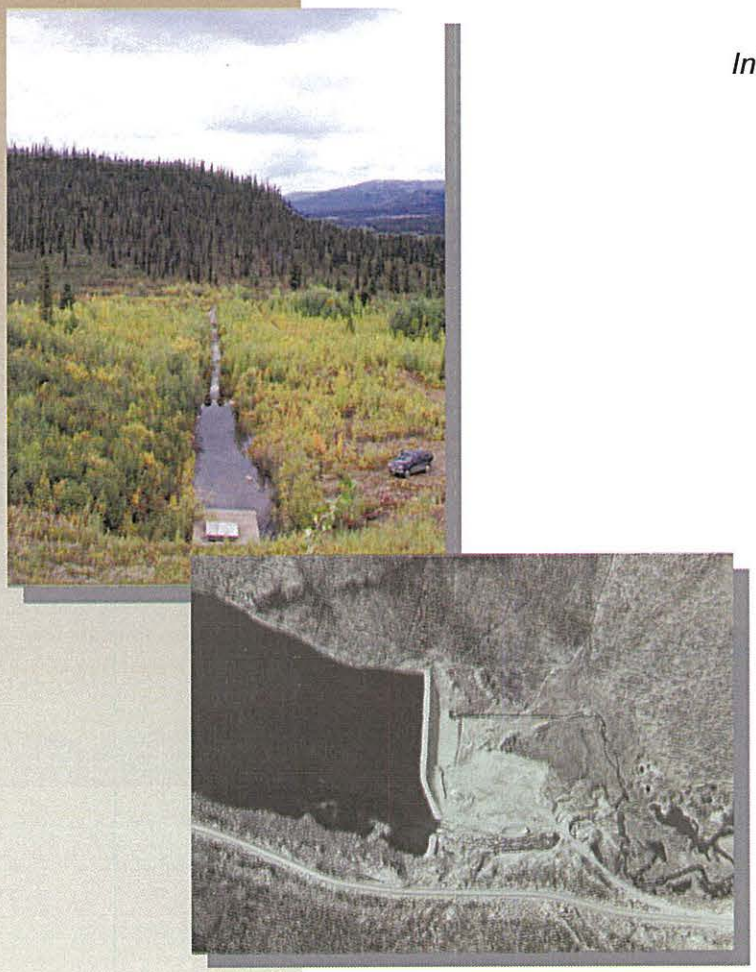
Deloitte & Touche

Final Breach Design
Fresh Water Supply Dam, Faro Mine



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April 2003

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Project 1CD003.22

FINAL BREACH DESIGN
FRESH WATER SUPPLY DAM, FARO MINE

1 INTRODUCTION

1.1 General

The Interim Receiver for Anvil Range Mining Corporation is planning to breach the Fresh Water Supply Dam (FWSD) prior to the 2004 spring freshet. The FWSD is no longer needed and, in the absence of further work, constitutes a risk to the tailings infrastructure and receiving environment located downstream.

The Interim Receiver has retained a team of engineers and scientists to develop a design for breaching of the FWSD. The team includes BGC Engineering Inc. (BGC), Gartner Lee Ltd. (GLL) and Northwest Hydraulic Consultants (nhc) working under the direction of SRK Consulting Inc. (SRK). As part of the design process, a meeting of the engineering team and representatives of Indian and Northern Affairs (DIAND) and Fisheries and Oceans Canada (DFO) was held in December 2002 to review options and select a preferred design concept for lowering the risk presented by the FWSD. A summary of the meeting is included in Appendix A. The selected design concept consists of an engineered breach through the body of the dam along the alignment of the original creek channel and re-establishment of the pre-construction creek. The engineering team has subsequently completed a design based on that concept.

The engineering team issued a preliminary design report (SRK, 2003a) and supplement (SRK, 2003b) in February and March, respectively, with the intention that these documents serve as an Environmental Assessment suitable for DFO and DIAND to complete their environmental assessment (EA) of the project. DFO confirmed on February 10, 2003 that the EA track for this project will follow a "screening level" of review under the Canadian Environmental Assessment Act (CEAA).

This report provides the final design of the breach of the FWSD, including a description of the current situation at and around the FWSD, the design criteria for the breach, supporting analyses, and design drawings. The report contains the reduced (50% reduction) version of the design drawings, initially prepared as D-sized drawings. The D-sized drawings have been prepared for use in the development of construction drawings.

1.2 Regulatory Approvals

The following agencies have been identified as being responsible for approvals prior to the commencement of the breach project:

- Fisheries and Oceans Canada (DFO);
- Indian and Northern Affairs Canada (DIAND);
- Yukon Department of Environment;
- Fisheries and Oceans Canada (Coast Guard); and
- Yukon Water Board.

As noted above, DFO and DIAND have indicated that they are responsible authorities (RA's) for the CEAA "screening level" review of the project, with DFO acting as the lead agency. As a result of devolution, the Executive Council Office (ECO) of the Government of Yukon is now a Responsible Authority under the Environmental Assessment Act (Yukon). Subject to a positive result from the CEAA screening review, DFO and DIAND can issue authorization to proceed. In addition, with the approval of the Minister of the ECO, the Board can issue a water licence for the project. It is anticipated that fish-related issues, including the details of the live fish transfer from the FWSD reservoir, will also require approval by the Yukon Department of Environment.

Coast Guard has indicated that the FWSD reservoir is considered to be a navigable water body and, therefore, requires a permit prior to the removal of the water body (which will occur following the FWSD breach).

The breaching of the FWSD will modify a dam with a height greater than 8 m that is not authorized within the existing water licence and will, therefore, require approval by the Yukon Water Board.

2 SITE DESCRIPTION AND CURRENT CONDITIONS

2.1 Location

The Faro Mine is located in the central Yukon, approximately 200 km north-northeast of Whitehorse. The Faro mine site is approximately 22 km north of the Town of Faro. The FWSD and reservoir are located south of the main access road to the Faro Mine site, approximately 5 km from the mine gatehouse. The location of the Faro Mine and the FWSD within the mine site are shown in Figure 2.1 and Drawing 1.

2.2 Fresh Water Supply Dam

2.2.1 Dam Construction and Components

The FWSD was part of the original mine development and was used to supply water for the milling process. A subsequent Water Licence requirement specified a minimum flow of 75 L/s in the Rose Creek Diversion, and the FWSD was used to sustain that flow during winter. A recycle water system replaced the reservoir as the primary supply of water to the processing plant in 1997. Fresh water supply from the FWSD is not required for the current care and maintenance activities.

The FWSD was constructed in 1968, on the South Fork of Rose Creek. Section, profile and plan views of the FWSD are shown in Drawing 2.

The dam is a zoned earthfill dam consisting of a low permeability compacted core and upstream blanket material (Zone 1), a broadly graded granular shell (Zone 2) and a compacted random fill zone (Zone 3). The Zone 3 material consists of material that did not meet the specifications for either Zone 1 or Zone 2 (Drawing 2). Zone 1 includes an upstream cut-off trench, but it does not extend to bedrock and is therefore referred to as a partial cut-off. The base elevation of the partial cut-off was limited to elevation 1079.9 m amsl (approximately coincident with the creek thalweg), to ensure that the excavation was completed in the dry. The Zone 1 material was extended approximately 80 m into the reservoir, forming an upstream blanket to reduce seepage under the dam. The seepage blanket is 1.5 m thick and is covered by a 0.6 m thick layer of gravel.

At the downstream toe of the dam, a seepage collection trench was installed. It extends to bedrock or a maximum depth of 4.6 m (15 feet). The material within the seepage collection trench was specified as filter gravel with maximum 1% silt sized particles allowed. This trench

was installed at the toe of the dam in the deepest section of the valley and extends about 114 m east of the valve house along the toe of the dam. The seepage collection trench exits near the valve house and feeds water into the fresh water channel (Drawing 2).

A cofferdam was constructed upstream of the seepage blanket (Drawing 2) to ensure that construction of the FWSD was completed in the dry. The cofferdam was constructed from compacted Zone 1 soil (Drawing 3) and had a crest elevation of 1083.5 m amsl. A 1.07 m (42 inch) diameter diversion pipe was used to direct the inflows around the cofferdam, under the FWSD construction site and into the downstream environment. After construction of the FWSD was completed, the central portion of the cofferdam was breached and the portion of the diversion pipe under the dam was plugged (Drawing 2).

The cofferdam was viewed using a ROV camera as part of the diving inspection performed in December 2002 (Territorial Diving Technologies, 2002). In this inspection, the edge of the cofferdam was found (but not measured and recorded) and the breaching of the cofferdam was confirmed. The ground surface elevation was measured during a detailed survey of the reservoir base (SRK, 2003b). The survey was performed in the area of the cofferdam and LLO inlet structure as part of the planning for the breaching project. The survey was used to determine the location and elevations of the cofferdam. The results of this survey program are included on Drawing 2.

The general arrangement of the FWSD is shown in Figure 2.2. According to recent (2001/2002) surveys of the FWSD (BGC, 2001a & BGC, 2002a), it is approximately 410 m long, 20.5 m high at its highest point (from original ground level) and 6 m to 7 m wide at the crest. A view of the crest of the FWSD is shown in Photo 1. The slope of the upstream face of the dam is approximately 2.6H:1V (horizontal:vertical) and the slope of the downstream face of the dam is 2H:1V. Table 2.1 contains a summary of the key elevations (based on the 1968 as-built drawings) for various features of the dam. The elevations contained in Table 2.1 include the original elevation in feet relative to the mine datum and metres above mean sea level (m amsl) (subtraction of 109.2 feet is required to convert original data to m amsl). The survey (BGC, 2001a) confirmed that the crest of the dam was 1099.0 m amsl (at the low point) and the low point on the concrete spillway was measured as 1096.1 m amsl.

Table 2.1
Key Elevations of the FWSD (1968 as built drawings)

Feature	Elevation (ft, FWSD datum)	Elevation (m amsl)
FWSD crest	3715	1099
Top of Zone 1 (core)	3710	1097.5
Spillway crest (1096.1 m in 2002 survey)	3705	1096
Top of trash rack (inlet to low-level outlet pipe)	3665	1083.8
Inlet elevation of low-level outlet pipe	3659	1082
Spring line of low-level outlet pipe at the inlet location	3646.5	1077.8
Natural elevation of ground in the center of the FWSD	3647.3	1078.4
Natural ground elevation at the u/s toe of the FWSD	3655	1080.8
Cofferdam crest	3664	1083.5

Water is released from the reservoir by two means: an overflow spillway located on the crest of the dam near the north abutment (Photo 2) and a low-level outlet pipe, which runs through the base of the dam near the south abutment (Photo 3). The locations of the two reservoir outlets are shown on Figure 2.2 and Drawing 2.

The low-level outlet (LLO) consists of:

- A 1.07 m (42-inch) diameter open orifice inlet covered with a trash rack (Drawing 3).
- A 1.07 m diameter concrete-encased pipe, which was placed in a trench excavated into bedrock with seepage collars, extending beneath the dam footprint. The total length of the LLO pipe, measured from the inlet to the valve house, is 127 m (based on the as-built drawings issued by Parsons-Jurden, 1968).
- A valve house and outlet located at the downstream toe of the dam (Drawing 3). In the valve house, the 1.07 m pipe is reduced to 0.61 m (24-inch) diameter. Following the reducer fitting, two valves are located in close succession. The outflow downstream from the valves releases into a chamber of the valve house (Photo 3), hitting the downstream wall of the structure for energy dissipation. The water in this chamber then flows over a weir in the side wall of the valve house and into the fresh water channel. The fresh water channel carries the flow downstream (Photo 4 and Figure 2.2) until it reaches the confluence with the natural channel.

An overflow spillway is located near the northern abutment of the dam (Figure 2.2). The spillway consists of a 30-m wide concrete sill, with vertical concrete wing walls (Photo 2). The top of the core (Zone 1) is located 1.4 to 1.5 m (Table 2.1 & BGC, 2001a) above the spillway crest. The calculated spillway discharge capacity is 94 m^3/sec (nhc, 2001a). The calculation was

based on treating the spillway as a broad crest weir, with a reservoir elevation of 1097.5 m amsl (the top of the core). The spillway discharges water into the South Fork of Rose Creek via a discharge channel excavated through rock and overburden materials. The discharge passes through two culverts under the access road (photo 5). Downstream from the culverts, the water rejoins the natural channel, as shown in Figure 2.2.

2.2.2 Dam Performance

Seepage was noted at the downstream toe of the FWSD immediately following first filling of the reservoir, which occurred during the 1969 freshet. The near-surface groundwater table and anticipated increase of pore pressure from the construction of the dam lead designers to expect seepage to occur at the downstream toe of the dam (Ripley, Klohn & Leonoff, 1969). Shortly after construction was completed, the appearance of seepage and accompanying sand boils lead to the design and construction of a downstream toe drain/berm in 1969. The location of the berm is shown in plan on Drawing 2 and the details of the berm construction are shown on Drawing 3. The designers noted that the total amount of seepage observed at the toe was less than expected (Ripley, Klohn & Leonoff, 1969).

Following a stability assessment by Golder Associates in 1988, another toe berm, including toe drainage measures, was placed for enhancement of the downstream slope stability. The berm addition contains a preferentially pervious lower section (0.5 m thickness) that provides discharge capacity for artesian seepage. The 1989 toe berm is 55 m long, approximately 7 m high at the original toe of the dam, and slopes downstream at 7.5H:1V to a seepage collection trench at the toe. The proposed construction details for the 1989 berm are shown on Drawing 3. The extent of the 1989 berm construction is reflected in the topographic contour lines included on Drawing 2. As-built records related to the construction of the 1969 and 1989 berms are not available.

Significant longitudinal cracking has been encountered on the upstream side of the dam crest for nearly 20 years (Photo 6). The cracking has been professionally investigated on more than occasion, most recently in 1994 (Golder, 1994). The cracking was attributed to frost action on the upstream face and crest of the dam. The investigation traced the cracks to a depth of almost 2 m. The results from thermistor monitoring at the crest of the dam indicates that frost penetrates to a depth of approximately 4 m, during normal reservoir operations. Results from the winter of 2001/2002 indicated that the depth of frost penetration was 6m (BGC, 2002b & BGC, 2002c); the minimum reservoir elevation of 1090 m amsl was measured during the winter of 2001/2002.

2.2.3 LLO Performance

The LLO operated between 1968 and 1997 in order to provide a consistent minimum flow of 0.475 m^3/s (0.4 m^3/s during initial operation). No available deficiencies or repairs to the LLO are documented. During a site review in support of a potential dam raise (Dome/Acres, 1984), the valves of the LLO were opened fully. Significant vibration and noise were reported, but the LLO operated for a short time at full flow conditions. There are discrepancies between the reported flow and expected flow for this condition (Klohn Crippen, 2003).

A diving inspection of the LLO was performed in 2002 (Diving Dynamics, 2002). The inspection revealed four key results:

1. Sonic testing indicated that the wall thickness of the pipe was 44% to 54% of its original thickness in three general locations. The thinnest wall thickness measured was 0.165 inches (compared to the original 0.375 inch) approximately 5 m downstream from the inlet.
2. The inside pipe walls were coated with a "growth material" with an average thickness of 50 mm.
3. The measured length of the LLO was about 15 m shorter than shown on the as-built drawings. The divers measured a total pipe length of 112 m and the as-built drawings indicate a total length of 127 m.
4. A bend, not shown on the as-built drawings, was encountered under the dam. The bend was noted as being located between 60 m and 70 m downstream of the inlet of the LLO. The bend consisted of an elevation drop of 1.5 m (5 feet) within the middle of this length. Additionally, the divers noted a small downwards bend (not quantified) near the inlet of LLO.

An assessment of the valves of the LLO by Klohn Crippen (2003) revealed the following:

1. A minor variation between the existing piping arrangement and the as-built drawings was noted. A 0.37-m (14.5-inch) length of pipe was located between the two valves.
2. The concrete supports appeared to have been cast prior to placement of the pipe work. The flanges on the pipe were not attached to the concrete supports and therefore only provided vertical support after the deflection of the pipe work.
3. Forty pipe wall measurements were made. The minimal wall thickness encountered was 0.300 inch, which is 80% of the original thickness.
4. Under the current configuration, the LLO, the outflow should be limited to 0.42 m^3/s (5,600 Igpm) in order to prevent absolute pressures in the existing outlet from dropping to a level that would induce damaging cavitation.

Klohn Crippen proposed modifications that would increase the maximum flow capacity of the LLO. The recommended modifications, consisting of shortening (by 0.3 m) the length of 24-inch pipe extending into the dissipator chamber, installing a 20-inch diameter orifice plate and providing support to the piping in the dissipator chamber, were implemented in March 2003 (Drawing 3 and Appendix B). Calculations performed to predict the flow capacity of the modified LLO indicated that the maximum flow rate would be about 2.65 m^3/s (35,000 Igpm) when the reservoir is full (elevation 1096.1 m amsl). The calculated discharge rating curve (Klohn Crippen, 2003), which relates reservoir elevation to discharge, is included in Figure 2.3 (note that the figure was prepared by Klohn Crippen using the original elevations in feet, based on the FWSD datum, and calculated discharge in the units of Imperial gallons per minute). A successful test of the modified LLO has been recently performed. The test confirms the predicted discharge rate for the current reservoir elevation (Appendix B).

Additional calculations were made, by Klohn, with respect to the planned increased flow within the LLO and the following statements were made concerning the larger flows:

1. The dissipator chamber was considered to be adequately reinforced to withstand the internal water pressures at the increased flow rates.
2. The end wall of the dissipator chamber was considered to have sufficient strength to withstand the force of the impact jet from the orifice plate (assuming a moderate total divergence angle of at least 4 degrees).
3. The critical buckling pressure calculation for the pipe indicated that, even for the thinnest wall measurement from the 2002 diving inspection, the pipe has adequate buckling resistance for the expected differential pressures induced by dewatering.

A successful test of the modified LLO was recently performed. Test procedures and results are included in Appendix B. The flows estimated during the test are shown in Figure 2.3.

2.2.4 Reservoir Operations

The Fresh Water Supply reservoir occupies part of the base of the Rose Creek valley. Figures 2.4 and 2.5 are air photos showing the reservoir area. Figure 2.6 presents a new topographic base plan of the reservoir area that was prepared for this project and Figure 2.7 presents additional survey information collected in February 2003 at the FWSD. The new base plan required the combination of results from a number of previous topographic surveys, as no survey of the entire project area has been performed. Drawing 4 shows the topography and bathymetry of the reservoir and immediate downstream areas, which is the combination of the surveys shown in Figure 2.6 and Figure 2.7.

The reservoir is approximately 1,454 m long with an average width of 315 m and an average depth of 8 m. Three tributaries, shown on Figures 2.4 and 2.5 and Drawing 4, flow into the reservoir. The largest of the three is the main channel of the South Fork of Rose Creek. Two smaller tributaries, North Tributary and the Southeast Tributary, are located near the east end of the reservoir.

