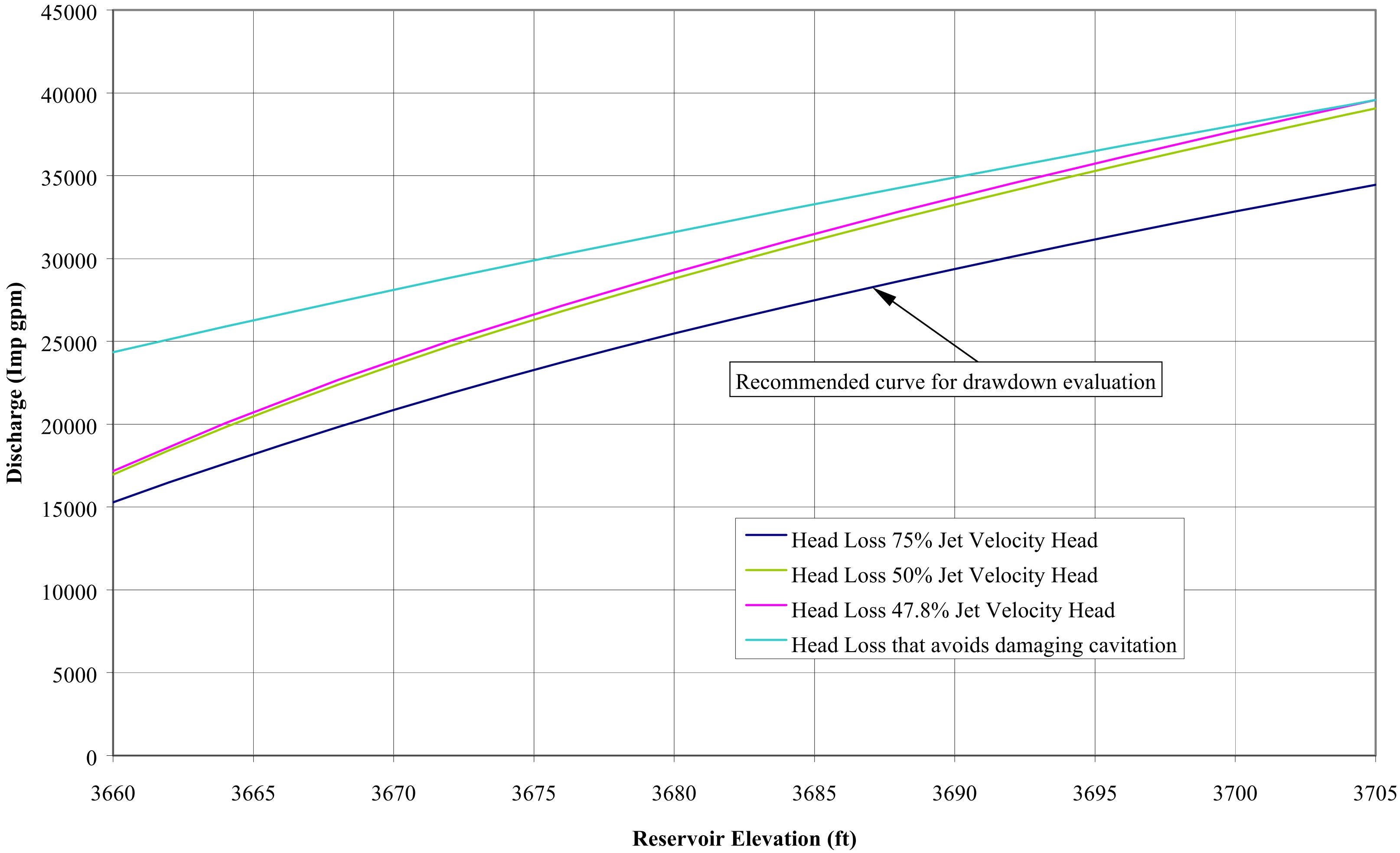
Notes:

1. Minimum thickness shown shaded.
2. Measurements in bold type are considered questionable because the measured thickness exceeded the original thickness of the pipe.

LIST OF FIGURES

Figure No.

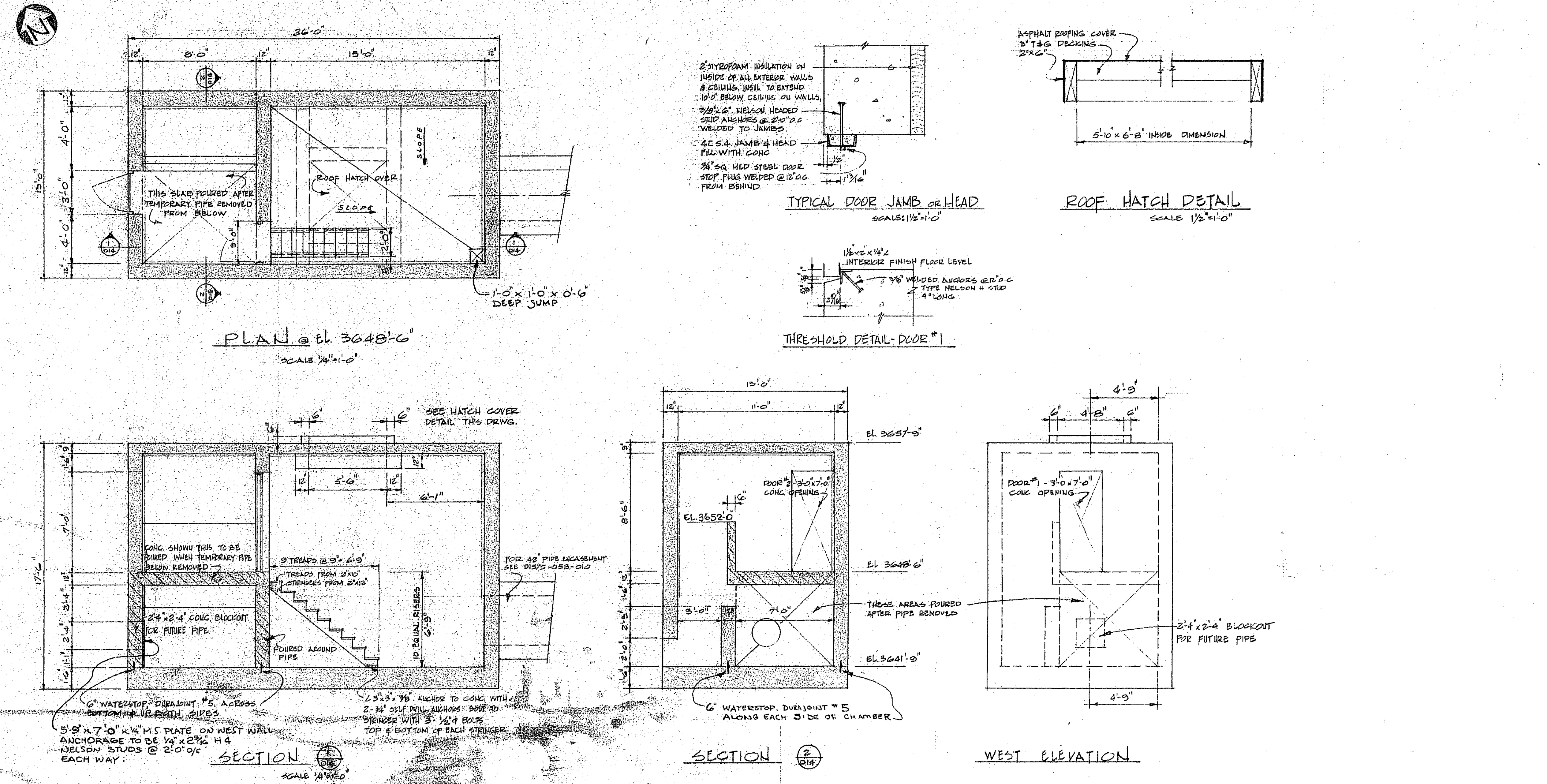
Figure 5.1
Low-Level Outlet Discharge Rating Curves
With Orifice Plate



LIST OF DRAWINGS

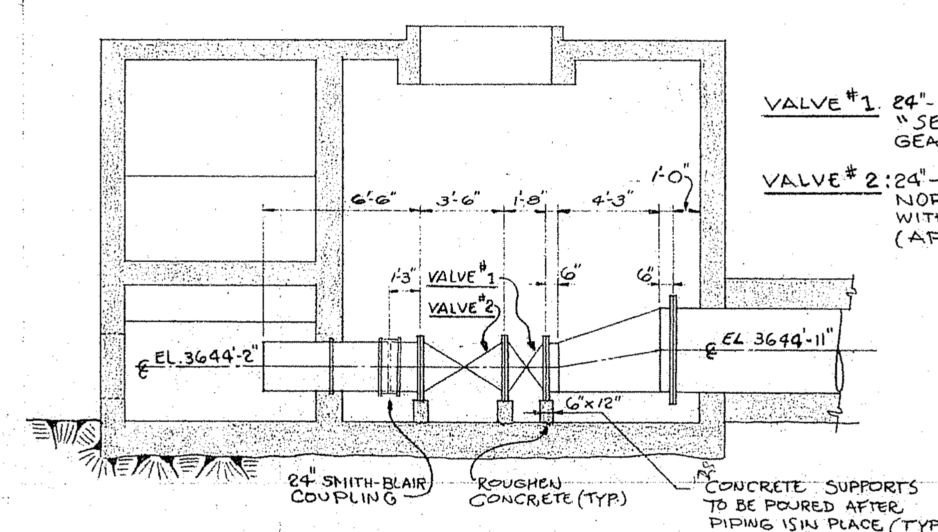
Drawing No.