Construction of the reservoir has shortened the lengths of the tributaries that formerly existed in the reservoir area. The length of South Fork of Rose Creek that has been either submerged or modified as part of the dam construction is about 2,420 m (1,900 m was submerged in the reservoir). About 190 m of the Southeast Tributary and 440 m of the North Tributary are submerged by the reservoir.

During operations, between 6,000 and 7,000 Igpm (0.45 and 0.53 m^3/s) of water were pumped from the pumphouse pond to the mill as make-up water. Inflows to the pumphouse pond included the South Fork of Rose Creek (water released from the FWSD), the North Fork of Rose Creek and water wells near the pumphouse. The water balance for the water supply was very tight and the mill personnel were concerned that they would run out of water each winter (personnel communications with site staff). Water outflow from the reservoir was kept to a minimum due to this concern. Despite minimizing the outflow from the reservoir, the reservoir was regularly drawn down by 6 m and, occasionally, by as much as 10 m by the end of the winter. The reservoir would typically (during mine operations) fill completely (to 1096.1 m amsl) and water would flow through the spillway from June through late fall. Due to the water balance concerns, in 1976, steel I-beams were placed within the spillway to allow for the addition of stop logs to raise the retained reservoir elevation. Stop-logs were typically placed across the spillway in the fall to provide increased water storage capacity. In 1999, DIAND instructed that the stop-log system be removed due to concerns that the excess water pressure caused by a higher reservoir elevation could lead to increased seepage at the downstream toe and exacerbate cracking of the crest.

During mine operations the outflow from the LLO was estimated to be a minimum of 0.4 m^3/s. The current Faro Water License (QZ95-003) requires that a minimum flow of 4.5 m^3/min (0.075 m^3/s) be maintained in the Rose Creek diversion canal for fisheries and conservation purposes.

Since the beginning of care and maintenance activities at the mine, the water level in the reservoir has fluctuated. Discharge through the spillway occurs for 8 to 9 months of the year and water is continually discharged through the LLO. The water is released through the LLO year-round at a rate estimated to be between 0.2 and 0.5 m^3/s.

The operation of the reservoir will be modified in 2003 to minimize the risk of uncontrolled breaching. The modified LLO, potentially in combination with siphons and pumps, will be used to maintain a nominal reservoir elevation of 1090 m amsl. Reservoir elevations are expected to fluctuate during 2003 and higher reservoir levels may occur on a short-term basis.

2.2.5 Storage Capacity Curve

The total height of the FWSD at its centerline is 20.5 m, which is the difference between the dam crest and the natural bed of the creek (see Table 2.1). The normal "full supply level" of the reservoir is 1096.1 m amsl (elevation of the spillway crest). The total storage of the reservoir is 4.2 million m^3 at the "full supply level". The height-capacity curve for the reservoir is shown in Figure 2.8 (based on the bathymetric survey by GLL, 2002).

The recent (GLL, 2002) height-capacity curve was compared to previous versions (Parsons-Jurden, 1968, Kilborn, 1986 and Harder, 1991). The Parsons-Jurden and Kilborn curves agree very well with the GLL (2002) results. The 2002 curve was, therefore, selected for use in the breach design.

2.2.6 Previous FWSD Investigations

A number of investigations have been performed at the FWSD, and provide additional information on site conditions. The following provides a summary of the main investigations that were reviewed as part of the breach design:

- Parsons (1967) performed borehole drilling along the original alignment of the dam. The investigation consisted of wash bore drilling to determine the depth of bedrock. The soil was described as sand, gravel and boulders with some silt.
- Ripley, Klohn and Leonoff Ltd. (1968) performed borehole drilling along a revised alignment for the dam; the dam was constructed on the revised alignment. The investigation included characterization of the depth to bedrock, characterization of the soil conditions (including laboratory testing) and determination of the ground water elevation. The pre-construction creek was described as being incised in a shallow meandering channel about 6.1 m (20 feet) wide and about 1.5 m (5 feet) deep. The creek bed dropped from about elevation 1080.7 m amsl to 1074.6 m amsl as the stream moved in a relatively straight channel passing the terrace where the dam was constructed.
- Dome/Acres (1985) performed drilling and testing pitting as part of an investigation for dam raising. The investigation included the installation of a thermistor and a number of piezometers both at the toe and in the crest of the dam.
- Golder Associates (1989) performed drilling to further define the piezometric levels in the dam, the soil properties of the dam and the foundation material properties. This

investigation was performed as part of a stability assessment of the dam. This lead to the installation of a toe berm in 1989 to improve downstream stability.

- Diving Dynamics (2001) completed a diving inspection of the LLO. The results are discussed in Section 2.2.3.
- BGC (2002d) performed drilling on the downstream side of the dam to characterize the depth to bedrock and soil properties. This investigation included installation of piezometers downstream of the toe of the dam.
- BGC (2002a) performed drilling in preparation for lowering of the existing spillway through the excavation of a bedrock notch. Drilling concentrated on determining depth to bedrock and the properties of the encountered soil and bedrock. Piezometers were installed within the dam to replace a non-functioning piezometer.
- Territorial Diving Technologies (2002) replaced the trash rack that was removed during a previous dive inspection. ROW inspection of the cofferdam location to confirm presence and to determine if breaching of the cofferdam had been performed. Depth of sediment near the LLO inlet was measured and two sediment samples were collected.
- Klohn Crippen (2003) performed a dam safety review of the dams at the Faro Mine, including the FWSD, in accordance with CDA guidelines. The review included a review of existing information available and a site inspection. The dam was given a preliminary classification and dam safety issues (both actual deficiencies and data gaps) were identified and discussed.
- Klohn Crippen (2003) performed an inspection of the low level outlet within the valve house and evaluated the condition of the valves. Calculations were made to determine safe discharge rates for the LLO. Recommendations were made on a method of increasing the discharge from the LLO and a discharge rating curve was prepared for the modified LLO.
- BGC (SRK, 2003b) completed a field investigation program that included visual inspections of the inflow tributaries to the FWSD reservoir and inspection of the fresh water channel downstream of the valve house. Sediment samples were collected from the base of the reservoir and the sediment was visually examined at various locations within the reservoir using an underwater camera. Detailed survey information was collected in the area of the upstream cofferdam and the inlet structure of the LLO, as well as the area surrounding the fresh water channel and its confluence with the natural channel.

2.3 Site Climate

2.3.1 Temperature

The Anvil climate station (operated by Environment Canada) was located at the mine site at an elevation of 1158 m amsl. The station no longer operates, but temperatures were recorded from 1967 to 1980 (RGC 1996). The mean monthly temperatures are listed in Table 2.2.

Table 2.2
Mean Monthly Temperatures (°C) at Anvil Climate Station

Parameter	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Yr.
Daily Max. Temp. (°C)	-15.1	-8.3	-5.3	2.2	9.3	16.0	17.5	15.2	9.6	1.6	-7.0	-12.6	1.9
Daily Min. Temp (°C)	-24.9	-18.8	-17.3	-8.7	-1.8	3.0	5.0	3.3	-0.9	-8.1	-16.7	-22.4	-9.0
Daily Temp. (°C)	-19.8	-13.9	-11.2	-3.2	4.0	9.9	11.5	9.5	4.6	-3.1	-11.6	-17.5	-3.4

The temperature data in Table 2.2 indicate the mean annual temperature is -3.4°C. July is the warmest month, with a mean daily temperature of 11.5°C, and January is the coldest month, with a mean daily temperature of -19.8°C. Over the period of record, temperature extremes of 29.4 and -46.1°C have been measured.

2.3.2 Precipitation

The mean annual precipitation (MAP) at the Faro airport station is 305 mm, based on precipitation data from 1978 to 2001 (BGC, 2002b). This total comprises roughly equal proportions of rainfall and snowfall as water equivalent. The mean monthly distribution of precipitation is listed in Table 2.3. For the period of record, the driest and wettest months are typically April and July, respectively. The greatest monthly precipitation measured over the period of record was 116.2 mm in August 2000.

Table 2.3
Monthly Mean Precipitation at Faro Airport

Month	Mean Precipitation (mm)
January	14.3
February	12.1
March	10.5
April	7.2
May	24.3
June	35.8
July	58.9
August	46.8
September	38.2
October	24.9
November	17.2
December	14.6
Annual Total	**304.7**

2.3.3 Snowpack

The Rose Creek snow course at the site was operated by DIAND from 1975 to 1985. The snow course was located near and at a similar elevation (1080 m) as the tailings impoundment area. The accumulation of snow at the tailings impoundment typically begins in October, and the snow has generally melted by the end of April, although in 1985, it persisted into May. At maximum snowpack in March or April, the density of the snowpack is about 200 kg/m^3.

The current snowpack at the Faro Mine site is approximately 50% of normal for April (D. Haggar, personnel communication, 2003).

2.3.4 Wind

Wind data from the Faro airport indicates that the prevailing wind direction is from the southeast, following the alignment of the Tintina Trench. The long-term monthly mean wind speed data collected at the Faro airport are summarized in Table 2.4 (RGC, 1996). The wind data was collected through the use of an anemometer on a 10-m tower near the airport terminal. The data is measured at each hour of the day, 365 days of the year.

Table 2.4
Long-term Monthly Mean of Wind Speed at the Faro Airport

Month	Mean Wind Speed (m/s)
January	1.4
February	1.7
March	2.2
April	2.6
May	2.7
June	2.7
July	2.6
August	2.1
September	2.1
October	2.2
November	1.7
December	1.5

2.4 Site Hydrology

The Rose Creek watershed covers an area of approximately 340 km^2 and is a significant part of the 980 km^2 Anvil Creek watershed which drains the southeast slopes of the Anvil Range Mountains. All of the Faro Mine site facilities are within the Rose Creek watershed.

Mine site stream flow measurements are collected at specific stations using automatic water level recorders and manual methods. The streamflow monitoring network was upgraded in about 1990, with further updates made in 1996.

Two local stream gauging stations have been operated by site staff since 1996: Stn. R7 (drainage area of 95 km^2) which is located on the North Fork of Rose Creek upstream from the mine site and Stn. X14 (drainage area 230 km^2) which is located on Rose Creek downstream from the mine site. The daily flow record for Station R7 is shown in Figure 2.9. The catchment area of Station R7 is comparable to that controlled by the FWSD, both in drainage area (95 km^2 vs. 67 km^2) and catchment median elevation (1470 m vs. 1420 m). Accordingly, the R7 flow record provides a good approximation of the hydrological regime of the FWSD. The flows at Station R7 are representative of a natural condition, having had experienced minimal influence from mining and other human activity (Appendix C1).

The FWSD reservoir drains an area of 67 km^2. A summary of the estimated monthly inflow to the reservoir is included in Table 2.5. The monthly inflow to the reservoir was estimated based

on the gauged stream flow of the North Fork of Rose Creek (Station R7). The data from this station were scaled by the ratio of drainage areas (67/95) to estimate flow into the reservoir.

The data are presented as minimum, average and maximum flow values encountered between 1996 and 2001, inclusive (based on R7 data presented in Appendix C1). Also included in Table 2.5, for comparison, are the estimated average inflows to the reservoir made prior to the construction of the reservoir (Parsons, 1968). The estimated average inflow hydrograph for the FWSD (2003 estimate) is shown in Figure 2.10.

A regional analysis (nhc, 2001a), based on seven gauging stations, was performed to estimate the peak inflow events to the FWS reservoir. The results of the analysis are summarized in Table 2.6.

Table 2.5
Estimated Monthly Inflow to the FWS Dam Reservoir in m^3/s

Month	Estimated Monthly Flow (m^3/s), Year of Estimate			
	Average (1968)	Minimum (2003)	Average (2003)	Maximum (2003)
January	0.113	0.08	0.16	0.22
February	0.085	0.06	0.14	0.20
March	0.085	0.06	0.13	0.18
April	0.113	0.11	0.16	0.18
May	1.42	0.94	1.38	1.91
June	2.92	0.94	1.96	2.92
July	1.49	0.64	1.01	1.25
August	0.906	0.59	0.96	1.48
September	0.736	0.53	0.97	1.72
October	0.595	0.39	0.61	1.23
November	0.269	0.22	0.29	0.37
December	0.198	0.12	0.20	0.25

Table 2.6
Estimated Peak Inflow Events at the FWSD

Return Period	Flood (m^3/s)
2-year	5.6
10-year	17
100-year	39
500-year	63
PMF	550

The regional analysis found that spring freshets (snowmelt events) defined the peak flood events at all stations. Therefore the events listed with a specific return period are spring freshet events. The PMF flood event was developed based on probable maximum precipitation (nhc, 2001a).

An analysis of potential flood inflows during the August to November period was performed (Appendix C2) to provide a basis for estimating the length of time required to drain the FWSD reservoir. The analysis examined inflows over a wide range of time windows from 7 days to 122 days and a wide range of return periods from 2 to 100 years. Table 2.7 summarizes the results of this seasonal flood analysis.

Table 2.7
Estimated Floods during Proposed Drawdown Period (August 1 to November 30)

Return Period (years)	Estimated peak average discharge (m^3/s) during the following number of consecutive days:					
	7	10	30	60	90	122
2	0.97	0.92	0.77	0.67	0.59	0.50
10	1.85	1.72	1.37	1.13	0.98	0.85
25	2.38	2.18	1.63	1.33	1.17	1.01
50	2.85	2.59	1.82	1.47	1.33	1.13
100	3.35	3.04	2.05	1.64	1.49	1.26

The regional analysis was extended to the period between December and March to estimate the winter baseflow conditions (Appendix C2) that will have to be managed throughout the construction period. This analysis determined that no significant rainstorms or early snowmelt events were recorded in this timeframe. The baseflow can be expected to be highest at the beginning of the construction period and then follow a recession curve through the remainder of the year, a situation shown for Station R7 (Figure 2.9). In a typical year, a peak daily inflow of 0.20 m^3/s could be expected, with an average inflow over the four-month period of 0.11 m^3/s

(Appendix C2). The corresponding flows for a 100-year wet year would be 0.56 m^3/s and 0.28 m^3/s.

The potential low flow conditions in the summer were determined based on a regional analysis of the period June through September (Appendix C2). The analysis determined that the summer 7-day low flow would be 0.47 m^3/s and 0.29 m^3/s, respectively, for the 2-year and 10-year return period events.

2.5 Site Seismicity

A range of peak ground accelerations (PGA) have been used for the design of various facilities at the Faro Mine. The PGA is used as part of slope stability analyses to estimate the effects of earthquake loading. A summary of the various PGA values determined for the Faro Mine is included in Table 2.8. When not specifically estimated as part of the assessment, the maximum credible earthquake (MCE) was estimated by doubling the magnitude of the 475-year event.

Table 2.8
Summary of PGA Earthquake Loading

Study	Return Period Event				
	475	1,000	10,000	Estimated MCE (twice the 475-year event)	MCE (deterministic)
Klohn Leonoff (1981)	0.07g	0.10g	0.32g	0.14g	0.40g[1]
Dome (1984)	0.063g	0.08g		0.126g	
Golder (1989)	0.08g			0.16g	
Robertson (1996)	0.05g		0.13g	0.10g	
BGC (2001a)[2]	0.063g	0.080g		0.126g	
Klohn Crippen (2002)[3]	0.05g/ 0.06g		0.15g/ 0.16g	0.12g	
SRK (2003c)	0.05g		0.15g	0.10g	

Note 1: Assumes an MCE of 6.5 in the Tintina Trench.
Note 2: Information provided by the Pacific Geoscience Centre.
Note 3: GSC-R model result/ GSC-H model result, where:
GSC-R is a model based on historical seismicity and regional tectonics, and
GSC-H is a model based on historical seismicity.

The studies sited above note that the source of the PGA estimation was the Pacific Geoscience Centre (PGC) of the Geological Survey of Canada. Until recently, the PGC used historical earthquake data to determine the PGA. As part of the most recent assessment of the earthquake

loading, the PGC estimated the PGA based on both historical data and regional active fault data (methodology included in 2002 estimation of PGA by Klohn Crippen).

Only one earthquake assessment included a deterministic calculation of the PGA based on an interpretation of the regional fault activity. Based on the historical movement rates within the Tintina Trench, Klohn Leonoff (1981) estimated that an earthquake with a magnitude of M6.5 could occur. However, Robertson Geoconsultants (1996) concluded that it is unrealistic to consider a deterministic estimate of seismic ground motions at Faro in which an earthquake is assumed to occur on the Tintina Fault. This conclusion is supported by recent seismic hazard maps prepared by Geological Survey of Canada (Adams et al., 1999). Determination of the validity of the deterministically determined earthquake loading is not relevant to the scope of this project.

2.6 Aquatic Environment

2.6.1 Reservoir Water Quality

The FWS reservoir develops thermal stratification and is likely a typical dymictic lake with a spring and fall turn-over period. Temperature and dissolved oxygen data collected in July and August of 2002 (Figure 2.11) clearly show thermal stratification occurring around 5 - 6 m. Harder (1991) reported temperature data from the reservoir, which showed only a weak thermal cline in the lake. Surface temperatures as high as 16° C were recorded and bottom temperatures between 5^{o} and 11^{o} C have been recorded (Figure 2.11). Dissolved oxygen profiles are also included in Figure 2.11 and show that the reservoir waters are for the most part well oxygenated. The August 2002 deep water dissolved oxygen level was below 6.5 mg/L, the lower limit considered by the CCME as optimal for cold water fish, however, the depressed oxygen levels at the bottom of the reservoir is not inconsistent with normal lake profiles.

Water quality data collected in August 2002, indicates the lake is oligotrophic. Water samples were collected at surface and at 10 m depth on August 9, 2002 for analyses of physical tests, nutrients and total metals. Results are tabulated in Table 2.9. The secchi depth reading (on both August 9 and July 26, 2002) was 5 m indicating a relatively clear water body. Nutrient concentrations (nitrogen and phosphorus) also support the conclusion that the reservoir is oligotrophic.

Total metals are at low levels in the reservoir, with many below detection and only one metal, lead, exceeding the corresponding CCME guideline for freshwater aquatic life. Lead was 0.0014mg/L at surface and 0.0012 mg/L at depth; slightly exceeding the 0.001 mg/L guideline. Much of the surrounding geology contains high levels of metals but, the drainage flowing to the

reservoir is not from a major deposit area. The limited data collected from Rose Creek upstream of the reservoir does not show elevated concentrations of metals but because the detection levels were quite high (i.e. lead was 0.02 mg/L) no specific conclusions can be made. The elevated lead is not inconsistent with recently collected sediment presented in section 2.6.3.

2.6.2 Rose Creek Water Quality

Considerable water quality data is available for several locations along Rose Creek. The water flowing into the reservoir was monitored at two stations (SMC and SRC). Prior to 1990, station SRC was located just upstream of the FWS reservoir. The second station (SMC) was located on Small Creek, which is a tributary of the South Fork of Rose Creek. Both of these stations were sampled by mine staff in the early 1970's and in 1989 and 1990. However, there is some question about these data as there appears to be some errors in the data set, specifically; the values for the dissolved metal concentrations exceed the values for the total metal concentrations. Generally, water at these sampling stations is alkaline (~ 8 pH units). The average alkalinity was 33.9 mg/L for SRC (which drains granitic rocks) and 215 mg/L for SMC. Total sulphate and zinc concentrations were low at both sampling stations ranging from 4 to 47 mg/L and 0.002 to 0.029 mg/L, respectively.

There are also two sample stations on the Rose Creek Diversion Channel. The first, referred to as station X3, is located at the upstream end of the channel and the second, X10, is located at the downstream end of the diversion channel (Figure 2.12). Station X3 includes all flow from the North and South Forks of Rose Creek except for some partial North Fork flow at times when the North Fork Diversion has been in use. Station X10 includes the influences of two tributary inflows from the south side of the Rose Creek valley and possible lateral seepage from the Second tailings impoundment. Water pH at stations X3 and X10 is similar and has been steady over time, with average values of 7.6 and 7.9, respectively. Sulphate concentrations are also similar and have generally been less than 60 mg/L with several isolated spikes. Total zinc concentrations have generally been less than 0.10 mg/L with occasional higher spikes. The concentration of total zinc at location X10 has generally been slightly greater than location X3 since 1995. The record of total zinc concentrations for station X3 displays seasonally (winter) elevated concentrations up to 1.85 mg/L from 1987 to 1991 that is attributed to the capture in pumping wells of groundwater containing elevated zinc concentrations. The elevated zinc concentrations were not observed at downstream location X10. The practice of augmenting the winter water supply from those pumping wells adjacent to the tailings impoundment was subsequently discontinued.

A summary of the water quality data from these stations can be found in Table 2.9.

2.6.3 Reservoir Sediments and Sediment Quality

The estimated amount of sediment within the reservoir is between 3,700 and 5,000 m^3. This estimated range in the volume of sediment was made by assuming that the reservoir had an average sediment thickness of 15 mm to 20 mm spread evenly through the reservoir surface area of 486,600 m^2. This estimate was made based on the results of a sediment testing program performed in February 2003 (SRK, 2003b). The sediment sampling and sediment viewing locations are shown, along with the estimated sediment thickness, on Figure 2.13.

Seven samples from the reservoir base (two of the nine samples collected were from the base of South Fork of Rose Creek) were collected during the February field program. Four samples were tested to determine their grain size and metals content. Based on the limited amount of sediment collected, three of the samples (from sample locations 5, 7 and 8) were combined to produce sample sizes large enough for grain size testing. Two photos of the exposed surface of the reservoir base, Photos 11 and 12, show that the soils consist of mostly course grained soil near the FWSD. The results of the grain size testing (Figure 2.14) indicated that Sample 3 (from near the inlet of South Fork of Rose Creek) consisted of sand with some silt. Results from the combined sample (from sample locations further into the reservoir) indicated that the material consisted of silt and clay with some sand. A copy of the results of the metal testing is included in Table 2.10. During the summer of 2002 the reservoir was temporary drawn down by approximately one metre and Photos 13 and 14 were taken near the inlet of the South Fork of Rose Creek and the Southeast tributary to the FWS reservoir.

2.6.4 Stream Substrates

The South Fork of Rose Creek above the reservoir has a gradient ranging from 2% near the reservoir increasing to 5% above the haul road. The dominant substrate in this section is boulder with cobbles and gravels, as shown in Photo 7. A sample (Sample 9 on Figure 2.13) of the substrate of the South Fork of Rose Creek was collected just upstream from the reservoir and it consisted of cobbles and gravel. The north tributary to the reservoir is somewhat incised and has a dominant substrate of cobble and boulders, Photo 8. The southeast tributary has a somewhat different character with a substrate dominated by fine material interspersed with boulders, Photo 9. The South Fork of Rose Creek, downstream of reservoir (Figure 2.15), is a low gradient, sinuous channel altered by beaver activity, Photo 10. The substrate in this area is primarily fine sediment. The current position of the South Fork of Rose Creek downstream from the FWSD is shown in Figure 2.15 as being slightly different than the original position.

Table 2.9
Water Chemistry of the Fresh Water Supply Reservoir

Parameter	Detection Limit	CCME Guideline	Surface 02/08/09	10 m Depth 02/08/09
Physical Tests				
Secchi depth	field		5 m	
Conductivity	field		80 uS	91 uS
Temperature	field		12.3 C	5.1 C
Dissolved oxygen	field	>9.5 early life stages, >6.5 others	9.7	6.2
Hardness ($CaCO_3$)	0.6		48.9	59.1
pH	0.01	6.5 - 9.0	7.69	7.34
Turbidity	field		1 NTU	1 NTU
Total Suspended Solids	3		<3	<3
Nutrients				
Nitrate Nitrogen	0.005		<0.005	<0.005
Nitrite Nitrogen	0.001	0.06	<0.001	0.002
Total Dissolved Phosphate	0.002		0.002	0.003
Total Phosphate	0.002		0.003	0.002
Total Metals				
Aluminum	0.005	0.1[a]	0.047	0.073
Antimony	0.0005		<0.0005	<0.0005
Arsenic	0.0005	0.005	<0.0005	<0.0005
Barium	0.02		0.02	0.03
Beryllium	0.001		<0.001	<0.001
Boron	0.1		<0.1	<0.1
Cadmium	0.00005	0.0011[a]	<0.00005	<0.00005
Calcium	0.05		15.1	17.8
Chromium	0.001		<0.001	0.001
Cobalt	0.0003		<0.0003	<0.0003
Copper	0.001	0.002[a]	0.001	0.001
Iron	0.03	0.3	0.07	0.11
Lead	0.0005	0.001[a]	**0.0014**	**0.0012**
Lithium	0.005		<0.005	<0.005
Magnesium	0.1		2.7	3.6
Manganese	0.0003		0.0077	0.0118
Mercury	0.00005		<0.00005	<0.00005
Molybdenum	0.001	0.073	<0.001	<0.001
Nickel	0.001	0.025[a]	<0.001	<0.001
Potassium	2		<2	<2
Selenium	0.001	0.001	<0.001	<0.001
Silver	0.00002	0.0001	<0.00002	<0.00002
Sodium	2		<2	<2
Thallium	0.0002	0.0008	<0.0002	<0.0002
Tin	0.0005		<0.0005	<0.0005
Titanium	0.01		<0.01	<0.01
Uranium	0.0002		0.0006	0.0008
Vanadium	0.03		<0.03	<0.03
Zinc	0.005	0.03	<0.005	<0.005

Notes to Table 2.9:
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.
a = criteria has been calculated based on hardness and pH of samples.
shaded values indicated exceedances of the CCME guidelines for freshwater aquatic life.

Table 2.10
Metal Concentrations in Sediment (by ICP method)

		February 2003 Samples		Regional Sediments (Reference Sites) (Godin and Davidge, 2002)						Sediment Criteria (CCME, 1999)	
				Vangorda Creek Sediments (1989)			Pelly River Sediments (1991)				
Sample:		5; 7; 8	3	Site Location ID: 222			Site Location ID:247			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).

2.6.5 Fish in Reservoir and Streams

Fish species present in the upper Pelly River watershed include Chinook (*Oncorohynchus tshawytscha*) and chum *(O. keta)* salmon, lake trout (*Salvelinus namaycush*), lake (*Coregonus*

clupeaformis), broad (*Coregonus nasus*), humpback (*C. clupeaformis)* and round whitefish (*Prosopium cylindraceum)*, least cisco (*C. sardinella*), inconnu (*Stenodus leucichthys*) , arctic grayling (*Thymallus arcticus*), northern pike (*Esox lucius*), burbot (*Lota lota*), longnose sucker (*Catastomas catostomus*)and slimy sculpin (*Cottus cognatus*). Various studies regarding fish presence and habitat use have been conducted at the Anvil Range Mine Complex between 1974 and 2002. During these studies, arctic grayling, burbot, Chinook salmon, slimy sculpin, longnose sucker and round whitefish have been captured in the Anvil watershed as part of sampling programs for fish presence, population, distribution and metal analysis purposes. Figure 2.16 and Table 2.11 indicate fish presence by stream reach. Chinook have been noted spawning within lower Anvil Creek during some years in relatively low numbers when compared regionally and juveniles have been noted in the lower 23 km of Anvil Creek in moderate numbers (based on regional comparisons, RGC, 1996). Chinook fry have also been found in the lower end of Rose Creek.

Arctic grayling are the dominant species in Rose Creek and have been captured throughout the Rose Creek mainsteam, and in the North and South Forks, including headwater areas of both. Harder (1991) reported that on a regional basis the South Fork of Rose Creek supports the greatest densities of arctic grayling. Once arctic grayling reach maturity (age three to four in the study area), they spawn annually between early May and early June in the Rose Creek drainage (Weagle, 1981; Harder, 1988).

Fish populations have been isolated by several barriers in the watershed (Figure 2.16). The population in the mainstem of Rose Creek can access reaches 1 and 2 of the South Fork, up to the spillway culverts. Access to the upper reaches of the North Fork is cut off by a culvert that controls flow into a diversion channel just above the confluence with Rose Creek. The culverts create a barrier when waters flow only into the diversion channel. Further upstream a rock drain is used to pass the North Fork under the haul road

Arctic grayling are present in the FWS reservoir and can access the reaches immediately upstream of the Reservoir of two small tributaries and reach 4 of the South Fork of Rose Creek. Culverts at the mine access road, approximately 4.5 km upstream of the Reservoir are the first of several barriers in the South Fork of Rose Creek. There is also a separate population of grayling that exists above the haul road and are distributed up to the headwaters and Dixon Lake. Similarly, the section of the North Fork above the haul road rock drain barrier supports a population of grayling that also extends up to a series of ponds in the headwaters of this fork.

Several studies of fish in the FWS reservoir have been conducted between 1981 and 2002 for presence, relative population and metals analysis purposes. Arctic grayling, slimy sculpin and burbot have been documented in the Reservoir and the South Fork of Rose Creek upstream. The arctic grayling caught in the Reservoir have ranged in size from 15 to 31 cm. Catch results of gill net sampling conducted in 2002 were directly compared to gill net sampling conducted in 1981 and 1989, as adequate data was available from these historical studies to derive an estimate of the number of fish caught per unit of effort. The 1981 studies (Weagle, 1981) indicate a catch ranging from 2 to 10 fish or 0.02 to 0.11 arctic grayling per 100 m^2 net area per hour for three 48 hour sets during July, August and October. The August 1989 study (Harder, 1991) captured 24 fish or 8.33 arctic grayling per 100 m^2 net area per hour during a day set. During the 2002 study, sinking and floating nets set during the day resulted in a catch of only 3 grayling (0.27 arctic grayling per 100 m^2 net area per hour), while an overnight set resulted in a catch of 61 fish (3.26 arctic grayling per 100 m^2 net area per hour). These results do not necessarily indicate a particular long-term trend in fish populations in the reservoir. Of the three sampling events, catch per unit effort was lowest in 1981 and highest in 1989.

The general conclusions of studies between 1981 and 2002 are that the arctic grayling populations in the reservoir and in reach 4 of the South Fork of Rose Creek area are in good biological condition and sufficient habitat exists to support all life phases of arctic grayling.

2.6.6 Stream Habitat

The Faro Mine is wholly within the Rose Creek watershed and, as such, there have been several alterations to the creek associated with the Anvil Range Mine Complex. These alterations include diverting Faro Creek around the Faro pit to enter the North Fork, rather than flowing directly into the mainstem of Rose Creek. The Faro pit and associated dumps are located north of the mainstem, just west of the North Fork. In addition to the diversion of Faro Creek, additional alterations to the Rose Creek watershed include:

- Diversion of the mainstem around the tailings impoundment facilities.
- Creation of the pumphouse pond on the mainstem at the upstream end of the Rose Creek diversion.
- Intermittent diversion of the lower 500 m of the North Fork.
- Construction of the FWSD converting approximately 1,900 m of stream habitat into lake habitat.
- Construction of the haul road over the North Fork, all tributaries to the east and the upper South Fork.

Table 2.11
Rose Creek Watershed Fish Habitat by Stream Reach

Watercourse	Reach	Arctic Grayling Habitat Rating			Channel Width	Gradient (%)	Channel Type	Bed Materials	Cover	Barriers	Other
		Spawning	Rearing	Winter							
Rose Cr. (not shown on map)	1	high	high	moderate	25	1.5	riffle (pool, run)	gravel (cobble, fine)			side channels, flows in winter
Rose Cr.	2	high	high	moderate	13	1	run (riffle, pool)	cobble, gravel (boulder, fines)	20% - pools, cutbanks, boulder, little wood debris		side channels, flows in winter
Rose Cr.	3	moderate	low	moderate	20	1.5	run (riffle, step-pool sections)	gravel, cobble (boulders in steps)	5% - boulders	step sections a potential juvenile barrier	flows in winter
Rose South Fork	1	moderate	high	high	10	1.2	riffle (pool, run) and pond	cobble (boulder, gravel)			pumphouse pond
Rose South Fork	2	low	high	high	6	0.5	pool (run)	fines			beaver dams, multiple channels
reservoir	3	low	high	high						spillway culverts	
North tributary	1	low	moderate	low	3.5	10	riffle (step, pool)	boulder (cobble)	boulder	mine road culvert	
Southeast tributary	1	low	moderate	low	2	4	glide	fines (boulder at mouth)	vegetation	low flow	
Rose South Fork	4	moderate	moderate	moderate	7	2.2	riffle (pool, run)	boulder (cobble, gravel)	20% - boulder, pools, vegetation, cutbanks		
Rose South Fork	5	low	low	low	7	4.3	riffle (pool, run)	boulder		mine road culvert, haul road and steep section	
Rose South Fork	6	moderate	low	low	5	5	riffle (run, step, pool)	boulder, cobble	20% - boulder, vegetation, cutbank		
Rose South Fork	7	low	high	moderate			Dixon Lake	fines			Dixon Lake
Rose North Fork	1	moderate	moderate	moderate	7	1.4	pool (riffle, run)	boulder (cobble, gravel, fine)	ponds, pools	mine road culvert (on one of the two lower channel options)	two options for water flow below mine road - through boulder channel or series of ponds
Rose North Fork	2	moderate	moderate	low	10	2	riffle (pool, run)	cobble (gravel, fines)	20% - pools, cutbanks, boulder	haul road	side channels
Rose North Fork	3	moderate	high	moderate	9	2	run (riffle, pool)	cobble (fines, gravel)			side channels, ponds
Rose North Fork	4	low	low	low			ponds	fines			ponds and small lake but very low pH (3) noted

Notes:

a. fines = <2mm, gravel = 2-64mm, cobble = 64-256mm, boulder = 256-4,000mm; sub-dominant substrate in brackets

A classification of fish habitat in the Anvil watershed was conducted in 1989 and 1990 (Harder & Associates, 1991) and other reports summarized in RGC (1996). These reports provide details of fish habitat in Anvil Creek. The most notable feature of Anvil Creek is the availability and use of Chinook spawning habitat primarily in the lower reaches of Anvil Creek.

The following details of fish habitat in Rose Creek are based on Harder's reports (Harder, 1988 and 1992) and fieldwork by Gartner Lee in July and August of 2002. A habitat summary of Rose Creek, by stream reach, is outlined in Table 2.11 and the reach breaks and main habitat features are shown on Figure 2.16. Habitat descriptions focus on arctic grayling. Lower Rose Creek (reaches 1 and 2 on Figure 2.16) contain good quality habitat for spawning and rearing arctic grayling and moderate value habitat for adults and sub-adults during both summer and winter. Rose Creek meanders through this section and contains diverse habitat including gravels for spawning as well as deep pools and side channels. Based on Harder (1988), arctic grayling

spawn in this reach. Flow is expected here in the winter. Next Creek flows into Rose Creek from the north at the upstream end of reach 2. This creek is narrow with little flow over a relatively steep gradient (>10%) of step-pools resulting in low value for all life stages of arctic grayling.

The diversion channel around the tailings (reach 3) is considered to have low rearing habitat and moderate value for spawning, and over-wintering habitat. The upper 2/3 of the diversion is a wide (20 m) channel with predominantly gravel and cobble substrate. The lower 1/3 contains steps of boulders and pools. Velocities in the lower section may make it difficult for juvenile grayling passage. Based on Harder (1988), arctic grayling spawn in this reach. Flow is expected here in the winter and is augmented with release from the Reservoir.

Reach 1 of the South Fork of Rose Creek includes the pumphouse pond and a natural channel that is predominantly riffle over cobble. Due to this combination and augmented winter flows, the habitat value is moderate for spawning but high for rearing and over-wintering.

Reach 2 is a meandering section with side channels modified by several active beaver dams. The deep water and augmented slow flow over a substrate of fines provides high value habitat for rearing, and over-wintering but low value for spawning.

Reach 3 is the reservoir (Section 2.6.6), which provides a considerable habitat for sub-adult and adults feeding and over-wintering but low value for spawning arctic grayling. There are two culverts under an access road that cross the lower end of the FWSD spillway and form an impassable barrier for fish movement from Rose Creek into the FWS reservoir (Photo 5).

The North tributary that flows into the reservoir from the north is a relatively steep gradient from the current Reservoir shore to the mine access road 40 m upstream. The substrate is primarily cobble (Photo 8). This channel section provides moderate rearing habitat and limited spawning and over-wintering areas.

The Southeast tributary that flows to the Reservoir from the southeast is an unconfined low-flow channel through the willow-sedge-spruce valley with a substrate of fines (Photo 9). The channel at the mouth is defined with boulder substrate. This channel offers possible rearing and low value spawning, and over-wintering habitat.

Reach 4 of the South Fork, is predominantly riffle channel over boulder and cobble from the Reservoir (Photo 10 and Figure 2.15) with some beaver dams in the upper end. Habitat is considered moderate for all grayling life stages.

Reach 5 contains three barriers at the lower end: a culvert under the mine access road, a culvert under the haul road and a steep gradient section (>20%). Fish can only migrate out of this area. This section offers low value spawning, rearing and over-wintering habitat.

Reach 6 is predominantly riffle over boulders at a 5% slope, with habitat considered moderate for spawning (grayling have been observed spawning at the upper end) and low for all other life stages. Dixon Lake is a shallow basin in reach 7, which offers high value habitat for rearing, and moderate value for over-wintering.

Within the South Fork, arctic grayling populations both upstream and downstream of the FWSD appear to have sufficient habitat to support all life phases. Within the study area, the best spawning habitat for arctic grayling is found at the upper end of the Rose Creek diversion channel and within the South Fork just downstream of the reservoir. Patches of spawning habitat are also present in the North Fork and in the South Fork upstream of the reservoir.

The best quality rearing summer habitat for fry, juvenile fish and adults is located within the pumphouse pond, the South Fork just downstream of the Reservoir, and possibly within the Reservoir itself. Arctic grayling fry normally spend at least their first summer in stream habitat however; Harder (1988) only captured grayling young-of-the-year in the FWS reservoir. Summer habitat also exists in pools within the South Fork, upstream of the reservoir, and the North Fork.