D1575-058-014 Rev. 05 Outlet Structure Concrete Outline



GENERAL NOTES:

1. FOR CONCRETE REINF. SEE D1575-058-015
2. DOORS SHALL BE HOLLOW METAL DOOR WITH FLUSH FACES OF MINIMUM 20 GA. STEEL & WITH 1 SHOP COAT OF AMINE CURED EPOXY RED LEAD PRIMER.
3. DOOR HARDWARE SHALL BE AS FOLLOWS:
   - 1 1/2 PRS. 4 1/2"x4 1/2" BUTTS, TYPE STANLEY, 241P - EACH DOOR
   - LOCKSET, SCHLAGE A51PD, BELL 28, 2 3/4" BACKSET - DOOR #1
   - LATCHSET, SCHLAGE A10S, BELL 28, 2 3/4" BACKSET - DOOR #2
4. INSULATION SHALL BE APPLIED WITH 'STYROTAC' ACCORDING TO MANUFACTURERS SPECIFICATIONS
5. ALL LUMBER SHALL BE STRUCTURAL GRADE DOUGLAS FIR & SHALL BE PROTECTED WITH CUPRINOL
6. FOR CONCRETE NOTES SEE D1575-058-008



MECHANICAL ARRANGEMENT
SCALE 1/4"=1'-0"

VALVE #1. 24"-150# CAST STEEL GATE VALVE "SELLA" TYPE 1111, WITH BEVEL GEARING. (WEIGHT: 3,260#)

VALVE #2: 24"-150# CAST STEEL "ROCKWELL-NORDSTROM" FIG. 4169 PLUG VALVE WITH WORM GEAR OPERATOR. (APPROX. WEIGHT: 3,500#)

DWG. ISSUED TO VENDOR	PURCHASE ORD... NUMBER	DESCR...

REQ'D FOR CONTR.	ASSOCIATED DRA...	
	D1575-058-015	OUTLET STRUCTU... REINF. DETAILS
	D1575-058-010	DIVERSION STRU...
	D1575-058-008	SPILLWAY STRUCT... CONCRETE OUTLIN...

ISSUE No.	D/M/Y	ISSUE
05	25/10/68	WATERSTOP ADDED EXT. DOOR RELOCATE... CUPRINOL NOTE ADD... AS BUILT
04	JULY 23 1968	JUL 23 1968 ISSUE FOR CONSTRUCT...
03	JULY 3/68	JUL 3 1968 MECH. ARRANGEMENT ADD...
02	JUNE 28/68	JUN 28 1968 DRAWING REDRAWN

CERTIFIED FOR CONSTRUCTIO...
HAS DEPT. MGR. HAS PROJ...

PARSONS - JURDEN CORPO...
ANVIL MINES PROJECT YUKON ...

H. A. SIMONS (INTERNATIONA...
CONSULTING ENGINEE...
VANCOUVER, B.C.

AREA: WATER STORAGE D...

SUBJECT: OUTLET STRUCTURE CONCRETE OUTLINE...

DRAWING No. HAS DRAWING No. D1575-058...

APPENDIX A
PHOTOGRAPHS

Photo. 1 Outlet structure valve chamber pipe work, flow is from right to left. Note spool piece between gate valve (at right) and plug valve.

Photo. 2 Side view of spool piece and plug valve. Note small concrete plinths beneath flanges of spool piece, but not beneath d/s plug valve flange.

Photo. 3 Close up of plug valve. Downstream end unsupported except for what appeared to be a piece of timber

Photo. 4 View of discharge channel looking downstream towards the v-notch weir in the distance.

Photo. 5 View from v-notch weir looking upstream towards the low-level outlet structure.

Photo. 6 V-notch weir plate in discharge channel. Note flow bypassing plate on right hand side.

KLOHN CRIPPEN

Appendix C

February Field Program

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
1605, 840 – 7 Avenue S.W., Calgary, Alberta, Canada. T2P 3G2
Phone (403) 250-5185 Fax (403) 250-5330

PROJECT MEMORANDUM

To:	**File**	**Fax No.:**	
Attention:	**1CD001.22**	**CC:**	
From:	**Gerry Ferris**	**Date:**	**March 13, 2003**
Subject:	**Summary of February Field Investigation – FWSD Breach Project**		
No. of Pages (including this page): 24		**Project No:**	**0257-012-06**

This memorandum regarding the February Field Program has been prepared in partial response to an information request contained in a letter received from Indian and Northern Affairs (DIAND) and Fisheries and Oceans (DFO), dated March 4, 2003. It is expected that this memorandum forms a portion of the response (information request number 4) to the request for supplementary information and, therefore, will form a portion of the Environmental Assessment report that will allow DIAND and DFO to complete their environmental assessment of the project.

Introduction

As outlined in the Preliminary Breach Design, Fresh Water Supply Dam, Faro Mine[1] report the interim receiver is planning to breach the Fresh Water Supply Dam (FWSD) prior to the 2004 spring freshet. The preliminary breach design was completed in response to a directive from Fisheries and Oceans Canada (DFO).

The Preliminary Breach Design Report identified some data gaps with respect to locations of structures within the reservoir, the amount of fish within the reservoir and the amount of sediment built up in the reservoir since construction. Within the report, the issues surrounding the data gaps were described and methods of investigation were outlined to fill the data gaps. A memorandum, dated February 4, 2003, summarizing an investigation program to be performed in February (prior to the completion of the final design) was provided to the interim receiver. As

[1] SRK Consulting Inc., BGC Engineering Inc. & Gartner Lee Limited. 2003. Preliminary Breach Design, Fresh Water Supply Dam, Faro Mine. Report submitted to Deloitte & Touche Inc., February 3.

outlined in the memorandum the February field program consisted of performing the following tasks:

- Sediment sampling to determine depth of sediment at a variety of locations through the reservoir;
- Collection of sediment samples for subsequent physical and chemical testing;
- Detailed depth probing within the reservoir footprint to confirm (1) the ground elevations near the inlet of the LLO, (2) the cofferdam location and condition, and (3) the pre-construction channel location on either side of the cofferdam;
- A detailed survey of the existing downstream channel; and,
- A detailed survey of the existing upstream channels, South Fork of Rose Creek, Southeast Tributary and North Tributary.

The investigation program was verbally approved by the interim receiver. The field program was completed between February 13 and 15, 2003. In addition to performing the tasks outlined above, the following additional tasks were performed:

- A visual inspection of the area downstream of the FWSD.
- A visual inspection of the tributary inlet conditions.
- An underwater camera inspection of the sediment conditions on the base of the reservoir. This was performed at locations where sediment samples were collected and areas where it was too deep to collect sediment samples.
- Preparation of a memorandum summarizing the results of the field program.

Field and Laboratory Program

The field program, as outlined above, was undertaken between February 13 and 15, 2003.

The surveying portion of the field program was performed on February 13 and 14, 2003. The survey company used to perform the required work was Yukon Engineering Services (YES) of Whitehorse, YT. The survey information collected was in accordance with the plan outlined in the February 4, 2003 memorandum. Modifications and additions to the survey program were made as directed by Mr. Gerry Ferris of BGC Engineering Inc. (BGC).

Sediment sampling and visual inspections were performed by Mr. Ferris with the help of mine staff. Sediment samples were collected from the base of the reservoir, beneath the ice cover. Sediment sampling was performed by using a SPT sampler, driven into the reservoir base and removed by hand.

Ice augering performed for the surveying required on the upstream side of the FWSD was performed by mine staff under the direction of Mr. Ferris.

The sediment samples collected during the field program were delivered to EBA Engineering, Whitehorse, for sieve and hydrometer analyses (gradation determinations). The sediment samples were then shipped to Canadian Environmental and Metallurgical Inc. of Vancouver for IPC metals analysis.

Survey Results

Figure 1 shows the location of the survey points collected in the region of the FWSD, both upstream and downstream of the dam. The topography shown on Figure 1 has been revised and updated based on the survey information collected. Figure 2 shows the location of the survey points collected further upstream in the reservoir and at the inlets of the three tributaries to the reservoir.

The survey information collected on the downstream side of the dam agrees in broad terms with the previous topography, but provides a greater level of detail than previously available. The survey information available on the upstream side of the FWSD changed the topography more significantly than on the downstream side. The most significant differences from previously provided topography are the flat area between the position of the cofferdam and the inlet of the LLO and that the position of the cofferdam is reflected in the topographic contours (the position of the cofferdam is slightly different than indicated in the Preliminary design). The differences in the topography between that presented in Figure 1 to the topography presented in the Preliminary Design report are due to the greater density of the survey information available in the area.

Review Reservoir Base

The review of the reservoir base consisted of two components; SPT sampling of the reservoir base (collection of samples from the base of the South Fork of Rose Creek by hand) and a visual inspection of the base of the reservoir through the use of an underwater camera.

Sediment Sampling

Nine samples were collected from either the base of the reservoir or the base of the South Fork of Rose Creek (SFRC) at the locations shown in Figure 3. Sample 4 was collected from the base of SFRC, in a location that would typically be within the reservoir (given the normal reservoir elevation of 1096.1 m amsl), but was not within the reservoir during the field program (the reservoir level was 1090.8 m amsl) due to a reservoir lowering program underway at the mine. Sample 9 was collected from the base of SFRC at a location which is normally outside of the reservoir. Samples 4 and 9 were collected by ice augering to expose the running water and then a disturbed sample of the substrate was collected by hand.

The other seven samples were collected using a SPT sampler. Photographs of the samples returned to the surface are shown in the attached photos 1 – 12. The samples returned to the surface were described based on a visual inspection, separated and bagged according to the visual description. As seen in the photos the majority of the sample returned to the surface consisted of mineral soils below an upper organic layer (either topsoil or peat). Only the portion of the sample above the organic layer was classified as sediment and sent to the laboratories for testing. An example of the sediment collected is shown in photograph 3.

Sediment from the location of sediment sample (SS) 3 and a combined sample from SS5, SS6 and SS8 were sent to the laboratory for testing (hydrometer and IPC). Samples from SS5, SS6 and SS8 were combined to make up the minimum sample size of 40g for hydrometer testing.

Results of Laboratory Testing

Two samples of fine sediments from the FWSD reservoir were collected and submitted to laboratories as described previously. Samples were tested for physical properties (grain size) at EBA in Whitehorse and then submitted to CEMI laboratories in Vancouver for chemical analysis. The grain size analysis included wet and dry sieving using brass screens. The <75 μm fraction of these samples were submitted for metal analysis by ICP.

The result of the grain size analysis for SS3 is presented in Figure 4. The result of the grain size analysis completed on the combined sample (SS5, SS6 and SS8) is presented in Figure 5. These results indicate that the SS3 sediment sample consists of 60% sand, 31% silt and 9.7% clay sized particles and the combined sample consists of 19% sand, 55% silt and 26.6% clay.

The results of the metal analyses are presented in Table 1, along with regional data from the Pelly River and Vangorda Creek (prior to development of the Vangorda Plateau) (Godin and Davidge, 2002). The metal content of the FWSD samples is comparable to the range observed in the regional sediments, with the exception of copper, which was significantly higher than in the Vangorda Creek sediments. Table 1 also shows a comparison of the data to Federal Canadian Council of Ministers of the Environment (CCME) interim sediment quality guidelines (ISQG's) and probable effects levels (PEL's) (CCME, 1999). The comparisons indicate that copper, lead and zinc concentrations in the FWSD samples exceeded the ISQG's, and that lead in one of the samples exceeded the PEL. However, sediment samples from Vangorda Creek also exceeded the ISQG's for these and several other metals (arsenic, cadmium, and zinc), and exceeded the PEL's for lead. Elevated copper concentrations in the samples may also be due in part to the use of brass sieves during physical characterization of the samples. In conclusion, while the sediments contain some metals that exceed the applicable guidelines, they are reasonably typical of un-impacted regional sediments.

Table 1 Sediment Metal Concentrations (by ICP method)

		February 2003 Samples		Regional Sediments (Reference Sites) (Godin and Davidge, 2002)						Sediment Criteria (CCME, 1999)	
				Vangorda Creek Sediments (1989) Site Location ID: 222			Pelly River Sediments (1991) Site Location ID:247				
Sample:		5; 7; 8	3							ISQG	PEL
		<75 um	<75 um	Max (n=9)	Min (n=9)	Average (n=9)	Max (n =10)	Min (n=10)	Average (n=10)		
Element											
Ag	ppm	<0.2	<0.2	5	<2	<1.2	<2	<2	<2		
Al	%	1.14	1.52	2.9	0.79	1.9	1.3	0.85	1.0		
As	ppm	**15**	5	**27**	**10**	**17**	**19**	-8	0.8	5.9	17
Ba	ppm	160	170	326	124	270.4	0.106	0.0787	0.08706		
Be	ppm	0.5	0.5	2.0	0.4	1.5	0.4	0.3	0.36		
Bi	ppm	<5	<5	-	-	-	-	-	-		
Ca	%	0.57	0.52	1.0	0.5	0.7	2.6	2.2	2.5		
Cd	ppm	**<1**	**<1**	**3.1**	**0.8**	0.3	**2.7**	**1.0**	**2.1**	0.6	3.5
Co	ppm	9	13	-20	-20	-20	-20	-20	-20		
Cr	ppm	34	**47**	**45**	29	**38**	32	26	29	37	90
Cu	ppm	**76**	**70**	**39**	17	30	35	22	27	36	197
Fe	%	2.62	3.3	5.0	17	34	3.0	2.3	2.6		
K	%	0.15	0.21	0.42	0.06	0.24	0.29	0.17	0.23		
Mg	%	0.69	0.92	1.1	0.45	0.69	1.2	1.1	1.1		
Mn	ppm	450	410	1260	334	1000	668	359	486		
Mo	ppm	<2	<2	<2	<2	<2	6	5	5		
Na	%	1.41	1.02	0.068	0.01	0.035	0.01	0.008	0.0094		
Ni	ppm	24	38	56	30	40	46	32	39		
P	ppm	5320	4450	1400	610	1000	1600	1200	1380		
Pb	ppm	**72**	**174**	**120**	**38**	**91**	16	9	11	35	91
Sb	ppm	<5	<5	-	-	-	-	-	-		
Sc	ppm	2	3	-	-	-	-	-	-		
Sn	ppm	<10	<10	<8	<8	<8	<8	<8	<8		
Sr	ppm	49	48	51	23	43	87	80	84		
Ti	%	0.04	0.06	0.11	0.33	0.68	0.027	0.017	0.021		
V	ppm	25	34	50	24	40	73	54	64		
W	ppm	<10	<10	-	-	-	-	-	-		
Y	ppm	5	5	-	-	-	-	-	-		
Zn	ppm	**162**	**209**	**662**	59	**312**	**251**	**165**	**205**	123	315
Zr	ppm	5	5	-	-	-	-	-	-		

Notes:
Bold indicates concentrations exceed interim guidelines
Underlined values indicate concentrations exceed probable effects levels (PEL)

Visual Inspection of the Reservoir base

The base of the reservoir was examined using an underwater camera. This was done at the seven locations where sediment samples were collected and also at 11 other locations (shown on Figure 3) were no sampling was performed. Table 2 provides a summary of the observations made and the estimated thickness of sediment at each location.