A large area for over-wintering has been created by the reservoir. Fish located downstream of the dam likely over-winter in the pumphouse pond or other deep areas of Rose Creek, where water flows continue below the ice.

2.6.7 Reservoir Habitat

Data to update the bathymetric map of the Reservoir was collected on August 6 and 7, 2002. Laberge Environmental Services collected the data. Fifteen transects were established and geo-referenced using a Garmin 12XL GPS unit. A Raytheon Survey Fathometer was used to collect the depth data. The elevation of the water surface at the time of the survey was determined relative to established survey points on the dam crest and was established to be 1095.5 m

geodetic. The transect locations and depth data were entered into Auto CAD and a contour map generated and provided in Figure 2.17.

Habitat data in the form of substrate composition in the littoral area of the Reservoir was also collected in July 2002 (Gartner Lee, 2002). The substrate along the shore measured to determine its type and size by using an Aquaview underwater camera and a metre stick for reference. This information was overlaid on the bathymetric map to determine the habitat polygons from 0 to 6 metres depth to characterize fish habitat under current full pool conditions of the reservoir.

As a general rule the near shore area of a lake to a depth of 6 m is defined as the littoral zone (RIC, 1999) and is the most productive area of the lake as light penetrates to the bottom sediments and aquatic plants can grow. Descriptions of each habitat polygon were developed (Gartner Lee, 2002). In addition, shoreline substrate exposed by wave action and vegetation was noted for the shoreline perimeter polygons, as shown in Photos 13 though 16. In general, the north side of the reservoir is more gradually sloped than the south side and has a greater abundance of aquatic vegetation. At the east side, two shallow bays are present. Aquatic vegetation identified within the reservoir includes milfoil (*Myriophyllum sibiricum*), bur-reed (*Sparganium angustifolium*), pondweed (*Potamogeton alpinus*) and mare's tail (*Hippuris vulgaris*). The near shore substrate is predominantly fines with boulders, with cobble and gravel visible in some areas. Angular material is located along the south side of the reservoir at the shale bedrock bluffs. Boulders are visible lining the upstream end (to 4 m depth) of the flooded South Fork Rose Creek channel (Photo 15). Branches from flooded vegetation (willow) are located throughout the Reservoir and are, generally denser at the 6 to 12 m water depth. In addition, stumps from cut trees (white spruce) are present throughout the Reservoir.

Prior to reservoir formation, reach 3 of the South Fork of Rose Creek meandered along the valley bottom, Figure 2.18. There are no pre-impoundment studies of the habitat conditions of this section of Rose Creek. The following information has been inferred from pre-impoundment mapping of the stream channel and the surrounding stream habitat conditions. The total length of the stream channel lost to reservoir formation, from east end of reservoir to end of the freshwater supply channel below the valve house, is approximately 2,400 m. The average channel width in this section was 10 m providing an estimated 24,000 m^2 of stream habitat. This section of stream has an average slope of 1% with sections ranging from 0.2 to 3.2 % (Drawing 4). Given the range of gradients, it is anticipated that the very low gradient stream section provided the meandering type habitat conditions similar to Reach 2 of the South Fork of Rose Creek while the steeper gradients would provide more pool-riffle habitat conditions. Prior to

construction of the dam, stream based fish populations were able to migrate freely up the South Fork of Rose Creek to the culverts under the mine access road.

2.7 Wildlife

Wildlife studies have been completed in the project area most of which focus on big game animals. Fannin sheep reside in the Faro area with a lambing area identified in the headwaters of the South Fork of Rose Creek approximately 4.5 km to the south of the FWS reservoir. Moose are also common in the area but no specific habitat issues have been reported in the project area.

Caribou are also in the area with the Pelly drainage area identified as winter range while alpine and sub-alpine zones of the Anvil Range are known summer range. Grizzly and Black bears have been frequently observed around the mine sites. A review of background reports including the RGC (1996) and Anvil Range Mining Corp (2002) do not provide any specific details on small mammals, or birds that are found in the study area.

2.8 Vegetation

The Anvil Range Mining Complex is located within the Yukon Plateau (North) Ecoregion, in the Boreal Cordillera Ecozone (Yukon Conservation Society, 1995). The region lies within the zone of discontinuous, widespread permafrost. Depressional areas consist of peat bogs, fens and local palsas. Lowlands frequently contain hummocks and sedge tussocks. Upland areas commonly include scree slopes and steep south-facing slopes with vegetation dominated by grasses. Treeline occurs at 1350 to 1500 m ASL.

Six vegetation zones were mapped within the study area, based on the field studies and mapping undertaken by Montreal Engineering in 1975. The vegetation zones include flood plain forest, upland forest, bog forest, alpine tundra, subalpine transition, and alluvial plain shrub. The FWS reservoir is in the alluvial plain shrub zone.

The South Fork of Rose Creek and its tributaries are included in the alluvial plain shrub vegetation zone. Shrub birch, shrubby cinquefoil *(Potentilla fruiticosa)*, Scouler's willow and other willow species dominate the vegetation communities in the alluvial plain shrub zone. Scattered stands of white spruce and alpine fir also occur. Dwarf shrubs consist of crowberry, Labrador tea, low-bush cranberry, dwarf dogwood, dwarf blueberry (*Vaccinium caespitosum*) and arctic willow. Herbs species include arrow-leafed senecio (*Senecio triangularis*), tall Jacob's ladder (*Polemonium acutiflorum*), sweet coltsfoot (*Petasites hyperboreus*), alpine harebell, wormwood, arctic lupine, clubmoss, common horsetail (*Equisetum arvense*), grass

(*Arctagrostis* sp.) and sedges. Feathermoss may form extensive mats in the alluvial plain shrub zone. Lichens, not well represented in this zone, include *Cladonia alpina* and other *Cladonia* species.

2.9 Resource Use

Other than mining, resource use in the Rose Creek watershed appears to be somewhat limited. Arctic grayling are the third most popular sport fish in the Yukon and sport fishing is known to occur in the accessible areas of Rose Creek, in particular the lower end of the South Fork and within the Reservoir (Harder, 1991)). Associated with the fishing activity on the Reservoir is a limited amount of recreational boating. While there are no specific records, big game hunting and fur trapping are also resource uses in the area. Caribou, moose and mountain sheep are all known to frequent the Rose Creek watershed.

First Nations traditionally used the Rose and Anvil Creek areas for hunting and trapping and they fished Chinook salmon near the mouth of Anvil Creek. Since the establishment of the Faro Mine, the hunting and trapping activities in the immediate area have been discontinued (Anvil Range, 2002).

3 DESIGN CRITERIA

3.1 Review of Project Alternatives

As noted in Section 1.1, representatives of DFO, DIAND, SRK, BGC, GLL, Geo-Engineering Inc. and Hydroconsult attended a project planning meeting in early December 2002. During the meeting, the attendees identified and evaluated seven alternatives for reducing the risks associated with the FWSD. A summary of this evaluation is provided below. Further details are provided in Appendix A.

The objectives for the FWSD breach were clarified as follows:

- Keep water levels within the range of natural fluctuations.
- Avoid long duration inundation.
- Avoid fish stranding in higher ponds.
- Respect dam stability constraints on dewatering rates.
- Provide fish passage for up to 10-year flood.
- Minimize risk of ice blockages downstream of the pumphouse, specifically by avoiding increases in flow rates after ice formation.
- Control sediment releases.
- Avoid creation of small volume pond that would result in winter fish kill.
- Consider construction, maintenance, future construction, and appurtenant costs.

The following alternatives were then considered and evaluated against the objectives:

- French drain;
- Existing 42-inch culvert (LLO), open full;
- Continual pumping;
- Broad crested weir;
- Complete removal of the FWSD;
- Embankment notch; and
- Bedrock notch.

Four of the alternatives ("French drain", "42-inch culvert", "broad-crested weir", and "continual pumping") were consequently rejected. The remaining three, all of which are variations of a dam breach, were judged to be capable of meeting the listed objectives. The main difference between these three is cost. The "complete removal" alternative would be significantly more costly for achievement of the same benefit than the either of the "notch" alternatives and was therefore rejected. Similarly, based on cost and construction considerations (primarily

requirements for blasting) the "bedrock notch" was rejected in favour of the "embankment notch".

3.2 Dam Classification

The Canadian Dam Association (CDA) has published dam safety guidelines that are intended for use by dam owners and engineers so that the safety of existing dams can be evaluated in a consistent and adequate manner across Canada. The evaluation of a dam's safety commences with its classification in accordance with the consequences of failure. The dam classification constitutes the basis for analysing its safety and establishes the appropriate design loading events that the structure must safely withstand.

The dam classification system recommended in the CDA guidelines (1999) is shown in Table 3.1.

Table 3.1
CDA Dam Classification in Terms of Consequences of Failure

Consequence Category	Potential Incremental Consequences of Failure[a]	
	Life Safety[b]	Socioeconomic, Financial & Environmental[c]
Very High	Large number of fatalities	Extreme damages
High	Some fatalities	Large damages
Low	No fatalities anticipated	Moderate damages
Very Low	No fatalities	Minor damages beyond owner's property

Notes to Table 3.1

a) Incremental to the impacts which would occur under the same natural conditions (flood, earthquake or other event) but without the failure of the dam. The consequence (i.e. loss of life or economic loses) with the higher rating determines which category is assigned to the structure. In the case of tailings dams, consequence categories should be assigned for each stage in the life cycle of the dam.

b) The criteria which define the Consequence Categories should be established between the Owner and the regulatory authorities, consistent with societal expectations. Where regulatory authorities do not exist, or do not provide guidance, the criteria should be set by the owner to be consistent with societal expectations. The criteria may be based on levels of risk which are acceptable or tolerable to society.

c) The owner may wish to establish separate corporate financial criteria which reflect their ability to absorb or otherwise manage the direct financial loss to their business and their ability to pay for damages to others.

No previous classification (according to CDA guidelines) of the FWSD has been made. However, relevant information is available from a Qualitative Risk Assessment of the Down Valley Tailings area (BGC, 2001b), a Dam Safety Review for the Anvil Range Property (Klohn Crippen, 2002) and an Extreme Flood Routing and Dam Break Assessment of the Fresh Water Supply Dam (nhc, 2001b).

The objectives of the BGC report (2001b) were to identify potential failure modes for the dams, diversion canals and associated structures within the Down Valley area and to estimate the probability of these failures occurring. This report concluded that the consequences of failure of the FWSD would result in repair, fines and clean-up costs in the range of US$10 million to US$100 million.

The nhc (2001b) assessment of extreme flood routing and dam break assessment noted that:

- With the current dam in place, the consequences of a probable maximum flood (PMF) event would include overtopping the FWSD and the subsequent breaching of the structure. The downstream consequences were not estimated.
- With the current dam in place, the consequences of a "sunny day" failure (i.e. failure caused by an event other than a flood, such as piping) are to overflow the existing Rose Creek diversion, mobilize tailings and likely overtop the Intermediate and Cross Valley dams, releasing tailings into the environment.

The Klohn Crippen report (2002) summarizing the recent dam safety review noted that the detailed analysis of the incremental consequences of dam failure was beyond the scope of that review, but the FWSD was likely to be a very high consequence structure.

Given the financial and environmental consequences projected by the BGC, nhc and Klohn reports, a "very high" classification is concluded to be appropriate for the existing FWSD. When the FWSD is breached, there is no possibility of a "sunny day" failure leading to significant downstream damage.

Given the financial and environmental consequences projected by the BGC, Klohn Crippen and nhc reports, a "very high" classification is concluded to be appropriate for the existing FWSD.

Following the breach of the dam, it will no longer retain water and, will be exempt from this classification system. It should be noted that once the dam is removed the risks from "sunny day" piping are eliminated. Therefore, the design criteria for the breached dam are open to interpretation based on the general engineering practice requirements and the objectives identified in the December planning meeting (Section 3.1 and Appendix A). The design criteria used to develop the preliminary design of the breach are discussed in the following sections.

3.3 Design Flood

The design flood affects the design of erosion protection to prevent undercutting of the slopes within the dam breach and to maintain the position of the stream channel within a stationary corridor (referred to as a floodplain in this report).

As noted above, typical guidelines, such as those by CDA (1999), do not provide suitable criteria for selecting the design flood. In the absence of firm guidance, the 1 in 500-year flood was proposed in discussions involving DFO, DIAND, Environment Canada and the Interim Receiver and accepted as the design flood. The 1 in 500-year flood event corresponds to a snowmelt event and has an instantaneous flood peak of 63 m^3/s (nhc, 2001).

The rationale for this selection was that the Rose Creek diversion canal, which is situated downstream of the FWSD, is sized to pass the 1 in 500-year flood. Selection of the 1 in 500-year flood provides consistency with the current capacity of the Rose Creek diversion canal. It is noteworthy, however, that the Rose Creek diversion canal will likely change as the final closure plan is developed and subsequently implemented. Furthermore, given the infrequency and relatively minor consequences associated with exceedance of the 1 in 500-year flood, it could be argued that a smaller design flood, such as the 1 in 200-year flood, would be acceptable.

3.4 Beneficial Use Habitat Requirements

There are three components to the beneficial use habitat requirements:

- The breach design should produce habitat for arctic grayling.
- Fish passage should be possible up to a specified flood level. Beyond this level, the water velocity will exceed the capability of the fish to swim upstream.
- To the extent possible, there should be sufficient water to allow fish passage under normal low river flow conditions.

Stream resident grayling rely on riffles for food production and pool habitat for resting and escape/cover habitat to avoid predators and for over-wintering habitat. Based on these habitat needs the general habitat design will be a riffle and pool configuration.

In regards to fish passage, the 1 in 10-year flood event was proposed and accepted as the design flood for which fish passage through the breach should be maintained (meetings involving DFO, DIAND and the Interim Receiver). The rationale for this selection was that this level is a commonly selected flood for projects involving channel restoration. It was agreed that another suitable flood could be selected if the 1 in 10-year flood is too restrictive (Appendix A).

The 10-year return period flood has an instantaneous peak flow of 17 m^3/s (Table 2.6). Arctic grayling are judged to be the species of interest in the system. The swimming speed for Arctic grayling is provided in Table 3.2, which has been obtained from DFO land development guidelines for the protection of aquatic habitat (DFO & MELP, 1993). Based on these guidelines and the breach channel length of about 270 m, the burst speed (4.3 m/s) is selected as the upper

velocity limit at the riffles and the prolonged speed (2.1 m/s) is selected as the upper velocity limit in the pools during the 10-year flood.

Table 3.2
Sustained, Prolonged and Burst Swimming Speed for Adult Artic Grayling

Sustained Speed (m/s)	Prolonged Speed (m/s)	Burst Speed (m/s)
0 – 0.8	0.8 – 2.1	2.1 – 4.3

Notes to Table 3.2:

Sustained speed – maintained indefinitely

Prolonged speed – maintained for up to 200 minutes

Burst speed – maintained for up to 165 seconds.

In addition to the requirement for fish passage at the upper flood, fish must be able to pass the newly constructed channel during most flow conditions. The interpreted normal low flow conditions within the South Fork of Rose Creek are 0.46 and 0.11 m^3/s, respectively, during summer and winter. To the extent possible, fish passage should be maintained during these low flow periods while recognizing that some natural sections of the creek may not maintain fish passage under all flow conditions. However, providing fish passage and meeting it should be recognized that this objective somewhat conflicts with the requirements of erosion protection criteria result in different material sizes within riffles and therefore are somewhat opposed. The design should therefore attempt to balance the objectives of fish passage during low flow conditions and erosion protection.

3.5 Low-level Outlet Pipe (LLO)

The selected option for breach of the FWSD consists of a breach in the approximate location of the creek channel prior to the construction of the dam. The LLO pipe was constructed part way up the south valley wall and will not be disturbed as part of this construction. The LLO needs to be appropriately abandoned such that it does not adversely impact the proposed breach section and fish habitat design elements.

3.6 Stability

The breach of the FWSD will, as noted previously, change the classification of this structure. The areas where stability will remain important during and following the breach activities include:

- The upstream stability during reservoir drawdown;

- The upstream and downstream stability of the dam at the end of drawdown and in the long term; and,
- The stability of the sides of the breach, particularly where the existing dam height is significant.

3.6.1 Reservoir Drawdown

Generally, a decrease in retained pond levels increases the factor of safety for embankment dams, although not in all cases. Terzaghi and Peck (1967) note that for dams with a sloping core, such as the FWSD, the stability of the upstream slope "may be more critical at an intermediate level, known as partial pool, than with the reservoir full". Furthermore, if the reservoir is lowered too quickly, there is a risk that the upstream slope can fail due to what is known as rapid drawdown.

The CDA (1999) recommendations for the factors of safety applicable to static stability analyses of embankment dams, including rapid drawdown, are summarised in Table 3.3. These guidelines are applicable prior to the breaching.

Table 3.3
Factors of Safety for Static Assessment (CDA, 1999)

Loading Conditions	Minimum Factor of Safety	Slope
Steady state seepage with maximum pond height	1.5	Downstream
Full or partial rapid drawdown	1.2 to 1.3[a]	Upstream
End of construction before reservoir filling	1.3	Downstream and upstream

[a] Higher values may be required if drawdown occurs frequently during operations.

Mitchell (1983) provides typical safety factors for impoundment dams, as summarized in Table 3.4. Within the context of Table 3.4, the FWSD would be a high risk dam during drawdown.

Table 3.4
Typical Safety Factors for Impoundment Dams (after Mitchell, 1983)

Case	High Risk Dam	Low Risk Dam
[a] end of construction	1.3	1.3*
[b] normal operation	1.5	1.3
[c] rapid drawdown	1.3*	1.1
[d] earthquake loadings	1.2	1.1
[e] earthquake loadings in combination with [a], [b] or [c]	1.1	1.0

* Applicable to the FWSD

In consideration of Tables 3.3 and 3.4, the target factor of safety against failure of the upstream face of the dam during reservoir lowering was selected (1.3).

3.6.2 Upstream and Downstream Slopes

Given that the FWSD will no longer be a dam following the proposed breach and the FWSD is part of a mining project, it is reasonable to base the stability criteria for the upstream and downstream slopes on factors of safety applicable to waste rock dumps. A typical example of minimum factors of safety for waste rock dumps is provided in Table 3.5, the source of which is the guidelines published by the BC Mine Waste Rock Pile Research Committee in 1991. The breached FWSD would fit with Case B, as the consequences of a failure of either the upstream or downstream slope are not severe.

Table 3.5
Interim Guidelines for Minimum Design Factor of Safety – Waste Rock Dumps

Stability Condition	Case A – more severe	Case B – less severe
Stability of Dump Surface		
Short term (active)	1.0	1.0
Long term (closure)	1.2	1.1*
Overall stability (deep-seated)		
Short term (active)	1.3 - 1.5	1.1 - 1.3
Long term (closure)	1.5	1.3*
Pseudo-static	1.1 - 1.3	1.0*

* Applicable to the FWSD

In consideration of Table 3.5, the appropriate factors of safety against failure of the upstream and downstream face of the dam in the long term are 1.1 at the dam face (shallow failure), 1.3 for a deep-seated failure and 1.0 under pseudo-static loading conditions, i.e. in response to the design earthquake.

3.6.3 Side Slopes in the Breach

During the excavation of the breach, the appropriate factor of safety for the side slopes corresponds to what is known as the end of construction case. This case is noted in Table 3.4, which indicates the minimum factor of safety is 1.3. This value is higher than the short-term value (1.1) for the stability of the dump face because of safety concerns for men and equipment working at the toe of the slope and because of the potential consequences to the works at the toe of the slope.

In the long term, it is reasonable to base the stability criteria for the side slopes in the breach on minimum factors of safety provided in Table 3.5. Therefore, the appropriate factors of safety against failure of the side slopes in the breach in the long term are 1.1 for at the slope face (shallow failure), 1.3 for a deep-seated failure and 1.0 under pseudo-static loading conditions.

3.7 Design Earthquake

Well built embankments that are sited on firm, non-liquefiable foundations and that do not incorporate large bodies of materials which, if saturated, might lose most of their strength during earthquakes, can be designed and evaluated using seismic coefficient methods, such as pseudo-static analysis (CDA, 1999).

The pseudo-static analysis requires selection of a peak ground acceleration, which in turns requires selection of the maximum design earthquake (MDE). Selection of the MDE should be based on the consequences of dam failure. The consequences of any slope failures involving the FWSD following the breach are judged to be very low.

The MDE selected for the related stability analyses has an estimated return period of 475 years. This corresponds to a 10% probability of exceedance in 50 years and is consistent with the MDE recommended by the National Building Code of Canada for structures built in Canada. The 475-year return period event has been determined during various assessments to be consistently between of 0.05g and 0.08g. The MDE selected for use in the designing the side slopes of the FWSD breach is 0.06g, which is the value estimated in the most recent analysis, by the Pacific Geoscience Centre (BGC, 2001a).

4 DESIGN

The FWSD breach design is illustrated on Drawings 5 through 13. As outlined in Section 3.1, the breach requires the excavation of a notch through the dam, in the approximate location of the creek channel prior to construction of the dam. The base of the notch will be formed such that the channel approximately matches both the hydraulic performance and habitat elements that existed prior to dam construction. Following successful performance of the FWSD breaching, the creek flows in this section of the South Fork of Rose Creek will be returned to their approximate pre-development conditions.

4.1 Breach Location and Width

As indicated in Section 3.1 the position of the breach was evaluated as part of the options analysis. Locating the breach as close as possible to the pre-construction channel offered several advantages, such as:

- The channel will be placed within its original alluvium.
- The use of pre-FWSD channel location will be maximized.
- No bedrock will be encountered during construction.
- The extent of inlet and outlet structures to connect the natural channel position with the breach channel will be minimized.

The breach will be over-excavated to a width of 25.4m to allow for the placement of rip rap. The width of the floodplain, defined as the basal area between the rip rapped side slopes, is 20 m (Drawings 5 and 10). At this width, the floodplain will be wide enough to accommodate the channel sinuosity necessary for fish habitat and the rip rap in the existing stockpile can be used in the channel to provide adequate erosion protection for the design flood. Hydraulic analysis of the 500-year return period flood indicated the depth of water would be about 1 m above the floodplain elevation. The riprap was designed such that it would be stable under the hydraulic stresses applied during this flood event (Appendix D3). Additionally, the 20 m wide flood plain produced velocities during the 10-year return period flood that would allow fish passage.

4.2 Breach Side Slopes

The design criteria for stability analyses used to determine the side slopes of the breach were outlined in Section 3.6. Stability analyses were performed to assess the stability of potential slide slopes of 2.5H:1V and 3H:1V (Appendix D2). The analyses considered the critical section through the exposed core of the dam and used conservative strength properties representative of

the soils within that section. The piezometric levels used in the analyses were based on judgment. The analysis was performed for the following conditions:

- Static analysis - immediately post-construction, with high piezometric conditions within the dam.
- Static analysis – long-term conditions, with the expected long-term piezometric conditions.
- Pseudo-static analysis of earthquake loading and long-term piezometric conditions.

The results for the case where the core of the dam has a friction angle of 30° are summarized in Table 4.1. Stability analyses were also conducted for the case where the friction angle of the core was 33° (Appendix D2). The computed factor of safety for the 2.5H:1V slope does not meet the factor of safety required for the immediate post-construction condition. As a consequence, the 3H:1V side slopes have been selected for current planning (Drawing 5). However, the existing wells and piezometer installations will be monitored to assess the actual piezometric levels as the reservoir is lowered. Prior to construction, the stability of the side slopes will be reassessed using actual piezometric data and, provided that the computed factor of safety meets the specified criterion for the immediate post-construction condition, the breach side slopes may be steepened to 2.5H:1V.

Table 4.1
Results of Stability Analysis – Breach Side Slope

Condition	Calculated Factor of Safety		Minimum Factor of Safety
	Side Slope of Breach		
	2.5H:1V	3H:1V	
Static, immediately post-construction	1.18	1.34	1.3
Static, long term	1.47	1.61	1.3
Pseudo-static (g=0.06), long term	1.23	1.33	1.0

Two benches, having a width of 2 m, are planned at elevations 1087 and 1092 m amsl. The benches were included to limit erosion, by breaking up the constant slope, and limiting the run-off velocity due to direct rainfall.

4.3 Channel Width and Depth

The design objective which governs the selection of channel dimensions is the requirement that the channel provide for fish passage under most flow conditions. The initial design channel

width was selected to mimic the natural channel. The original investigation for the dam construction (Ripley, Klohn & Leonoff, 1968) reported that the channel at the location of the dam was 6 m wide and 1.5 m deep.

The overall grade of the proposed channel through the dam construction footprint is 1%. The side slopes of the channel were selected to be 1.5H:1V. Using the overall grade of the expected channel base, combined with the 2-year design flow (5.6 m^3/s), general hydraulic geometry guidelines were used to define the channel characteristics (Appendix C2, Appendix D3). An 8-m wide channel was selected on the basis of these guidelines.

The proposed channel consists of a series of riffle-pool elements (which, as indicated in Appendix D3, is the expected morphology of the stream for the given combination of grade and dominate discharge). The design for the channel was undertaken such that the 2-year return period flood (5.6 m^3/s) would be retained within the channel section. Given that the flow control within the channel is at the riffles, this location defines the required channel depth to ensure the 2-year flow can be passed in the channel section. Based on hydraulic analysis, the channel depth of 0.3 m was selected for the crests of the riffles (Drawing 10). A deep pool depth is preferable for the channel. However, based on the low stream energy, the analysis indicates that it is unlikely that a pool depth of greater than about 1 m (from the floodplain level) can be sustained.

Given that the 2-year flood was used to determine the bankfull conditions, the 10-year flood (target flood to ensure fish passage in channel) overtops the channel and flows onto the floodplain. A hydraulic analysis indicated that the water with in the channel would have a velocity of 2.5 m/s and the water flowing in the floodplain would have a velocity of 0.9 m/s. The depth of water on the floodplain would be about 0.2 m. A comparison with Table 3.2 indicates that fish passage will be maintained for this flood condition.

The details of the channel layout are included on Drawings 5, 7 and 10.

4.4 Channel Elements

Preliminary channel design was based on empirical relationships (Appendix C2, Appendix D3) developed largely in western Canada. The empirical relationships provided the following guidelines for the design of the channel:

1) the slope of the channel (approx. 1%) is consistent with a riffle-pool morphology;
2) the pool-riffle-bar unit has a characteristic spacing of 50 m;

3) for a stable channel, pools comprise about 50% to 75% of the channel length and have a wide range of depths;
4) the average width of a stable channel with a bankfull discharge of 5.6 m^3/s should fall in the range of 8 m, based on hydraulic geometry relationships for gravel rivers in Canada; and,
5) the soils investigation report referred to in the previous section suggests the original channel width was about 6 m.

The channel details are included on Drawings 7 and 10.

The design channel details are expected to produce pool sections that have a residual total depth of 0.7 to 1.0 m of water. The average winter base flow of 0.08 to 0.12 m^3/s is expected to provide over-winter refuge with sufficient oxygen for fish survival.

4.5 Erosion Protection of Breach

The erosion protection at the edge of the floodplain (start of residual dam structure) has been designed (Appendix D3) to be stable during the 500-year return period flood. This flood will produced a water level approximately 1 m above the floodplain level, and is expected to scour to a depth of about 2.5 m. Protection from this erosion would typically require that the erosion protection element extend to a depth of 2.5 m, however due to the winter construction period and the expectation that this construction would required excavating through sand and gravel below the water table, the total excavation depth was limited to 1.75 m at the riffles and 1.0 m along the sides of the floodplain, between the riffles. The volume of rip-rap to be placed below the floodplain level (Drawing 8) is maintained at a minimum of 4.5 m^3 per lineal metre (maintaining the ideal design volume). During the design flood, this volume of rip rap would be expected to "launch" (the water would scour the floodplain alluvium and undermine the rip rap, which would then fall into the appropriate position) to provide erosion protection. The specific design requirements for the floodplain erosion protection are: side slope 2H:1V, median rock size of (D_{50}) 400 mm, riprap thickness of twice D_{50}, the range of rock sizes should be D_{85}/D_{15} = 5.3 and use angular, clean and durable rock.

Due to the size difference between the Type I riprap and the base soil, geotextile separation layer will be required (Drawing 10) on the angular slope at the side of the erosion protection.

4.6 Sediment and Erosion Control Elements

Two components of sediment control are required as part of the construction: control of sediments generated in the construction area; and determination of the potential for erosion of sediments stored within the reservoir.

Control of sediments generated within the construction area will require collection of the water from the area and, prior to releasing it into the creek, modifying it so that it meets the discharge criterion for total suspended sediments (TSS). "Canadian Water Quality Guidelines for the Protection of Aquatic Life' (Canadian Council of Ministers of the Environment 2002) criteria will be applied to the discharge of suspended sediments during the construction phase. Therefore, the maximum allowable concentration of TSS in water released from the construction site will be no more than 25 mg/L above background or 10% above background if background is greater than 250 mg/L TSS. Further details of the sediment control are provided in Sections 5 and 6.

The water within the South Fork of Rose Creek will be intercepted upstream of the construction area and transferred around the construction zone to maintain winter base flows within the creek. This has the effect of completing the construction in the dry and reducing the volume of water within the construction zone, and therefore the amount of sediment affected water to the dealt with.

Erosion control within the former reservoir area will be achieved through a proactive program of revegetation. The thickness and gradation of sediment that has been measured on the base of the reservoir (Figure 2.13) effectively eliminates other methods of erosion and sediment control. For example, machine movements on the surface of the former reservoir base (to remove or contain sediment) are likely to result in greater erosion and release of sediment due to disturbance. The best available technology for erosion control is to vegetate the surfaces as soon as possible after they become exposed. Pre-construction and post-construction vegetation plans for the base of the reservoir are described further in Section 5.

As discussed in Section 2.6.3, the preliminary estimate of total volume of sediment within the reservoir is between 3,700 and 5,000 m^3. Of this total, 30 to 60% (1,110 to 3,000 m^3) is expected to be fine grained (silt and clay sizes) material.

In order to assess the likely maximum potential effects of sediment mobilization, it was assumed that all of the fine-grained sediments would be mobilized in the first post-construction freshet.

The total flow associated with a 2-year freshet was estimated at 5,500,000 m^3 (developed using an instantaneous inflow of 5.6 m^3/s and the spring inflow hydrograph from nhc, 2001a). These assumptions result in estimated suspended sediment concentrations ranging from 404 to 1,090 mg/L. The actual suspended sediment load will depend on the amount of sediment exposed to erosion, which in turn will depend on the timing and magnitude of storm events and the vegetation within the reservoir. Experience from other dam decommissioning projects indicates that the sediment that has collected within the channel area will be transported downstream, but as little as 20 to 30% of the total sediment is transported out of the reservoir (case is based on thicker sediments than present in the FWSD) (Sentinelles Petitcodiac Riverkeeper, 2002). If this case study result can be used as a conservative guide, assume 20% to 30% of the total sediment is transported during the first freshet, the actual sediment load during the first freshet would most likely range from 80 to 330 mg/L. The suspended sediment measured at the site (locations upstream from the disturbed mine operations) has ranged from 4 to 698 mg/L (Gartner Lee, 2002).

Based on the above analyses, dewatering scheduling, construction season and setting, no further instream sediment removal measures are proposed regarding sediment release from the dewatered reservoir.

4.7 Rehabilitated Channel

The breach of the FWSD (including the floodplain and channel sections) will discharge water into the fresh water channel (Drawing 7). The fresh water channel was constructed as part of the original dam construction, and was sized according to the flows required to handle during the construction and operation of the FWSD. The capacity of the fresh water channel is much lower than the capacity of the proposed breach and, as a consequence, the fresh water channel will require some measure of rehabilitation in order to accept the discharge from the designed channel section through the breach.

Re-establishment of the channel downstream of the breach will be undertaken according to an adaptive management approach. The guiding principles of adaptive management are to re-establish a natural channel section and to minimize the disturbance of the vegetated floodplain area where the channel will be re-established.

Two options to achieve the guidelines noted above will be explored further in the summer of 2003 and the final decision on the appropriate channel rehabilitation will be made as part of the construction.

Option 1 (the preferred option) consists of extending the 8 m wide channel section and the 20 m wide flood plain as needed by the topography of the immediate outlet from the breach section (Drawing 8). Once this widened channel reaches the approximate position of the creek (pre-1968) a berm will be placed within the straight section of the fresh water channel to divert water back to its original position. The construction activities for this portion of the new channel would be limited to removal of the current bank, leaving the channel to reform in its original alluvium.

The erosion protection and dyke are intended to divert water from the fresh water channel to the south, such that the creek can re-establish itself in its former position. It is expected that, due to vegetation, the rehabilitated channel will stabilize over time, but as part of the adaptive management strategy, some erosion may occur in this area in the short term.

Option 2 also consists of extending the 8 m wide channel section and the 20 m wide flood plain as needed by the topography of the immediate outlet from the breach section (Drawing 8). This option would not divert the rehabilitated channel from the course of the current fresh water channel, but continue widening of the channel section (8 m width), to allow the dominant discharge to flow through the section. The widening of the channel (to 8 m width) would be terminated when the existing fresh water channel section is deemed to have sufficient capacity to handle the 2-year return period flood.

5 CONSTRUCTION PLANS

The major components of the breaching of the FWSD are:

- Lowering the reservoir.
- Breaching the dam.
- Constructing channel elements.
- Decommissioning of the LLO.
- Performing revegetation of the exposed reservoir base.

As noted in Section 4 it is proposed the FWSD be breached by excavating a notch through the dam, approximately at the location of the pre-dam creek location. Construction of the breach is envisioned to consist of three main phases: preparatory activities, construction activities and post construction monitoring. The existing conditions at the FWSD and proposed breach construction details are shown on the attached series of 13 drawings.

5.1 Construction Constraints

5.1.1 Spring Freshet

As noted in Section 1.1, the FWSD breach project is planned for completion prior to the spring freshet of 2004. Recorded (based on site specific information) and expected dates for the onset of the spring freshet are summarized in Table 5.1 (nhc, 2001a). The actual timing of spring freshet will be dependent on the climatic conditions in 2004. For the purposes of planning reservoir lowering and construction, the onset of the spring freshet was assumed to be April 14.

Table 5.1
Onset of the Spring Freshet

	Start Date for Spring Freshet
Earliest anticipated:	April 14
Earliest recorded:	April 21
Latest recorded:	May 20
Latest anticipated	June 1

5.1.2 Reservoir Drawdown

The reservoir drawdown will determine the start date for the construction of the breach. There are five main factors that affect the reservoir drawdown schedule:

- Permits.
- Completion of the fish transfer.

- Capacity of the LLO in relation to reservoir inflows.
- Prevention of "rapid drawdown" failures on the upstream face of the dam.
- Potential flooding events during construction.

The first two factors control the start time for the reservoir drawdown and the last three control the rate and timing of the completion of the drawdown. As outlined in Appendix D1, the expected start of reservoir drawdown is July 22, 2003, with the starting reservoir elevation being between 1086 and 1092 m amsl. Sometime between mid-October and mid-November, depending on the inflows to the reservoir, the reservoir can be maintained at the inlet elevation of the LLO (1082 m amsl). The reservoir can be lowered to 1082 m before this date, but given expected inflows it may not be able to be maintained at this level (Appendix D1). At 1082 m amsl, the reservoir volume will be about 50,000 m^3 (Figure 2.8).

Pumping will be required to lower the reservoir level below elevation 1082 m. The volume of pumped water will include the residual 50,000 m^3 and the inflow water from the South Fork of Rose Creek (Table 2.5). The average inflows expected are 0.61, 0.29, 0.20 and 0.16 m^3/s for October, November, December and January, respectively. Based on recorded maximum inflows at Station R7, the inflows during this period could be as high as 1.23, 0.37, 0.25 and 0.22 m^3/s for October, November, December and January, respectively. As part of the design, it has been assumed that the water pumped to complete the reservoir drawdown will be pumped into the LLO (Drawing 12) which discharges into the existing fresh water channel (Drawing 2).

During mine operations, the flow rate through the LLO was about 0.4 to 0.5 m^3/s. This flow was discharged to the fresh water channel. However, use of the modified LLO (Klohn, 2003 and Appendix B) to lower the reservoir will increase the volume of water flowing in the fresh water channel to as much as 2.3 m^3/s. An evaluation of the channel (4 m wide base, 10 m wide at bankfull with a base slope of 1%) indicates that a discharge of 2.3 m^3/s would result in a water depth of less than 0.4 m, which will be contained within the existing channel section.

5.1.3 Summer Field Program and Planning for Fish Salvage

Studies have shown there is a healthy population of fish in the FWS reservoir (Section 2.6.5) of an unknown size. It is anticipated that in order to minimize impacts to this fish population by forcing more fish into the available stream channel in the reservoir than can be supported by that habitat, a fish salvage program will have to be developed. The fish salvage program will be developed according to guidelines provided by DFO and Yukon Department of Environment, an ongoing dialogue with these agencies is underway. Approval for the program will be required before the salvage can begin.

During the summer of 2003, a field program will be undertaken to collect additional information that cannot be collected in winter (given the current snow and ice conditions). The information collected in this program will not affect the final design, but will be used to define the fish salvage program.

5.2 Preparatory Activities

Prior to construction of the breach, the following activities will need to be undertaken:

1) Lower the reservoir;
2) Fish salvage;
3) Preliminary (Phase 1) revegetation;
4) Prepare construction and spoil areas; and,
5) Stockpile required materials.

5.2.1 Lower the Reservoir

As noted in Section 2.2.4, the water in the reservoir will be maintained at a nominal elevation of 1090 m amsl throughout the spring and early summer of 2003.