Table 2 Summary of Visual Inspection of Reservoir Base

Inspection Location (Figure 3)	**Estimated Sediment Depth (mm)**	**Observations**
SS1	1 – 2	Small bushes present.
SS2	1	Almost no sediment, roots clumps from grasses exposed.
SS3	5 – 10	Small loose twigs present on base of reservoir.
SS4	N/A	Course Sand in base of SFRC (inside normal reservoir)
SS5	10 – 20	Small shrubs present, interpreted as mostly sand/silt sized.
SS6	10 – 15	Small shrubs present, interpreted as mostly coarse silt (fine sand) sized.
SS7	10 – 15	Small bushes present, interpreted as a mix of silt and sand sized sediment.
SS8	1	Small bushes and loose branches present, almost no sediment present.
SS9	N/A	Gravel and Cobbles in base of SFRC (outside of normal reservoir)
VI1	15 - 20	Small shrubs present, interpreted to be mostly clay sized with some silt.
VI2	10	No vegetation present (location is outside of the disturbed footprint of dam construction), interpreted to the old channel location. Sediment interpreted to be mostly clay sized.
VI3	15 – 20	No vegetation present (within disturbed footprint), interpreted as mostly clay sized.
VI4	15 - 20	No vegetation present (within disturbed footprint), interpreted as mostly clay sized.
VI5	15 – 20	Occasional small bush present, interpreted as mostly silt sized.
VI6	15 – 20	Extensive appearance of small bushes, thin coating of sediment on the branches of bushes, interpreted to mostly silt sized.
VI7	10	Extensive appearance of small bushes, interpreted as silt and clay sized particles.
VI8	10 – 15	Extensive appearance of small bushes, interpreted as mostly silt sized particles with some clay sizes.
VI9	15 – 20	Extensive vegetation, interpreted to be mostly clay sized with some silt.
VI10	10	No vegetation (within disturbed footprint), interpreted to be mostly clay (flocculated) sized.
VI11	2 – 5	No vegetation (within disturbed footprint). Interpreted to be mostly silt with clay (flocculated) sizes.

Note: SS refers to sediment sample and VI refers to visual inspection location.

Summary of sediment testing

The information presented above provides a different picture with respect to the amount and chemical characteristics of the sediment than presented in the Preliminary Breach Design Report (Section 2.6.5). The results presented in this memorandum supersede the results previously presented, for the following reasons:

1. Results of the February program conform to expectations of sediment types (gradation) and locations. For example based on the February program; the sediment near the head of the reservoir consists of sand with some silt, near the center of the reservoir the sediment is mostly silt with some sand and clay, and the sediment near the dam consists mostly of clay sizes with some silt. This pattern reflects the speed that sediment particles will settle within a still body of water. Whereas the results of the previous testing would indicate that sand & gravel would have floated about 2 km in still water.
2. Sediment thicknesses were estimated both by visual inspection of the base of the reservoir and through drive sampling during the February program. Sediment thickness near the dam was estimated by the divers by pushing a metal rod into the reservoir base. The sediment was estimated based on the rod hitting a “hard” base. The method used by the divers, does not take into account softening of the upper soil in an underwater environment. It should be noted that during the dive sampling performed in February the sampling was stopped when a “hard” base was encountered, similar to the testing performed in December. As can be seen in photograph 7, the sampler was driven 19 inches before hitting hard material, but based on the sediment returned in the sample and visual inspections only 2 to 5 mm of sediment was present at this location.

The results of the IPC testing reported in this memorandum are different that those presented in the Preliminary Breach Design Report. This is due to the nature of the sediment collected. As part of the testing previously presented, the sand and gravel sizes of the sediment were crushed and tested along with the finer particles. The results therefore would have been skewed by the chemistry of the sand and gravel. The testing results presented in this memorandum consisted only of the finer grained particles.

Based on the revised sediment testing presented in this memorandum, between 3,700 and 5,000 m^3 of sediment could be expected within the reservoir. These estimates were made by assuming that the reservoir had an average sediment thickness of 15 mm or 20 mm spread evenly through half of the reservoir surface area of 486,600 m^2.

In order to determine the worst possible effects of mobilization of the fine-grained sediments from the reservoir a calculation was performed by assuming that all the sediments present in the reservoir would be mobilized in the first spring freshet. The freshet used for the calculation was an average (2-year return period) size. Given the depositional history for the sediment, it would be expected to be in a very loose condition. The mass of the sediment in the reservoir is estimated to be 3,700 to 5,000 t (using a density of 1.0 t/m^3). The average spring freshet for the FWSD reservoir results in a total inflow volume of about 5,500,000 m^3. If the first spring freshet were to mobilize the entire fine-grained portion of the sediment, this would result in between 672 and 909 mg/L of suspended sediment.

Surface Visual Inspections

Visual inspections were performed by way of a walking inspection. Observations were recorded through a series of photographs and descriptions recorded by using a Dictaphone. The inspection was complied into a field record which is stored in the file.

Downstream of FWSD

The purpose of the inspection was to review the area downstream of the FWSD to help in planning of the outlet location of the completed channel, planning the location for the rehabilitated channel, determine the condition of the fresh water channel and determine the state of vegetation in the area.

Photographs 13 and 14 show two views looking downstream of the fresh water channel. Photo 13 was taken from the location of the second weir within the fresh water channel. At this location the height of the right (North) hand bank is about 3 m, and the left (south) hand bank is about 1.5m. At the location of this weir is also the location of a path that crosses the fresh water channel. Photo 14 was taken about 50 m further downstream. At this point the right bank of the channel is about 1.5 m high and the left bank is about 0.5 m high.

Photograph 15 was taken from the edge of the flat ground located on the south side of the fresh water channel. This photo looks across the channel (along the trail) and towards the north abutment of the dam. This photo shows the amount and type of vegetation present in this area and the general flat terrain in the area to the south of the fresh water channel.

Inlets to Reservoir

The purpose of the inspection was to review the inlets to the reservoir to determine if the channels could be located or if they had been filled and a delta formed due to sedimentation at the inlets to the reservoir. The inspection of the channels occurred prior to completion of the sediment testing program.

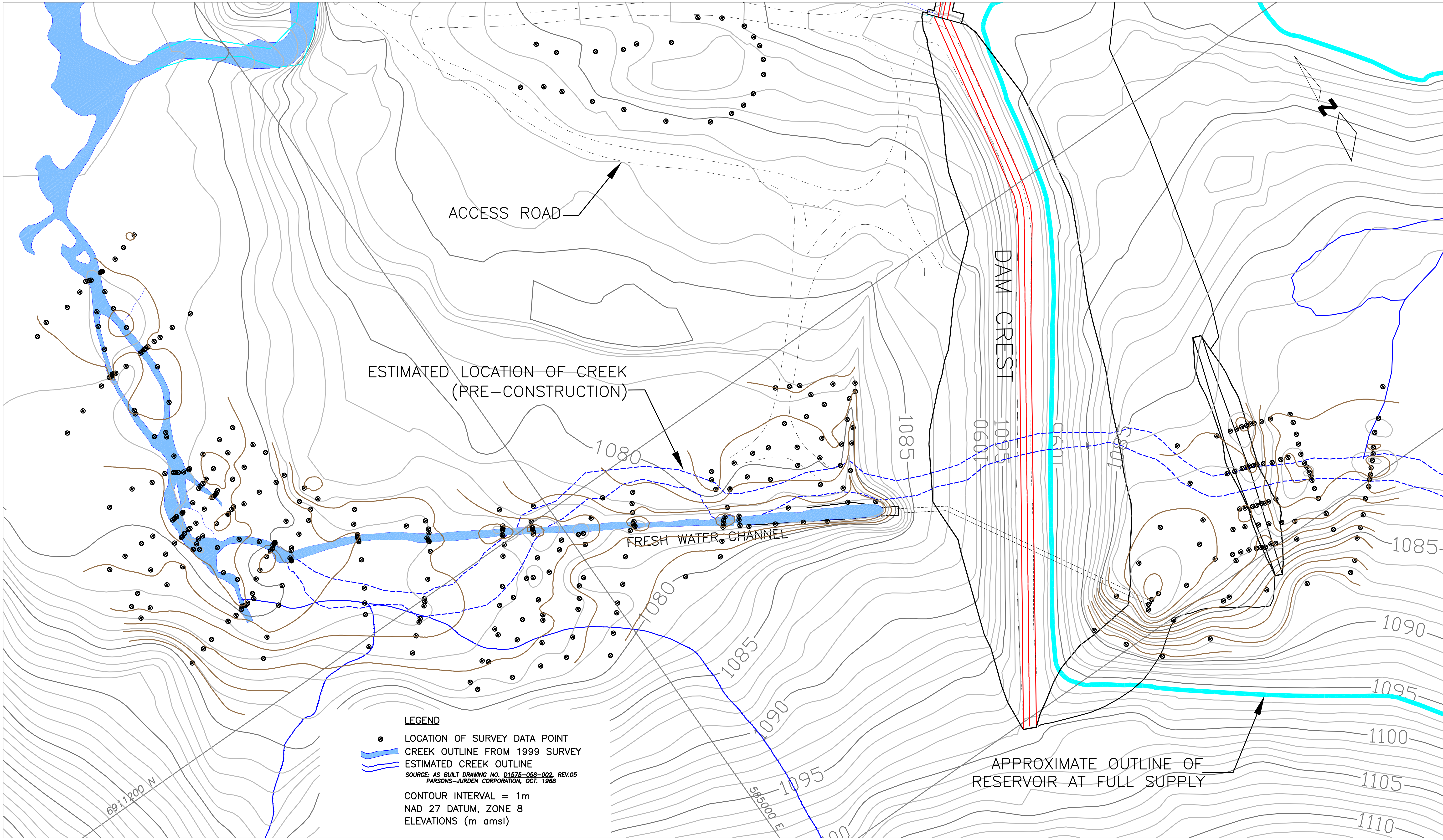
Photograph 16 shows a view of the South Fork of Rose Creek (SFRC) that would normally be within the reservoir. The outline of the creek is clearly visible. Photograph 17 shows a second view of the SFRC which indicates the approximate bank height of the creek at this location.

Photograph 18 shows a view of the southeast tributary that would normally be within the reservoir, the outline of the creek is clearly visible. Photograph 19 shows a second view of the southeast tributary which indicates the approximate bank height of the creek at this location.

References

Canadian Council of Ministers of the Environment, 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg.

Godin, B, and Davidge, D. 2002. Benthic Information System for the Yukon. URL:http://www.ec.gc.ca/bisy)



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							A	PRELIMINARY DESIGN	GWF	FEB 3/03
REFERENCE DRAWINGS		REVISIONS					ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

PRELIMINARY DESIGN
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DATE: March 2003	DATE:
CHECKED BY:	DISCIP. ENGR.
DATE:	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.20	

Deloitte & Touche Inc.

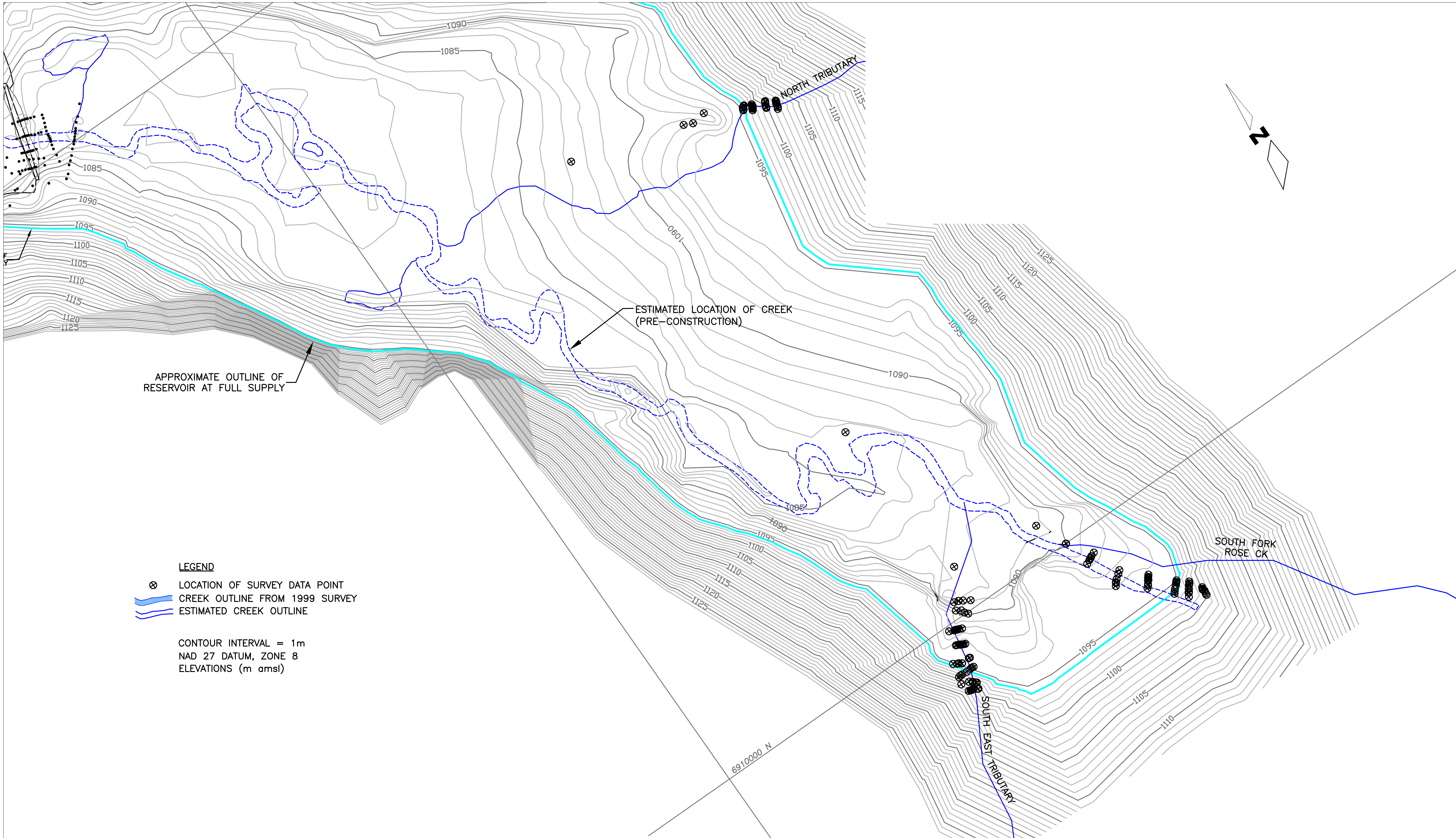
FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:800
0 10 20 30 40 50 metres

SURVEY LOCATIONS
FWSD

DRAWING NUMBER 1
REV. A

FILE NAME: F:\Deloitte_touche\Acad drawings-Faro\faro FWSD\Figure 4.dwg



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REFERENCE DRAWINGS		REVISIONS					ISSUE AUTHORIZATION			

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DATE:	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.20	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:2000