As outlined in Section 4.3 and Appendix D1 the reservoir lowering will likely commence on about July 22, 2003. This start date for the reservoir drawdown is controlled by permitting requirements and the transfer of live fish from the reservoir. Reservoir lowering will be accomplished through the use of the recently upgraded LLO pipe. The time to complete the lowering is dependent on the reservoir inflows during drawdown, but drawdown to elevation 1082 m is expected to be completed some time between mid-October and mid-November (Appendix D1).

Once the reservoir has been lowered to elevation 1082 m amsl using the LLO, the remaining drawdown will be accomplished through the use of pumps. The pumps will be situated in an area that includes fish exclusion nets or they will have appropriate screens. Water will be pumped into the LLO and discharged to the existing fresh water channel.

5.2.2 Fish Salvage

The fish salvage will be mostly completed prior to the reservoir being lowered below elevation 1086 m (Appendix D1), however contingencies will be developed so that the transfer is completed given all anticipated drawdown and fish capture scenarios. Successful completion of the fish transfer is not thought possible beyond about mid-October as the development of ice on

the surface of the reservoir would severely limit fish capture activities. The transfer program is dependent on receiving DFO and Yukon Department of Environment authorization for the transfer. Details on the fish transfer program are provided in Section 7.2.2.

5.2.3 Preliminary (Phase 1) Revegetation within Reservoir

The reservoir will be maintained over the spring and early summer at a nominal reservoir elevation of 1090 m amsl. As shown on Drawing 13, the area of the reservoir base that is exposed will be seeded/planted during summer of 2003 (Phase 1 revegetation). As the reservoir is lowered, additional seeding/planting will be performed, and it is expected that these efforts will continue into the fall. The termination date for revegetation work in the fall of 2003 will depend on the weather conditions. Seed can be spread on exposed areas prior to the establishment of the permanent snow cover, as seed in place under the snow will germinate early in the spring, immediately following snow melt.

The seed mixture used for the revegetation is likely to consist of a mix of native grasses and contain a large grass seed variety (i.e. some form of rye) that will germinate rapidly and provide immediate erosion control. This planting will also provide root structure to reduce erosion during spring snowmelt and rains. It is expected that the seed mixture will be manually broadcast. If the soil is dry enough, the use of a four-wheel all terrain vehicle, or "quad," may be considered. The exposed riparian zone will include revegetation with grass willow and spruce plantings (where appropriate, see below). The spruce and willow will be planted in a 10 m wide zone (extending 10 m from the edge of the bank) adjacent to the South Fork of Rose Creek and a 5 m wide zone adjacent to the smaller tributaries, as shown in Drawing 13. As indicated on Drawing 13, the riparian zone will include willow plantings. Given the timing of the Phase 1 revegetation program it is unlikely that willow planting can be completed in Phase 1 (due to the need to cut dormant willows). Most or all of the willow planting will likely take place during the Phase 2 revegetation program (Section 5.4.2).

Planting of white spruce or alpine fir as part of the Phase 1 revegetation will be performed within the riparian zones of the stream channels within the reservoir. This planting of conifers, may be delayed until the Phase 2 revegetation depending on the weather conditions and availability of the appropriate number of seedlings (the number can not be estimated until the reservoir base is exposed). The actual areas to be planted will be determined throughout the summer of 2003, after snow melt. The areas selected will be those that have stumps indicating the presence of these trees prior to reservoir formation. Preliminary plans for planting trees include the use of larger planting stock to ensure the trees a good chance of survival amongst the grass and sedge that will be established through seeding. Planted trees will be fertilized with an appropriate

starter mix to accelerate root establishment as the nutrient condition of the soils within the reservoir are likely depleted through years of saturation. The anticipated planting density will be equivalent to 800 stems per hectare.

The Phase 2 planting program will be developed after the spring 2004 survey of the reservoir area and the actual areas for planting are selected, the need for fertilizer assessed and the appropriate mix of tree species determined.

5.2.4 Prepare Construction and Spoil Areas

The existing riprap stockpile area and spoil areas are shown on Drawing 13. The spoil areas are relatively flat with sporadic grass cover. The spoil area downstream of the FWSD has previously been used for construction activities related to the dam. Construction of perimeter containment dikes will be performed as part of spoil placement (although not in the spillway location, since this will consist of filling the previously excavated channel).

It is expected that a portion of the spoil area downstream of the dam (or, alternatively, a portion of the spillway) will be used as the contractor's work area. This area will require only minor preparation for the construction offices, storage facilities and fuelling area. The fuelling area is to be constructed in accordance with the appropriate regulations for fuelling near water sources. No fuel tanks are proposed for the construction area, the existing fuel tanks at the mine shall be used. Transportation of fuel from the mine will be performed using trucks as it is needed. Spill contingency plans will be prepared as part of the final design and will be the contractor's responsibility (an example of the spill contingency plan is outlined in Section 7).

5.2.5 Stockpile Required Materials

Materials required (excluding locally derived common fill) to complete the construction of the breach and erosion control elements include:

- Type I riprap: material is required for protection of the edges of the floodplain to limit erosion of the exposed breach side slopes (Drawing 10). This material will also be used to form the riffles (Drawing 10) and dyke erosion protection (Drawing 8). The median size of this material is 400 mm. This material is currently stockpiled at the FWSD (Drawing 2).
- Type II riprap: material is required to construct the inlet structure for the channel (Drawing 9). The median size of this material is 450 mm. This material will be obtained by reprocessing a portion of the Type I riprap stockpile.
- Cement grout (or cement / bentonite grout) will be required to backfill the inlet end of the

LLO (Drawing 11).

- Geotextile: required to act as a separation layer between Type I riprap and the adjacent soil (dam core, dam shell and in situ foundation soil, Drawing 10).

5.3 Construction Activities

Excavation of the breach through the dam will require the disposal of approximately 75,000 m^3 (neat excavation volume) of material. The construction activities will result in the completion of the breach and a rehabilitated section of channel to replace part of the existing fresh water channel (Figure 5.1). Figure 5.2 shows schematically the general arrangement of the FWSD area and creeks following completion of the project.

The construction related activities involved in breaching the dam include the following:

- Manage water;
- Excavate the breach;
- Excavate the channel;
- Place riprap for floodplain erosion protection;
- Construct the riffles;
- Construct rehabilitated channel;
- Abandon the LLO; and,
- Clean up.

5.3.1 Manage Water

Surface water and groundwater will be managed throughout construction. As outlined in Section 4, the water management has two components; diverting winter base flows past the construction area and ensuring water which collects in the construction area meets TSS discharge criteria before it is discharged into the creek. There will, therefore, be two types of water during construction: creek water and construction water.

The proposed water management program for the reservoir lowering was outlined in Section 5.2.1. During the reservoir lowering phase (below elevation 1082 m amsl), pumps will be used. This water will be pumped into the LLO for discharge into the downstream environment (as is done during normal reservoir operation). The pumping will be done using either a fish exclusion screen around the pumping area or properly screened pumps, which will be available for maintenance of the reservoir during this phase of the water management.

In order to capture and pump the winter base flow in the South Fork of Rose Creek, a sump is proposed within the base of the creek channel (Drawing 12). The construction of the sump will temporarily cause high TSS within the disturbed area of the sump construction. Following construction of the sump, the disturbed sediment will be allowed to settle prior to the commencement of pumping activities (Alternatively this water would be treated as construction water). Throughout the construction period, the reservoir will be frozen and snow covered, with little likelihood of generating sediment. The water collecting in the sump may be affected by sediment generated as the creek restores itself within its former channel and potentially by moving sediment collected in the former channel. However, the recent sediment investigation (SRK, 2003b) indicated only minimal amounts of sediment in the reservoir and that the creek location was discernable (Figure 2.7) which indicates that the effects are likely to be minimal.

The volume of creek water that can be expected throughout the construction period is outlined in Table 2.5. Sufficient pumping capacity will be available to handle the expected inflows.

Pumping of the water from the sump to the downstream receiving environment will require pumping around the downstream construction area and discharging the water into the natural downstream channel. The discharge of the water to the downstream environment is envisioned to consist of two phases. The first phase will precede the disturbance of the fresh water channel, during which time it will possible to pump to the LLO inlet and discharge water through the established channel. The second phase will commence with the disturbance of the fresh water channel and continue through the construction of the rehabilitated channel. During this disturbance and reconstruction period, the creek water will be transferred downstream of the construction area by pumping water into an open flume or through a series of pipes.

Water that collects within the disturbed construction area is construction water. This water will be pumped and discharged onto a vegetated area upslope of a temporary holding area (which will be built using a temporary berm on the north side of the existing fresh water channel, Drawing 12). As the construction water runs across the vegetated ground surface, it is anticipated that the sediment content will decrease significantly before it reaches the holding area. Water which collects in the holding area behind the berm will be pumped into the creek (subject to meeting discharge criteria). Alternative methods of clearing the sediment from the construction water will be examined as part of final construction planning.

The water management will vary as the construction proceeds in various stages, likely in accordance with following the sequence outlined below. The final construction sequence will

meet the requirements of the Environmental Monitoring Program, but efficiencies on the construction side will be sought from the contractor.

- Perform bulk excavation of the notch. The excavation will not extend to the position of the inlet structure. Water will be pumped through the LLO and into the existing fresh water channel.
- Perform construction of the rehabilitated channel. Water will be collected at the outlet of the LLO and pumped around the construction area. Following completion of the rehabilitated channel, water will be allowed to flow through this completed section of the construction.
- Perform installation of the channel erosion protection and formation of the stream channel through the breach. Water will be pumped through the LLO and allowed to flow through the rehabilitated channel.
- Abandon the LLO and complete excavation of the upstream portion of channel and install inlet control. Water will be pumped into a flume/pipe which will outlet into the rehabilitated channel (or the channel through the breach, if construction activities have been completed in that section of the channel). The timing of the abandonment of the LLO is uncertain but will likely occur in conjunction with completion of the installation of the erosion protection. Whenever the LLO is abandoned, water will be pumped directly into a flume/pipe system around the active construction area.

5.3.2 Excavation of the Breach

The breach excavation consists of the bulk excavation that will extend the breach section to the floodplain level. The excavation will extend through the dam section, the two downstream berms, the downstream seepage collection trench and the upstream seepage blanket. Drawings 5, 6 and 7 show the location and general arrangement of the breach excavation. Approximately 75,000 m^3 of soil will be excavated and hauled to three main spoil areas (Drawing 13). Due to bulking, the volume of the spoil after disposal will be about 90,000 m^3. A portion of the excavated material will be used to cover both ends of the LLO (Drawing 11).

Drawings 2 and 3 show the soil types used in the construction of the dam and downstream berms. To the maximum practical extent, the different soil types will be separated as they area excavated and deposited in separate spoil areas. The materials to be excavated are expected to include:

- Phyllite riprap from the surface of dam;
- Acid generating material in the stabilizing buttress downstream of the dam;
- Shell material;

- Core material;
- Random material; and,
- In situ foundation soils (original creek alluvium).

The phyllite riprap on the upstream face of the dam was determined to be potentially acid generating (PAG) as part of a preliminary study (BGC, 2002e). The riprap excavated as part of the breach construction and all the riprap located to the south of the breach section will be hauled to a separate part of the spoil areas. The spoil area will be located such that run-off from this material can be tested and the final disposal location for the material determined (potentially the Faro Pit).

The stabilizing berm downstream of the dam, on the north side of the creek, is expected to contain PAG material. This material will be hauled to the spoil areas and dumped in an area separate from other PAG waste. As with the phyllite rip rap described above, the spoil area will be located such that run-off from this material can be tested and the final disposal location for the material determined (potentially the Faro Pit).

Excavation of the breach will extend to the approximate level of the original South Fork of Rose Creek, returning the creek to its original alluvium. The excavation extending to the floodplain level is expected to be above the long term post-construction groundwater table and, given the fast response of the piezometers within the alluvium to changes in the reservoir level, only minor volumes of water are expected to be encountered during the breach excavation.

The possibility of beginning the breach excavation prior to complete reservoir lowering may be evaluated in the event the start of construction is delayed.

5.3.3 Excavation of the Channel

The base of the channel through the breach will link the thalweg of the natural channel upstream of the 1968 cofferdam (Drawing 4) with the thalweg of the fresh water channel (Drawing 7). The channel excavation is expected to encounter mostly alluvial material (assumed to be a random mixture of sand and gravel with some cobbles and silt). The channel location will vary (Drawing 7) throughout the floodplain and will be based 1 m below the top of the floodplain elevation. The channel will be intersected on a regular basis by the riffles (Drawing 7 and 10) which are described in Section 5.3.5.

5.3.4 Place Riprap for Erosion Protection

Type I riprap will be placed at the edges of the floodplain to protect the residual dam structure from erosion (Drawing 10). A geotextile separation layer will be required between the Type I riprap and the foundation (base) soils, given the variation between the grain size of the riprap and base soils. Excavation for installation of the floodplain erosion protection will extend below the expected water table, through the alluvial material at the base of the valley. The drawings indicate that the erosion protection will extend 1 m below the base of the floodplain throughout the majority of the breach and 1.75 m in locations where riffles are to be installed. The minimum thickness of the erosion protection rip rap is 0.8 m and 4.5 m^3 per running metre of length (below the top of floodplain) is required in all locations along the edge of the floodplain.

As shown on Drawing 8, the channel is sinuous, extended completely to the edge of floodplain. When the channel is co-incident with the edge of the floodplain the erosion protection shall be widened (Drawing 10) to ensure that the minimum 4.5 m^3 per running metre of length (below the top of floodplain) is maintained.

5.3.5 Construct Riffles

Riffles, which extend to the floodplain erosion protection, are to be installed on a 40° angle to the centreline of the floodplain (Drawing 7). The riffles are to be spaced at approximately 50 m on center. The riffles are to be constructed from Type I rip rap in accordance with the details shown on Drawing 10.

At the upstream end of the channel, an inlet structure will be installed (Drawing 9). The inlet will be formed to match the angle of the cofferdam, to direct the water from the upstream creek into the channel through the breach and to prevent down-cutting at the point were the channel slope steepens. The inlet structure will be constructed from Type II rip rap. The crest of the inlet is to be 0.5 m above the base of the natural channel.

5.3.6 Channel Rehabilitation

The channel downstream of the FWSD will be rehabilitated to augment the existing straight section of the fresh water channel. This will be performed either by widening the channel or re-aligning the flow to match the location of the creek that existed prior to the construction of the FWSD (Drawing 8).

The channel rehabilitation will conform generally with the locations shown on Drawing 8, although some changes are expected on a field-fit basis. Both of the options include widening

the portion of the channel immediately downstream of the breach to match the channel and floodplain section of the breach portion of the channel.

Riffle-pool (or other habitat) elements may be added to the downstream segment on a field-fit basis.

5.3.7 Abandon the LLO and Valve House

Abandonment of the inlet of the LLO will consist of removal of the existing trash rack and covering (plugging) the inlet with a steel plate. The remaining structure will be buried and the ground surface shaped to match pre-construction slopes (Drawing 11).

Abandonment of the valve house will consist of removal of the structure, removal of a portion of the piping that was previously located within the valve house, plugging the inlet end of the LLO and burial of the exposed footprint. The resulting ground surface will be shaped to ensure drainage towards the creek and will be revegetated in the spring/summer of 2004.

The following details have been developed in relation to the abandonment of the LLO:

1) The inlet section of the LLO will remain in place.
2) The trash rack of the LLO will be removed and a barrier installed at least 10 m downstream from the center line of the vertical inlet.
3) Grout (cement or cement/bentonite) will be pumped into the inlet, completely filling pipe to the inlet of the LLO.
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. The surface will be shaped to match the existing topography and drain towards the center of the valley.
5) The entire concrete valve house will be demolished and removed. Waste generated from the removal will be taken to an appropriate spoil area.
6) A plate shall be bolted or welded to cover the outlet of the LLO. The plate will be slotted to drain.
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 soil greater than 2 m. The surface will be sloped to drain towards the breach and will be revegetated during the Phase 2 revegetation program.

5.3.8 Clean up

At the end of the construction activities, the construction site will be cleared of any construction-related debris, the sump will be backfilled and water will be allowed to pass through the breach. If practical (dependent on the weather conditions at the end of construction), the construction area will be revegetated as part of the site clean-up.

5.4 Post-Construction Activities

5.4.1 Complete Channel Upgrades

The completed breach section of the channel will be evaluated following the spring 2004 freshet and through the summer to ensure that the elements are performing as expected. Due to the winter construction period, some frozen material may be incorporated in the construction zone. The effects of any settlement due to the winter construction, build up of sediment in the channel and the performance of the riffle elements in the spring flood will be evaluated and necessary repairs made during fall 2004. The habitat elements included in the rehabilitated channel section will be evaluated and repaired, if necessary.

5.4.2 Follow-up (Phase 2) Revegetation

In the spring/summer of 2004, the revegetation program will be continued in both the general reservoir and the riparian zones (Section 5.1.4). The area of the reservoir to be revegetated is shown as Phase 2 re-vegetation (Drawing 13). The revegetation will also extend to the construction zone and the spoil areas.

The seed mixture used for the revegetation is likely to consist of a mix of native grasses and contain a large grass seed variety (i.e. some form of rye) that will germinate rapidly and provide immediate erosion control. This planting will also provide root structure to reduce erosion during spring snowmelt and rains. It is expected that the seed mixture will be manually broadcast. If the soil is dry enough, the use of a four-wheel all terrain vehicle, or "quad," may be considered.

The riparian zone will include revegetation with grass, willow and spruce (or white fir) plantings. The willow and spruce will be planted in a 10 m wide zone (extending 10 m from the edge of the bank) adjacent to the South Fork of Rose Creek and a 5 m wide zone adjacent to the smaller tributaries, as shown in Drawing 13.

Planting of white spruce or alpine fir as part of the Phase 2 revegetation will be performed within the riparian zones of the stream channels within the reservoir. The actual areas to be planted will be determined throughout the summer of 2004, after snow melt. The areas selected will be those that have stumps indicating the presence of these trees prior to reservoir formation. Preliminary plans for planting trees include the use of larger planting stock to ensure the trees a good chance of survival amongst the grass and sedge that will be established through seeding. Planted trees will be fertilized with an appropriate starter mix to accelerate root establishment as the nutrient condition of the soils within the reservoir are likely depleted through years of saturation. The anticipated planting density will be equivalent to 800 stems per hectare.

Using the estimated alignment of the original channel, this will involve an area approximately 2,400 m long and 20 m wide, for a total area of 48,000 m^2. Willow stakes should be placed on 1 m centres; therefore, 48,000 stakes will be required. Stakes should be collected while the plants are still dormant (i.e. late winter or early spring before leaves start to form).

5.5 Construction Quality Assurance and Quality Control

5.5.1 General

It is assumed that the field team responsible for the execution of the construction quality assurance (QA) and Quality Control (QC) will comprise a Resident Engineer and Site Supervisor (Contractor). The Resident Engineer (or a designated representative) will be on-site daily throughout the construction. The QA/QC program will be the responsibility of the Resident Engineer. The Resident Engineer will ensure that the constructed works conform to contract documents (construction drawings) and the design intent of the proposed breach described in this document. The Resident Engineer will have the authority to reject any substandard work and order the contractor to redo the work such that it meets the requirements of the contract and drawings.