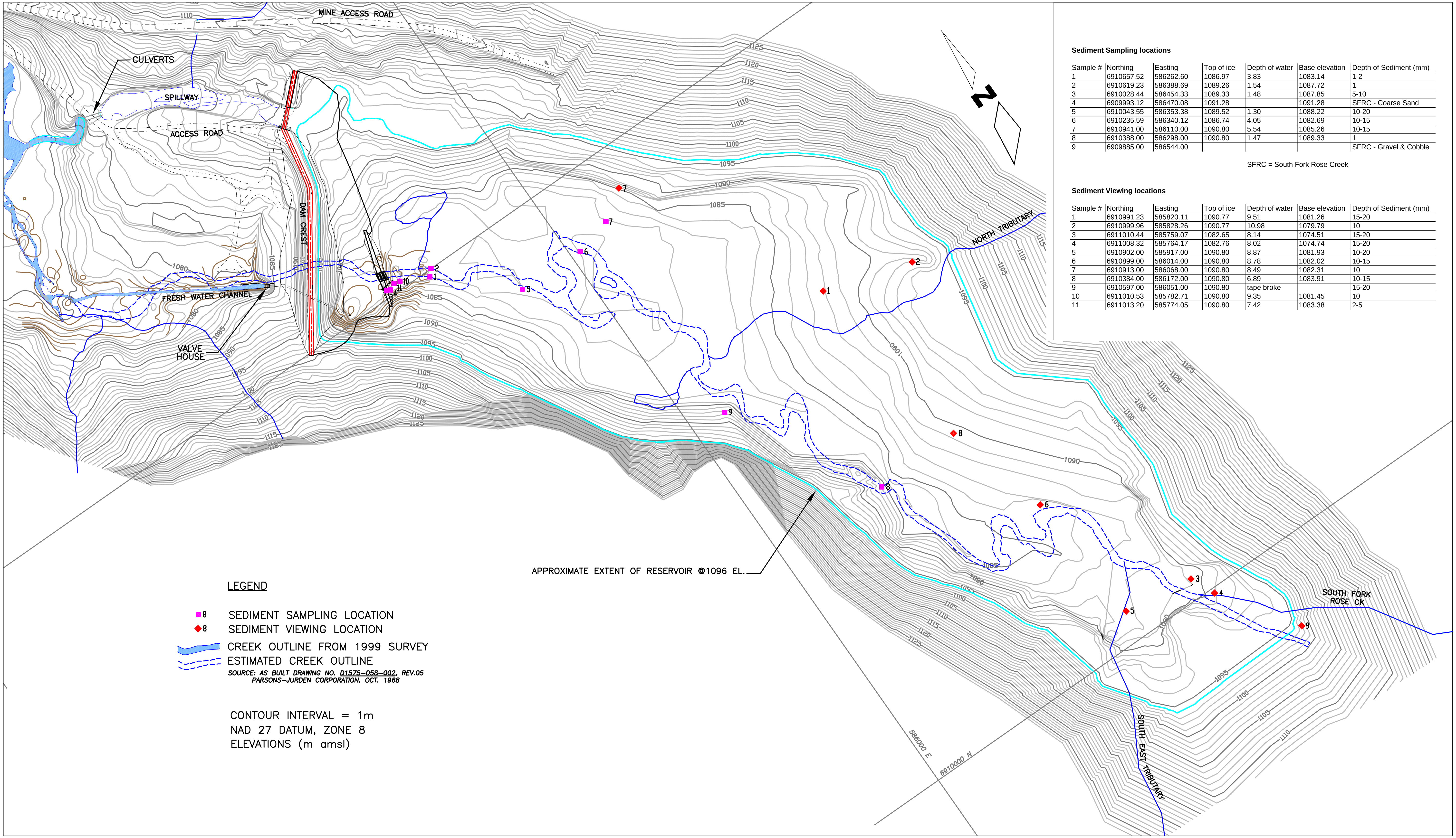
0 20 40 60 80 100

SURVEY LOCATIONS – RESERVOIR

DRAWING NUMBER: 2

REV.: A

FILE NAME: F:\Deloitte_touche\Acad drawings-Faro\faro FWSD\Figure 4.dwg



Sediment Sampling locations

Sample #	Northing	Easting	Top of ice	Depth of water	Base elevation	Depth of Sediment (mm)
1	6910657.52	586262.60	1086.97	3.83	1083.14	1-2
2	6910619.23	586388.69	1089.26	1.54	1087.72	1
3	6910028.44	586454.33	1089.33	1.48	1087.85	5-10
4	6909993.12	586470.08	1091.28		1091.28	SFRC - Coarse Sand
5	6910043.55	586353.38	1089.52	1.30	1088.22	10-20
6	6910235.59	586340.12	1086.74	4.05	1082.69	10-15
7	6910941.00	586110.00	1090.80	5.54	1085.26	10-15
8	6910388.00	586298.00	1090.80	1.47	1089.33	1
9	6909885.00	586544.00				SFRC - Gravel & Cobble

SFRC = South Fork Rose Creek

Sediment Viewing locations

Sample #	Northing	Easting	Top of ice	Depth of water	Base elevation	Depth of Sediment (mm)
1	6910991.23	585820.11	1090.77	9.51	1081.26	15-20
2	6910999.96	585828.26	1090.77	10.98	1079.79	10
3	6911010.44	585759.07	1082.65	8.14	1074.51	15-20
4	6911008.32	585764.17	1082.76	8.02	1074.74	15-20
5	6910902.00	585917.00	1090.80	8.87	1081.93	10-20
6	6910899.00	586014.00	1090.80	8.78	1082.02	10-15
7	6910913.00	586068.00	1090.80	8.49	1082.31	10
8	6910384.00	586172.00	1090.80	6.89	1083.91	10-15
9	6910597.00	586051.00	1090.80	tape broke		15-20
10	6911010.53	585782.71	1090.80	9.35	1081.45	10
11	6911013.20	585774.05	1090.80	7.42	1083.38	2-5

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	REV.	ISSUE PURPOSE	AUTH. BY	DATE
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DATE | DATE
SRK PROJECT NUMBER: 1CD003.20

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:2500
0 50 100 150 200 250 M

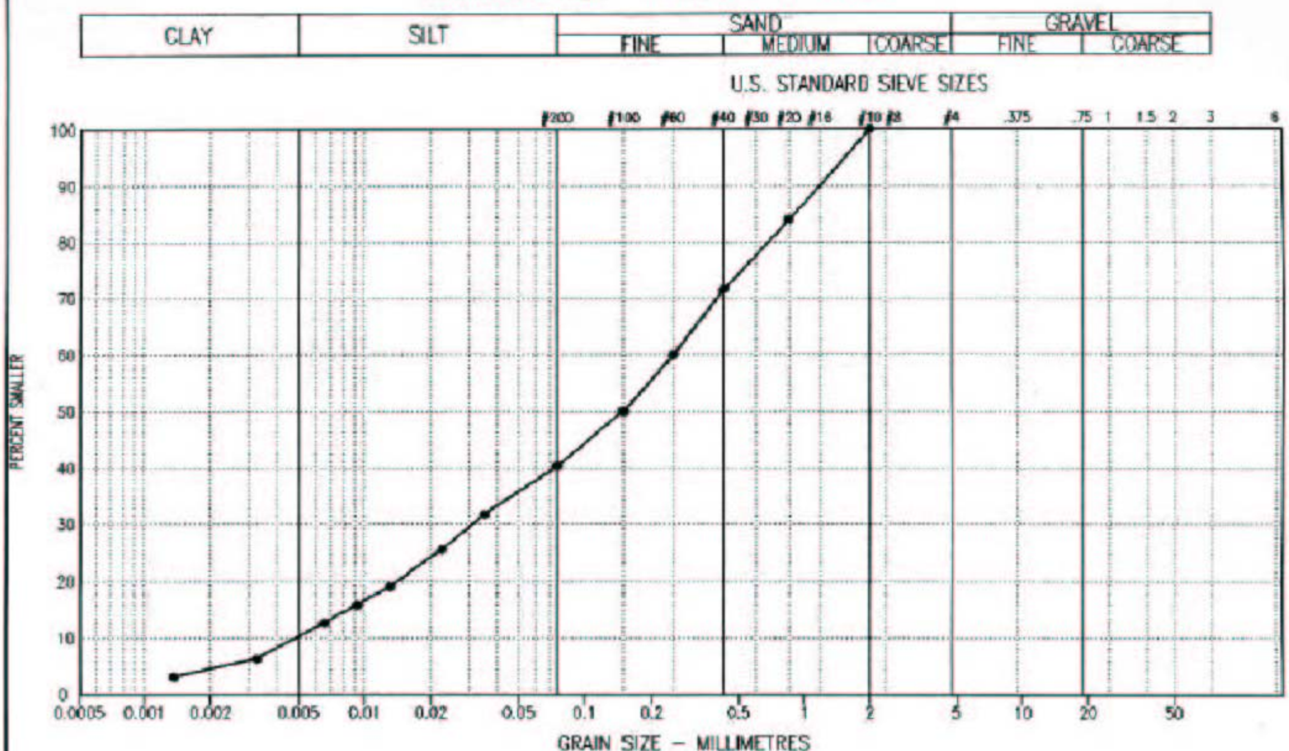
SAMPLING LOCATIONS

DRAWING NUMBER 3

REV. A

FILE NAME: F:\Deloitte_touche\cad drawings-Fwsd\fws FWSD\Figure 4.dwg

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
•—•	1200035–BH03	0.00	9.7	31	60	0	48.5	0.8	SM

Project: 0201–1200035 Date Tested: 20/02/03 BY: MCP

Tested in accordance with ASTM D422 unless otherwise noted.

Source: EBA Engineering Inc. Fax Dated Feb. 24, 2003

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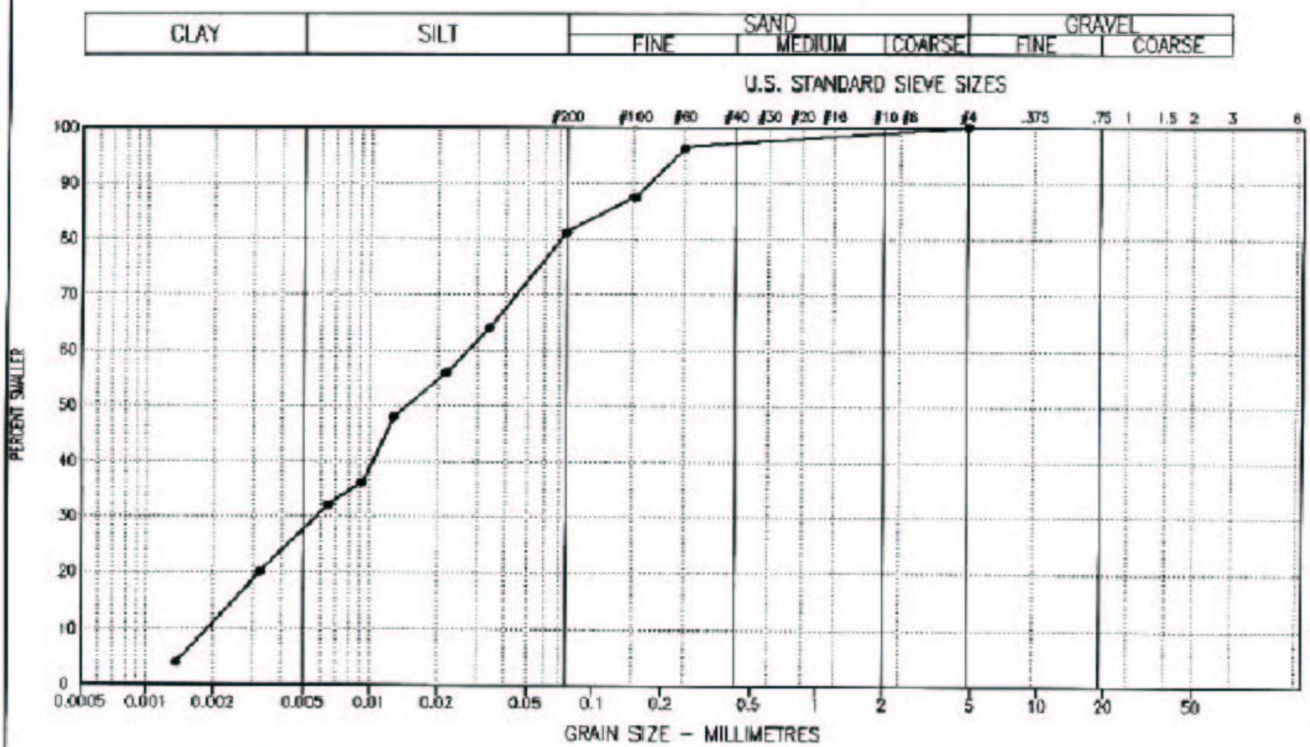
Deloitte & Touche Inc.

Supplement to the FWSD Breach
Faro Mine, Yukon Territory

Particle Size Analysis of Soils

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	March 2003	GWF	4

PARTICLE SIZE — ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
•——•	5,7,8	0.00	26.6	55	19	0	13.5	0.6	

Project: 0201-1200035 Date Tested: 20/02/03 BY: MCP

Tested in accordance with ASTM D422 unless otherwise noted.

Source: EBA Engineering Inc. Fax dated Feb. 24, 2003

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

Deloitte & Touche Inc.

Supplement to the FWSD Breach
Faro Mine, Yukon Territory

Particle Size Analysis of Soils

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	March 2003	GWF	5

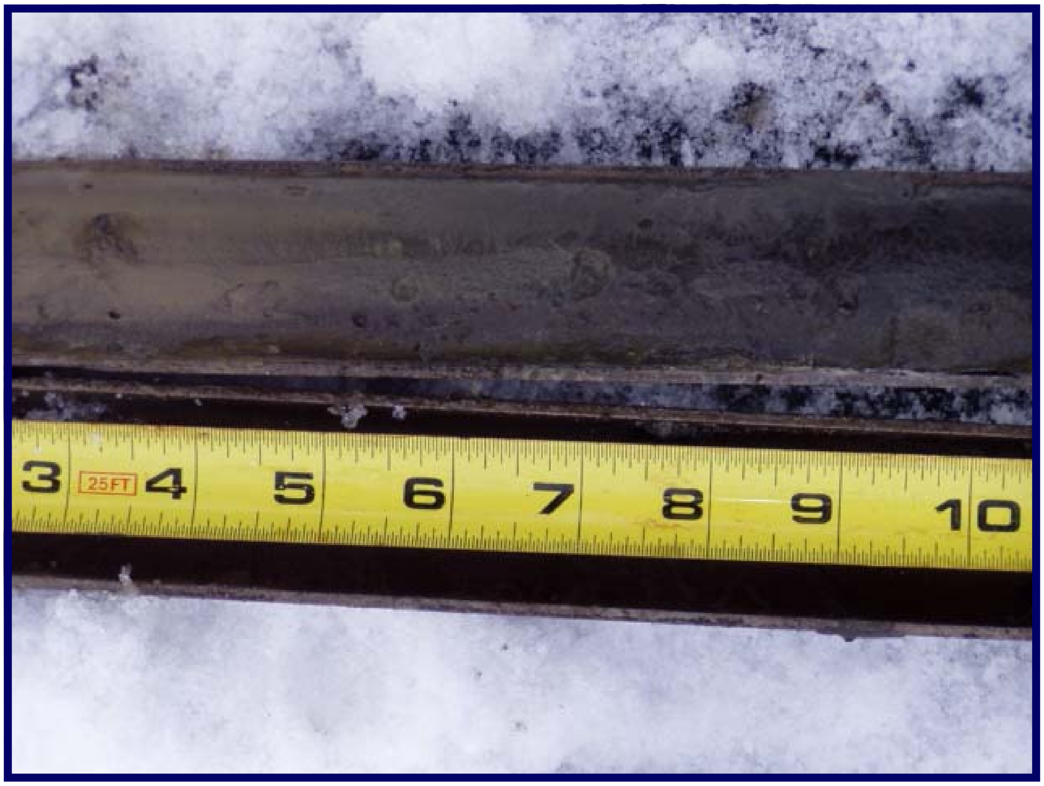
Photograph 1
Sample 1— Zero at the base of sample.

Photograph 2
Sample 2—Zero at the base of the sample.

Photograph 3
Sample 3—Zero at base of sample.

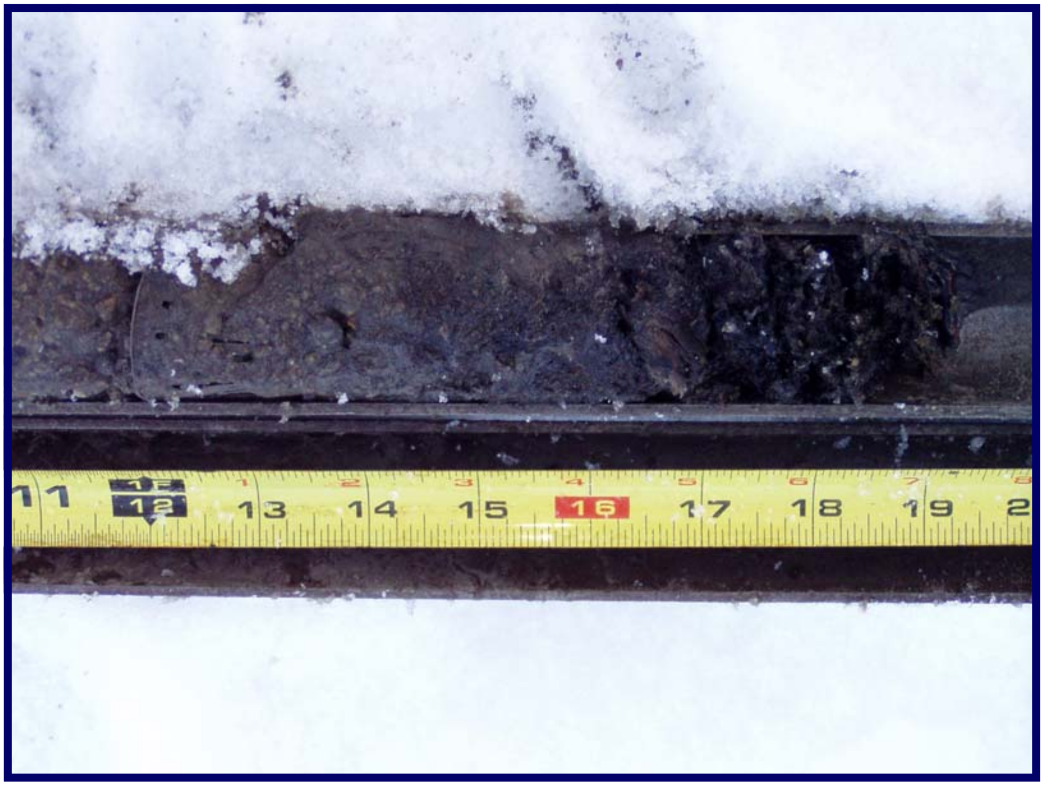
Photograph 4
Sample 5—Upper portion of sample. Zero at the base of sample.

Photograph 5
Sample 5—Middle portion of sample. Zero at base of sample.