A preliminary set of construction QA/QC procedures is outlined in Appendix E. The procedures outlined below do not address the environmental monitoring, as this is covered in Section 7.5. Refinement of the QA/QC procedures will be undertaken in conjunction with the development of technical specifications, environmental monitoring plans and construction drawings.

5.5.2 Construction Monitoring and Responsibilities

- Prior to initiation of construction, an evaluation of the piezometeric levels and probable stability of the sides of the dam breach will be completed. This will facilitate a decision as to whether or not it is appropriate to steepen the breach side slopes (Drawing 5).

- Monitor the set up of construction area including laydown areas, spoil areas, fueling site, establishment of drainage and sediment control measures for construction
- Monitor the pumping operations: for the construction water and the creek water.
- Establish protocols (in conjunction with the environmental monitor) for monitoring and verifying construction water quality prior to the discharge of construction water to the environment.
- Ensure that the constructed works meet the requirements described in the contract documents and the design intent described in this design report.
- Decide on the appropriate channel rehabilitation to be constructed (Drawing 8), based on the conditions of the site.
- Advise on the amount of spoil material to be placed in a separate PAG spoil area.
- Provide on going advice to the owner and contractor on technical elements of the works undertaken.

5.5.3 Post-Construction Monitoring

- Evaluate the conditions of the constructed works after the 2004 freshet (Fall 2004). Prepare a report on the performance as compared to the expected performance and recommend any necessary repairs.
- Evaluated the riprap (and any other PAG spoil) spoil area, checking the condition of the material with respect to potential acid generation. Make recommendations for ongoing monitoring of the area and if necessary recommendations for removal of the spoil to an appropriate disposal area.

5.5.4 Reporting

- Resident Engineer will maintain suitable records and photographs throughout the construction phase. Weekly reports that summarize work activities (and incidents or issues) will be submitted to the Interim Receiver.
- Any significant changes in construction methods or to habitat rehabilitation, stream channel design, monitoring procedures, etc. will be presented to the Interim Receiver, DFO, DIAND and the Yukon Department of Environment along with justification for the changes.
- A report on the construction phase is required within 6 months of the completion of the construction work and should include photo documentation of the construction activities, summary of significant incidents (as-built report).
- A report on the assessment of the performance of the channel, flood plain and rehabilitated channel after the first freshet along with recommendations for additional work or any remedial action taken will be submitted by December 2004.

5.6 Construction Schedule

The preliminary schedule for the project is presented in Figure 5.3. This schedule includes the main tasks required to complete the construction portion of the project. The schedule indicates that the main construction elements will occur between 24 November 2003 and 31 March 2004. However, the dates included on this schedule should be considered as relative rather than absolute, since the actual dates will depend on when the necessary permits are in place, weather and logistical factors such as contractor mobilization. The dates presented in Figure 5.3 assume the necessary permits are received in accordance with normal permitting timelines. A revised construction schedule will be developed if delays occur at the front-end of the project.

5.7 Construction Quantities

The estimated construction quantities required to complete this breach project are outlined in Table 5.1.

Table 5.1
Estimated Construction Quantities

Material	Units	Quantity	Comments
Excavation	m^3	75,000	To neat lines
Geotextile	m^2	1,700	To neat lines
Type I riprap	m^3	5,000	To neat lines
Type II riprap	m^3	650	To neat lines
Grout	m^3	13	

6 ENVIRONMENTAL ASSESSMENT

6.1 Introduction

This section provides the assessment of the environmental effects associated with breaching the FWSD and returning the reservoir area to pre-dam conditions. DFO has indicated (letter dated November 15, 2002) that "through a full breach DFO would consider reduction in downstream risks by return to a stable system as sufficient offsetting justification for loss of the reservoir". Therefore, for the purposes of this report, the baseline conditions used to assess the effects of the project will be the pre-dam conditions of the South Fork of Rose Creek and downstream in Rose Creek. This project will be reviewed under the CEAA and the Yukon Environmental Assessment Act and will have to meet the standards for a screening level study. Despite the overall reduction of risk, the project has the potential to result in the harmful alteration, disruption or destruction of fish habitat (HADD), and an authorization under the *Fisheries Act* is therefore required for the project to proceed.

6.2 Project Components and Environmental Effects

This section will review the effects of each major component of the project relative to the pre-dam conditions including stream habitat, riparian areas and vegetation. This environmental assessment will focus primarily on fish and fish habitat as these are the environmental components that will experience the greatest effect through the construction activities and removal of the reservoir. Also, in addressing erosion and riparian habitat requirements through mitigation activities, vegetation and wildlife components within the project area will be rehabilitated. A summary description of the project components are provided here with a more detailed description provided earlier in this report.

6.2.1 Low-level Outlet (LLO)

Modifications to the LLO have been made that should allow it to pass up to 2.65 m^3/s, subject to testing. The LLO will be used drain the reservoir down to 1082 m. Flows through the low-level pipe decrease as the water elevation (head) decreases and should pass approximately 1.1 m^3/s as it approaches the 1082 m elevation. The inlet consists of a 42 in diameter pipe with four vertical trashrack panels forming a square and covered by a steel plate. The openings on the trashrack are wide enough to allow fish to pass into the pipe. Historically there have been no reports of fish passing through the LLO into the valve house. However, with the significant increase in flows through the low level outlet fish may be drawn into the pipe.

An adaptive approach will be taken to minimize the impact to fish passing through the LLO. Initially, monitoring for fish passing through the pipe will be conducted. If injured or dead fish are found in the channel below the valve house a fish exclusion net will be installed to keep fish out of the region of the low-level pipe inlet. It is unlikely that a small mesh screen could be placed over the trashrack as the water velocities across the screen would likely be high enough to impinge smaller fish unable to escape the velocity of the water being drawn into the pipe.

6.2.2 Reservoir Dewatering

The rate of reservoir dewatering is provided in Appendix D1 and is contingent on the LLO's ability to pass water at the predicted flow rates, the weather conditions throughout the dewatering process and the issuance of the *Fisheries Act* Authorization allowing the capture and transplant of arctic grayling out of the reservoir. There are three issues associated with reservoir dewatering:

- stability of the sediments within the reservoir and the potential for erosion during the spring freshet in 2004;
- the fish currently in the reservoir; and
- fish habitat restoration.

6.2.2.1 Erosion Control

The soil conditions within the drawdown area could be susceptible to erosion, due to lack of vege ive cover. Overland flow from rain or snow melt on newly exposed reservoir areas could mobilize sediments and transport them into the stream channel and downstream. The proposed mitigation to minimize the erosion potential is to implement a proactive re-seeding plan. The proposed operation of the reservoir includes holding reservoir levels close to 1090 m through the 2003 freshet. Holding the water level around at 1090 m will expose approximately 36% of the reservoir area during most of the 2003 growing season allowing for a preliminary assessment of the erosion potential of exposed, unvegetated areas of the reservoir. After freshet and the return of water levels to 1090 m, the seeding program will begin. Initial seeding will include the entire exposed base of the reservoir (Phase 1 revegetation on Drawing 13), including the noted riparian strip along either side of the stream channels. An underwater camera survey of the reservoir substrate in 2002 indicated that the base of the reservoir contains a thin layer of fine sediment that could erode, but should also be able to support seed germination. Additional seeding in the spring of 2004 will be done in the Phase 1 revegetation area, as required, to and in the Phase 2 revegetation area addresses potential or active areas of erosion and minimize the transport of fine sediments into the south fork of Rose Creek.

6.2.2.2 Fish Population

The potential effects on fish due to dewatering are related to process of removing the water and the loss of lake habitat. Effects on fish during dewatering include:

- possible injury or mortality from passing through the LLO or pumps,
- stranding of fish as the reservoir dewaters and
- reduction in number of fish that can be supported by the stream habitat.

Plans to mitigate these effects are described below.

Dewatering of the reservoir will be accomplished primarily through the LLO, as indicated above. However, it may be necessary to use siphons or pumps to augment the flow through the LLO. The pumps will be properly fitted with screens that comply with DFO intake screen guidelines to eliminate fish from being drawn into the pumps. The siphons will also be fit with screens if the water from the siphons is discharged to an area where fish will not survive.

The reservoir habitat has become home to a viable population of arctic grayling, burbot and sculpins. The dewatering of the reservoir will eliminate a significant area of fish habitat. In order to minimize overcrowding in the resulting stream habitat, a fish salvage program will be carried out. A detailed salvage program will be developed for inclusion in the *Fisheries Act* Authorization. The general approach of the salvage will be to remove the fish from the reservoir and out plant them to suitable habitat downstream of the reservoir. Out-planting will only move fish to an area that the fish in the reservoir currently have access to in order to eliminate the possibility of transferring disease. Therefore, the optimal area for relocating fish is the lower sections of Rose Creek, however much of this area has no road access and out-planting would have to be done by helicopter. If possible, the preference for out-planting sites will be those areas that are road accessible. A salvage program will be developed that includes:

- Rationale for selecting out-planting sites including the method for determining pre and post out planting densities,
- A process for quantifying the number of fish that need to be transferred and the number that should be left to seed the stream habitat within the reservoir
- Live capture methods for removing fish from the reservoir (this needs to address the potential problems associated with the live capture at different reservoir levels and the need to capture a range of size classes)
- Biological data to be collected during the program
- A follow-up monitoring program to assess fish densities in the out-plant areas and the stream habitat in the reservoir area

The other aspect of fish salvage is protecting fish from entering the construction area or from stranding in pools that become cut off from the main body of water as the reservoir level drops. To avoid mortality of fish in the construction area, fish will be removed from the area around the dam and cofferdam, alternatively barriers would be installed to keep fish out of these areas so that fish are not trapped or stranded in the construction area and areas that will be totally dewatered during construction. The use of fish exclusion nets prior to freeze up will depend on the final plan for dewatering, the construction area and the extent of work on the channel downstream of the dam. Other aspects to consider include the length of time fish must be kept out and if the area can be effectively kept fish free during that period, given expected flows.

During the drawdown process potential stranding sites within the reservoir will be identified. If fish become isolated from the main body of water, the fish will be salvaged and either out-planted with the other fish collected during the fish salvage or they will be placed into the south fork of Rose Creek above the dam.

6.2.2.3 Fish Habitat

The construction of the FWSD inundated 2530 m of stream habitat and temporarily created lake-like habitat that has provided over-wintering and rearing habitat for arctic grayling and likely provides habitat for all phases of the life history needs for the burbot and sculpins that reside in the reservoir. As presented earlier, DFO has determined that the reduced risk to downstream facilities provided by removing the dam is considered sufficient mitigation for the loss of the reservoir. Therefore, the basis for assessing the impacts of this project will be the pre-dam condition of Rose Creek. Section 6.2.2.1 described the approach to minimizing erosion on newly exposed soils within the reservoir. This seeding will also help re-establish the functionality of the stream habitat within the reservoir. In addition to grass seed, a 10 m wide strip on either side of the South Fork of Rose Creek and a 5 m wide strip along the two main tributaries will also be re-planted with willow stakes interspersed with spruce. Proactively planting these riparian areas will enhance the recovery of the fish habitat. Re-establishment of other components of fish habitat will be addressed through an adaptive management program. At this time, these other components are considered to be access and instream habitat. The adaptive management program will include monitoring of these aspects of habitat and, if necessary, plans developed to assist in rehabilitation or to remove artificially created barriers. The proposed mitigation measures will minimize erosion and ensure that the re-established creek habitat is brought back to pre-dam productive capacity as quickly as possible.

6.2.2.4 Recreational Effects

The loss of the reservoir will impact the opportunity to use the reservoir as a navigable water and therefore effect the limited recreational boating activity on the reservoir. This effect is expected to confined to the local community in that the population of recreationists most likely impacted are the residents of Faro. In order to offset this impact to recreation, the proponent will identify opportunities to enhance recreational boating use on a nearby lake that is accessible to the residents of Faro. Potential compensation would include improved boat launching facilities or dock facilities on a lake.

6.2.3 Site Preparation

The areas to be used for the contractor's work area and spoil disposal are shown on Drawing 13. The area downstream of the FWSD has been used in the past for construction activities and was previously cleared. The spoil site upstream of the dam is within the footprint of the reservoir. The construction plans call for the construction of perimeter containment dykes as part of the placement of spoil. The three sites have been previously disturbed and the use of these areas during this project will not result in the incremental loss of terrestrial habitat and measures for controlling run off and sedimentation from the spoil areas are part of the construction plan. A re-fueling site will be established at the contractor's work area adjacent to the spoil area downstream of the FWSD. During the project, fuel will be stored at the existing tanks on the mine site and trucked to the re-fueling area. The re-fueling area will be appropriately set up to contain any spill and appropriate spill kits will also be on site.

6.2.4 Dam Breach

The primary purpose of breaching the FWSD is to eliminate the risk to downstream mine structures associated with the failure of the FWSD and to return Rose Creek to pre-mine conditions. Breaching the dam will remove barriers to fish movement, re-establish natural flow patterns in Rose Creek and re-establish 2,530 m of stream habitat in the South Fork of Rose Creek. There are two aspects of the project addressed in this assessment, the effects of constructing the breach and the longer term effect on fish and fish habitat. Mitigating the effect on fish populations has been addressed in the previous section on dewatering the reservoir.

Re-establishing the natural flow regime in Rose Creek will result in a change from the current operation of the reservoir which has typically released between 0.2 and 0.5 m^3/s through the LLO for the last five years. The ongoing release from the LLO has been maintained, in part, to ensure that the mine meets the requirement of the current water licence to have a minimum flow of 0.075 m^3/s in the Rose Creek Diversion Canal. This flow release probably provided a benefit

to fish over-wintering in the south fork of Rose Creek below the dam as the flows would be higher than natural winter flows. Data from R7 on the north fork of Rose Creek, prorated to the watershed area of the south fork upstream of the reservoir estimates a mean flow between December 1 and March 31 at 0.11 m^3/s (Appendix C2). Once the flows combine with the north fork, the estimated winter flow in the Rose Creek Diversion Canal is estimated at 0.31 m^3/s. As expected, further downstream the less the reduction in over winter flows as a result of removing the water release from the LLO. A preliminary review of the regional flow analysis presented in Section 2.4 indicates that with a natural flow regime from the south fork of Rose Creek, predicts that the 10 year, 7 day low flow event at the inlet to the Rose Creek Diversion Canal would be 0.075 m^3/s. The removal of the FWS Dam should have little impact on the mainstem of Rose Creek. However, it will result in lower over winter flows in the south fork of Rose Creek, but this would be offset by the natural hydrograph which would result in earlier onset of freshet in the creek which may improve conditions for arctic grayling spawning and the flows in the fall would be prolonged which may improve rearing conditions for young of the year grayling. Construction of the breach has been described in section 5.2.2. Breaching the dam will involve the removal of an estimated 75,000 m^2 of material from the dam and will take place in winter months when water flows are at a minimum and the risk of erosion and sedimentation are minimized. The parameters used to design the breach, as presented in Section 4, were selected to provide for long-term stability and to minimize the potential for erosion along the face of the breach and at the base. The features of the breach design include a 20 m wide flood plain at the bottom of breach. This breach width provides limited attenuation of very large floods, resulting in returning the creek to its natural hydrograph.

The work will be carried out in the dry and the plan for accomplishing this includes the dewatering plan in Section 5.1.2 and the water management plan presented in Section 5.2.1. The volumes of water anticipated in the South Fork of Rose Creek upstream of the project site, during the construction period, is in the order of 0.11 to 0.20 m^3/s and easily managed with pumps. The objective of the water management plan is to ensure that clean water flowing down the South Fork is intercepted before it reaches the work area and is diverted around the work site. The final stages of reservoir draw down (1082 to 1080 m) will be done using pumps and drawing water from the residual reservoir. Eventually sumps will be dug immediately upstream of the old cofferdam and the inflow directed into the sump before being pumped into the LLO (Drawing 12). All pumps will be equipped with the appropriate fish screens, or fish exclusion nets will be in place. Appropriate care will be taken to minimize sedimentation during the transition from pumping from the reservoir to drawing water from the sumps. The sumps will be constructed within the main channel and any sediment generated during construction will be allowed to settle

prior to resumption of pumping operations. The water will be pumped around the construction area, either by pumping into the LLO or through the use of a pipe/flume system.

Within the construction area, any seepage is assumed to contain sediment and will be collected and pumped to an appropriate discharge location so that there is no risk of the sediment-laden water reaching the creek. The volumes of water seeping into the construction area are expected to be easily handled by pumping and disposal to upland areas and allowed to seep into the snow or vegetation. Also, standard mitigation practices for work in and around water courses will be followed to minimize the potential for impacts associated with fuel spills and sedimentation, as outlined in Section 7.

The original stream habitat that was lost under the footprint of the dam will be re-established by constructing approximately 290 m of stream channel through the breach with an average width of approximately 8 m (estimated from pre-dam mapping as no pre-dam fish habitat information is available). The channel details have been described in Section 5.2.3 and are designed to provide a sequence of riffles and pools through the dam breach. The channel is designed to be stable under normal bank full flows but will be able to migrate naturally within the breach at higher flows. A residual pool depth of 0.7 to 1.0 m is expected to be adequate to provide over-winter habitat as long as there is some flow in the channel under the ice. The total area of stream habitat created will be approximately 2,320 m^2. It is anticipated that it will take a period of several years for this channel to regain the productive capacity available in this section of Rose Creek before the dam was built.

The removal of the dam will allow the resumption of bedload movement through the South Fork of Rose Creek. Depending on freshet and rain conditions in 2004 and subsequent years, increased bedload movement could affect the habitat in Reach 2 of the South Fork, the low gradient section. Depending on the size of the substrates that move downstream after the breach, fish habitat conditions could be impacted positively, through increased gravel deposition, or negatively through increased deposition of fine materials. The consequence of the initial resumption of bedload movement downstream of the FWSD is unknown and will be addressed through the adaptive management plan to ensure no long-term negative effects on fish habitat.

6.2.5 Stream Channel Rehabilitation

This section addresses the stream channel below the dam, extending down to the confluence with the spillway channel. Below the dam the freshwater channel has only handled the release of water from the low-level pipe, about 0.2 to 0.5 m^3/s, for the last 34 years, far less than the flows anticipated during a normal freshet of up to 5.6 m^3/s. To leave the channel as is would likely

result in considerable erosion over a period of years as the channel adjusts to the re-established, natural flow regime. The preferred approach for this section of channel is to take some steps to minimize excessive erosion but also minimize impact on the existing stream channel and riparian habitat. To achieve this, some of the fill material that was placed on the right bank of the freshwater channel immediately below the dam will be removed. The lower half of the freshwater channel (down to the 90° bend) will be diverted into a remnant of the original stream channel (Drawing 8). However, there are only preliminary indications that suggest the channel exists and some minor brush clearing may be necessary. After snow-melt, a survey of this area will be made to confirm the presence of the channel. If diverting the channel is viable, this may provide the opportunity to turn the remaining length of the freshwater channel into side-channel fish habitat. This would be an ideal opportunity to provide approximately 75 m of additional fish habitat from an existing, seasoned channel with established riparian vegetation.