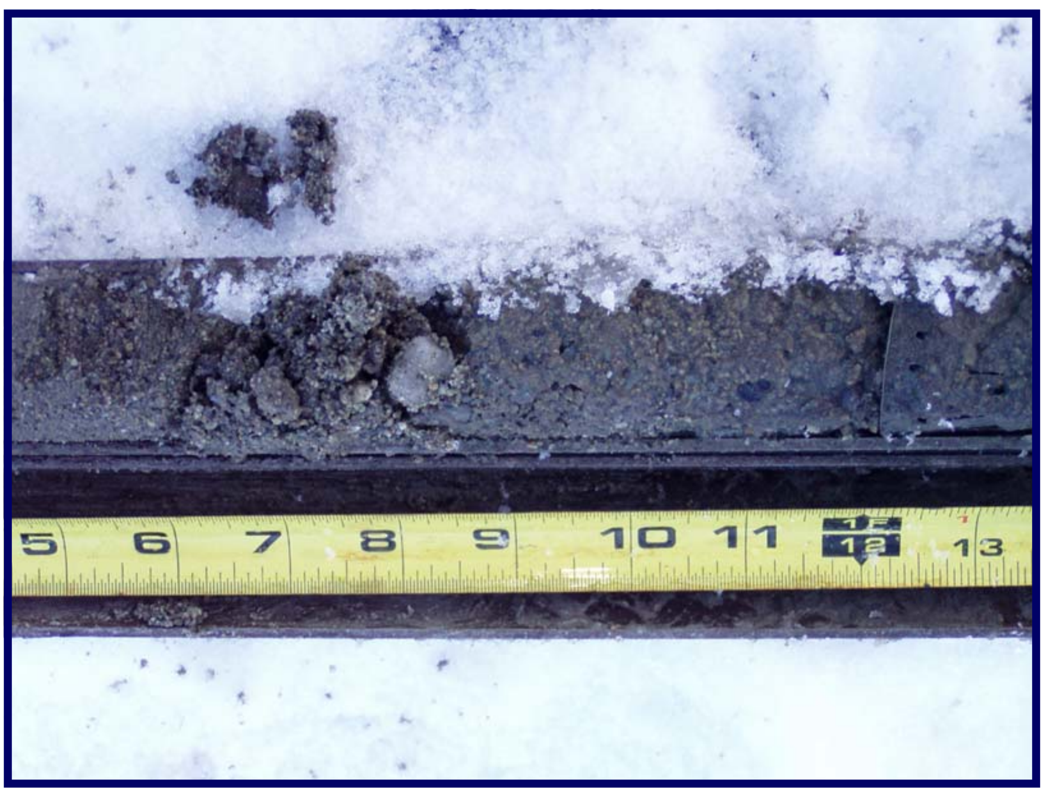


Photograph 6
Sample 5—Lower portion of sample. Zero at base of sample.

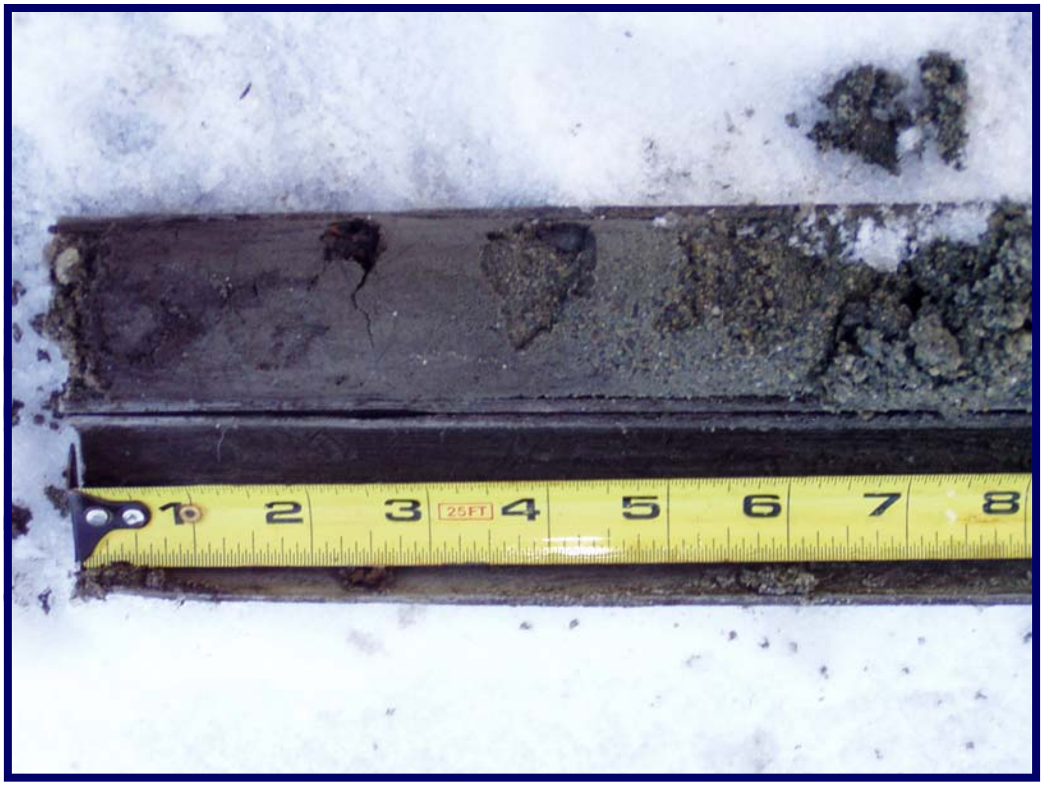
Photograph 7
Sample 6—Upper portion of sample. Zero at base of sample.



Photograph 8
Sample 6—Middle portion of sample. Zero at base of sample.

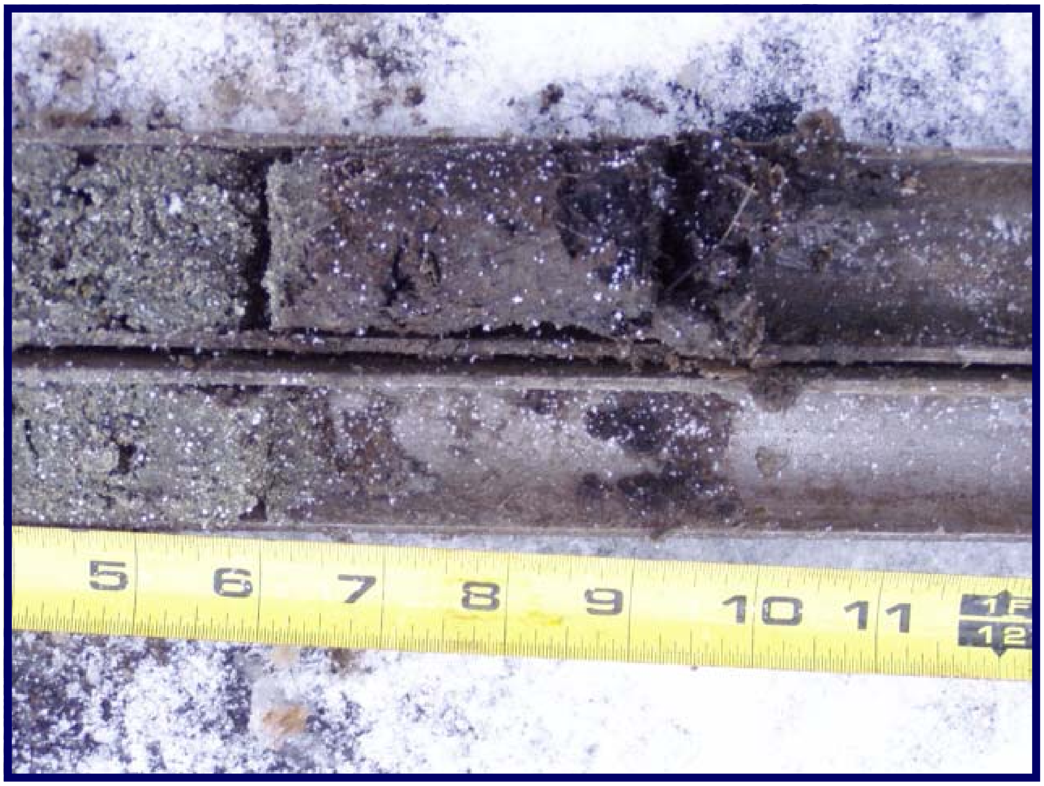


Photograph 9
Sample 6—Lower portion of sample. Zero at base of sample.



Photograph 10
Sample 7—Zero at base of sample.

Photograph 11
Sample 8—Upper portion of sample. Zero at base of sample.



Photograph 12
Sample 8—Lower portion of sample. Zero at base of sample.

Photograph 13
View (looking downstream) of the fresh water channel. Photo taken standing at the second weir within the fresh water channel.

Photograph 14
View of the fresh water channel, looking downstream. Note: bank heights on the LHS of the photo.

Photograph 15
View of the area to the south of the freshwater channel. Note the position of a path within the center of the photo. The path crosses the fresh water channel at the location of the second weir within the fresh water channel.

Photograph 16
South Fork of Rose Creek. Note the stakes marking the position of the channel. This portion of the channel would normally be within the reservoir outline.

Photograph 17
View of the South Fork of Rose Creek channel in an area that is normally within the reservoir.

Photograph 18
Southeast tributary as is enters the reservoir. Note the stakes marking the position of the channel.

Photograph 19

View of the channel of the southeast tributary, this portion of the creek is below normal reservoir levels.