As outlined in Section 5.2.1, during this phase of the construction the water collected in the sump will be transferred around the construction area. This may be achieved by pumping into a flume located near the south abutment of the dam, which then discharges to the undisturbed section of the creek.

6.2.6 Accidents and Malfunctions

Risks associated with the use of the low-level pipe are, for the most part, linked to its operation during the freshet and during the lowering of the reservoir. Recent studies of the LLO indicate that the main risk is that the allowable discharge rate constrains the ability to keep water levels at the target level (1090 m) during the freshet. Post-freshet, the risks associated with the LLO are minimal. During and post-construction, there are no risks associated with the LLO and the closure plan for the LLO as described in Section 5.2.8, is designed to ensure that the pipe and valve house do not provide any risk to the environment or human safety.

Spills of fuel and other deleterious substances will be minimized and managed through the implementation of a spill contingency plan. Where practicable, equipment working within the normally wetted channel of Rose Creek will use vegetable-based hydraulic fluids and lubricants. Fuel storage will be offsite and fuel transfer will take place 100 m away from water courses.

Any failure of the water management system could result in erosion and sedimentation and the transport of turbid water into watercourses outside the work area. Carrying out the construction during the low flow winter months means that there will be minimal flows to manage. Water within the construction zone will be directed to sump areas and pumped to an appropriate upland location to allow the water to filter into the snow or vegetation before the water reaches the creek

(Drawing 12). Back-up pump(s) will be available to ensure flow of Rose Creek water around the construction site is maintained at all times.

A downside of winter construction is the potential for snow and ice to become mixed with the substrate of the rebuilt stream sections. Appropriate measures will be taken to ensure that this is minimized and new stream channels are not compromised by the melting of layers of snow or ice trapped below the surface substrates. Since it is not likely possible to completely remove these effects, evaluation of the stream channel construction will take place during the fall of 2004 (allowing time for melting of any ice) and appropriate repairs made as needed.

Equipment failure and other delays could result in the instream work not being completed prior to the onset of freshet in the South Fork of Rose Creek. While there is no specific contingency plan to deal with this possibility, initial planning indicates that there will be at least 102 days available to complete the work (assuming a January 2, 2004 start, although work could commence as early as November 15, 2003), which should be adequate time to complete the breach and instream works with room to accommodate delays through equipment failure. Once the project begins, it will be imperative to complete the breach before freshet to eliminate the risk of overtopping the dam and the associated threat to the downstream tailings facilities. Scenarios of an early freshet are provided in Section 6.2.7.

6.2.7 Effect of the Environment on the Project

The design parameters for the breach have been the 1:500 year flood event and the channels have been designed to the 1:10 year flood event. The final report will include an evaluation of risks to the residual dam structure that might result during an event in excess of the 1:500 year flood.

Early snowmelt and freshet produces the same problems as construction delay described above and could have significant environmental effects. Table 6.2 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 (Table 4.1). This date has been used as the final date for completion of construction activities.

Table 6.2
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 overtopping of the FWSD will likely 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.

The mitigation measure is that if the construction schedule were to be so severely delayed that only the upper 1.5 m of the dam would be excavated prior to spring freshet, the construction would not be started.

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. Such events would also result in significant volumes of sediment being flushed downstream into Rose Creek with the total volume of sediments directly related to the total volume of water. 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 current information of previous freshet 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.
- During an uncontrolled breach there would be no opportunity to control sediment and a post event evaluation of the downstream fish habitat would be required and a habitat rehabilitation plan developed appropriate to the level of impact.

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. Depending on the stage the work is at sediment releases downstream could range from minor to significant. No other significant downstream impacts are expected but there will be additional 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 primary 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 current information of previous freshet records. The same approach to addressing impacts of sediment releases for Case 2 would apply here.

As discussed in Section 3.8, the maximum design earthquake (MDE) selected for the stability of the FWSD has a return period of 475 years, which corresponds to a peak ground acceleration of 0.06g. Table 4.2 indicates that, in the long term, the factor of safety associated with both the 2.5H:1V and 3H:1V breach slopes meet the design criterion of a factor of safety of 1.0.

6.3 Project Effects Summary

The environmental effects associated with the construction of this project are primarily related to erosion and sediment control and returning stream habitat to levels of productivity similar to the pre-dam conditions. There is no information on the productivity of this habitat prior to dam construction so this assessment assumes that if the habitat features similar to those found upstream and downstream of the reservoir are re-established (i.e. in the stream segments currently with the reservoir, under the footprint of the dam and immediately downstream of the dam), then the project should be judged to have no significant impact on fish or fish habitat.

Construction activities such as clearing of vegetation will be kept to a minimum and disturbed and dewatered areas will be re-seeded as soon as practical. Appropriate best management construction practices around water courses will eliminate or minimize these effects.

The re-establishment of the stream habitat in the South Fork of Rose Creek is designed to return the creek to its original, pre-dam condition. Planting of grasses, willows and spruce trees along the riparian corridors of the mainstem and tributaries will result in the re-establishment of the riparian habitat within a few years of project completion. The removal of barriers in this section of Rose Creek will allow fish species to access the re-established stream sections and re-colonization to densities consistent with the carrying capacity of the stream habitat. Other benefits of dam removal include the re-establishment of close to 49 ha of terrestrial habitat. Proactive planting of willow stakes and spruce along the riparian corridors will provide initial habitat for birds and wildlife.

Also, the removal of the dam will re-establish the natural flow regime within the lower sections of the South Fork of Rose Creek and downstream. Currently the LLO is used to discharge between 0.2 and 0.5 m^3/s year round. One effect of this flow release is that it augments the over-winter flows in Rose Creek but prematurely cuts off spring and fall flows when water levels are below the spillway elevation. The natural flows into the freshwater supply reservoir are estimated to average 0.11 m^3/s from December through March. This reduction in over-winter flows in the South Fork of Rose Creek may reduce the creek's capacity to support fish through the winter months. However, re-establishing natural flows and connectivity through the watershed will result in more prolonged flows in spring months when arctic grayling are spawning and in the fall months when young of the year require flows for effective pre-winter growth. Removal of the dam will also re-establish the natural gravel recruitment downstream of the reservoir.

The potential residual impacts include:

- the stability of the re-established stream habitat, particularly in the stream section above the cofferdam and of the tributaries flowing to South Fork of Rose Creek.
- downstream accumulation of bedload material that has accumulated within the reservoir over the past 34 years. Based on sediment testing (Figure 2.13) this volume is expected to be small, and therefore these effects are minor.
- mortality of fish left in the reservoir after the surface freezes. There is the potential for these fish to become stranded in pools and/or become caught in areas that freeze to the bottom.

The extent of these impacts is unknown at this time and an adaptive management approach will be taken to ensure they do not cause ongoing impacts. Such an approach would involve surveys of stream habitat conditions, barriers, soil stability and bedload movement in the summer of 2004. The associated report would make comparisons to like stream conditions in other parts of the South Fork of Rose Creek and propose restoration plans, if necessary. The stability and fish passage conditions of these channels may not be known until the snow is off the reservoir in the spring of 2004; therefore, contingencies may have to be developed to provide the necessary compensation to offset these potential impacts. Based on the examination of the inlets of the reservoir in February 2003 (SRK, 2003b) and the thickness of sediment observed, sediment barriers in the creeks are not expected. However, a review of these potential barriers to fish migration would be assessed to determine if they existed prior to the formation of the reservoir or were a result of the reservoir. Barriers created because of the reservoir would be assessed and a plan to remove them would be developed. The plan would likely involve some form of regrading areas of sediment accumulation to allow fish to pass. The stream channel stability issue will depend on the extent to which the water finds the original stream channel as the reservoir is lowered, based on the limited sedimentation of the reservoir this is expected. It is possible that rip rap and other materials from the dam breach work could be used to stabilize sections of channel that might be identified as problematic during the post-construction monitoring phase. However, issues of access and consequence of hardening sections of stream channel will have to be evaluated prior to any channel stabilization works are undertaken.

The main effects of removing the dam will be a loss of reservoir habitat and the loss of the ability to augment flows in the South Fork of Rose Creek through water release from LLO. Both of these impacts have been determined to be adequately offset by the elimination of the risk of dam failure and subsequent impact of washing out the downstream tailing facilities and flushing tailings downstream into Anvil Creek and the Pelly River. The remaining residual impacts are associated with the re-establishment of the pre-dam habitat in and around the South Fork of Rose

Creek. While no detailed habitat survey was done prior to 1968, the existing pre-dam mapping indicates that the proposed channel re-habilitation and re-construction will approximately equal the area/length of stream channel impacted by dam construction and reservoir formation. Therefore, the residual impact is primarily one of a temporal nature. It will take a number of seasons for the in-channel and stream-side habitats to regain the level of productivity that existed prior to 1968.

6.4 Cumulative Effects Assessment

6.4.1 Introduction

A Cumulative Effects Assessment (CEA) is required to evaluate 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 *Canadian Environmental Assessment 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.

This CEA will focus 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. Over the long term the effects will be neutral 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 pumphouse 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. The care and maintenance program and the breach of the freshwater supply dam are linked and any effect that restoring a natural flow regime in the south fork of Rose Creek may have on the care and maintenance program for the mine site over the next five years is provided in the water licence EAR.

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.

6.4.2 Potential Cumulative Effects

Rose Creek Diversion: This project altered approximately 6 km of Rose Creek when it was diverted 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 at least 0.4 m^3/s. During operation of the mill the reservoir would have fluctuated 6 m per year but was as much as 10 m on some occasions, which likely limits the productive capacity of the reservoir. Following the installation of the reclaim system the reservoir was maintained near full supply level, and the discharge was about 0.1 m^3/s. 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 1,425 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). 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:
    - 1900 m of the South Fork of Rose Creek within the reservoir,
    - 630 m of the tributaries to the South Fork that now flow into the reservoir
    - 100 m under the foot print of the FWSD
    - approximately 140 m under the haul road rock drain and culvert
    - 1200 m due to diverting Rose Creek around the tailings
    - Total loss = 3,970 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.

6.4.3 Cumulative Effects Assessment

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 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 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 (nhc, 2001b).

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

6.5 Conclusions

Breaching the dam, removing the reservoir and restoring the stream habitat to pre-dam conditions are judged to have no long-term negative effects on the environment. This conclusion is based on comparing this project activities and results to the pre-dam conditions in the Rose Creek watershed. The loss of reservoir habitat and the ability to augment flow into the South Fork of Rose Creek have been judged to be acceptable losses that are offset by removing the risk of failure of the FWSD and the impacts that would cause to downstream tailings facilities and the significant impact to fish and fish habitat in lower Rose Creek, Anvil Creek and the Pelly River as a result of tailings contamination. Re-establishing the natural flow regime in the South Fork of Rose Creek may be beneficial to stream resident fish as it will likely result in increases in flow earlier in the spring and higher flows through late summer and fall months when the only flow downstream of the dam has been through the LLO. However, releases from the LLO likely had a beneficial effect on fish habitat through the release of higher flows into the South Fork during the winter low-flow periods. There is no fisheries information available to assess the trade-offs between increased over-winter flows and a natural hydrograph in spring and fall. However, arctic grayling are spring spawning fish and would likely benefit from a return to the natural spring flow conditions they have evolved in and respond to, for spawning.

The assessment of the newly re-established fish habitat against the pre-dam habitat indicates that the mitigation measures will re-establish habitat that is approximately equal to pre-dam in terms of area and length. The new habitat will take some time to achieve full productivity. An adaptive management program of monitoring and corrective action is proposed to ensure that the re-established habitat does return to pre-dam levels of productivity. The current plan also includes the opportunity to provide additional habitat in the section below the dam through maintaining a section of the freshwater channel as a back channel to the main flow of the South Fork of Rose Creek. These steps should ensure that there is no-net-loss of productive capacity over the long term.

7 ENVIRONMENTAL MANAGEMENT PLAN

This section will form the basis for a stand-alone Environmental Management Plan (EMP) that will likely become an appendix to the *Fisheries Act* Authorization for the dam breach project. To that end, this section in its current form is not complete. Additional work is required to further develop an adaptive management plan that will be used to ensure that any unexpected impacts to fish or fish habitat are addressed and mitigation of compensation measures are developed to offset them. The adaptive management approach is required as it will not be able to fully assess the impact of restoring the stream channel within the reservoir until the reservoir is removed.

7.1 Construction Methods and Sequencing

The details of preparing the area for construction and the actual construction works are presented in Section 5. These activities include:

- Drawing the reservoir to 1082 m elevation using the LLO
- Removing excess fish from the reservoir
- Site preparation – contractor work area and spoil disposal sites
- Management of flows in the South Fork of Rose Creek when water levels drop below 1082
- Excavation of the breach
- Construction of stream channel through the breach
- Modification of the stream channel below the breach

7.2 Environmental Issues and Mitigation

The direct effect of the project on the environment is associated with the drawdown and exposure of unvegetated areas within the reservoir and the potential alteration of fish habitat because of the work within the footprint of the dam and immediately downstream of the dam. We have assumed that the section of the South Fork of Rose Creek above the dam will naturally find the original channel as the water levels drop. During the bathymetric survey conducted in August 2002 and additional sampling in February 2003, the original creek channel is still evident and it shows up on the hydroacoustic tracings of the reservoir bottom. Indications are that sediment accumulations have been minimal and there is a high likelihood that re-establishment of the old creeks will occur.

7.2.1 Reservoir Dewatering and Erosion Control

The reservoir water level will be kept as close to 1090 as possible through freshet, however, it will likely temporarily rise above this level and may not return to 1090 until freshet is passed, despite efforts by site staff. Exposure of unvegetated slopes because of the drawdown has the potential for erosion and sedimentation. A proactive approach to stabilizing the bare soils will be implemented to minimize erosion and potential sedimentation into the South Fork of Rose Creek. A two-phased re-vegetation program of the reservoir is proposed:

Phase 1. Broadcast seeding of the exposed soils between 1096 and 1090 m amsl. This will take place during the 2003 growing season, after the reservoir has returned to the 1090 m elevation after freshet. A seed mixture consisting primarily of a variety of native seeds will be used but this should also include a large grass seed variety (i.e. some form of rye) that will germinate rapidly and provide immediate erosion control. Even though the grasses die off over winter, this planting will provide root structure to reduce erosion during spring snowmelt and rains in the spring of 2004. Seed mixture will likely be spread by hand seeding, however if access conditions allow seeds may be spread using a quad. Dependant on conditions, this phase of revegetation may also include willow staking and tree planting in the riparian zone exposed during the 2003 growing season. Over the summer, the erosion potential for areas between 1090 and the water level just prior to permanent snow cover will be assessed and seed applied where necessary. This seed would then be in place under the snow and can germinate early in the spring right after snow melt.

Phase 2. Spring 2004 seeding after snow melts. This seeding will focus the areas of the reservoir base that were not seeded during the first two phases of revegetation. Also, this may include the reapplication of seeds in areas seeded in Phases 1 and 2 where there is low germination or seed has been washed away be rain or snow melt or eaten by wildlife. The willow staking and tree planting program, described in Sections 5.1.4 and 7.3, will also take place in the spring of 2004.

The specific timing of these phases will be contingent on the final program for dewatering the reservoir and weather conditions during the summer and fall of 2003 and spring of 2004.

7.2.2 Fish Salvage

There are three components to fish salvage for this project:

- The salvage of excess from the reservoir as it de-waters

- Salvage of fish stranded in pools that become cutoff from the main body of water as the reservoir level drops, and
- Salvage of fish from the construction area.

A fish salvage program will be developed to remove excess from the reservoir as described in Section 6.2.2.2. This program will be developed for inclusion in the EMP as part of the *Fisheries Act* Authorization. Details of the program are currently under development and review by DFO and Yukon Department of Environment.

The drawdown of the reservoir will be monitored and any pools that form will be checked for fish. If these fish appear to be at risk of stranding will be collected and relocated. Potential stranding in the construction area around the coffer Additional salvage may be required as the reservoir level continues to drop and to keep fish out of the construction area. There is the potential for pools containing fish to become cut off from the main channel. In this case the fish will have to be salvaged and relocated. In the vicinity of the cofferdam and main dam could occur as the area is prepared for construction. Electrofishing and minnow traps would likely be used to collect fish from the work area. This work would take place prior to freeze up and exclusion nets installed to keep fish out of the construction area.

7.2.3 Fish Habitat Restoration and Revegetation

An important component of this project is the re-establishment of the original fish habitat in the South Fork of Rose Creek. There are three components of the fish habitat restoration.

1. Creek and tributaries upstream of the cofferdam.

The current plan for work in this area (approximately 2530 m) is focused on re-establishing fish passage to Reach 4 of the South Fork of Rose Creek and re-establishing riparian vegetation as quickly as possible.

- Streams will be assessed for blockages that have formed as a result of the reservoir in the spring of 2004 and if necessary a plan developed to remove the blockages if they were formed as a result of the reservoir.
- The seeding for erosion control will be augmented by riparian planting and will include willow staking and conifer planting in a 10 m wide strip on either side of the South Fork of Rose Creek and a 5 m wide strip either side of the tributary streams. A vegetation planting program will be developed after a field reconnaissance after snow melt in the spring of 2004. The initial plan will be to identify areas where trees grew previously based on the presence of stumps. These areas will be re-planted with spruce or alpine fir

at a density of 800 stems per ha. Other areas will be planted with willow stakes at a density of 10,000 per ha.

2. Stream channel through the breach.

This section of channel will be 290 m long and engineered as described earlier in the report into a riffle and pool configuration. The channel will be designed to reach bankfull at 2 year return period flood flows and will be able to migrate naturally within a 20 m wide flood plain. The edge of the flood plain will be hardened with suitably sized riprap to protect the residual dam structure from water scour. The sides of this section of channel, above the riprap, will be finished off with suitable soil material to facilitate the growth of grasses and willow staking. Details of the channel construction are provided by Northwest Hydraulic Consultants (Appendix D3) and are shown on Drawing 7.

3. Stream channel below the dam, down to the confluence with the spillway channel.

Minimal work will be carried out on the channel below the dam. In order to reduce the amount of material available for erosion during freshet some of the fill material along the right bank will be removed. The lower half of the freshwater channel (down to the 90° bend) will be diverted into a remnant of the original stream channel (Drawing 8). However, there are only preliminary indications that suggest the channel exists and some minor brush clearing may be necessary. After snow-melt a survey of this area will be made to confirm the presence of the channel. If diverting the channel is viable, this may provide the opportunity to turn the remaining length of the freshwater channel into side-channel fish habitat. This would be an ideal opportunity to provide approximately 75 m of additional fish habitat from an existing, seasoned channel with established riparian vegetation (Drawing 12).

The work on the three sections is designed to re-establish the form and function of the habitat in this section of the South Fork of Rose Creek to a condition similar to the system prior to the construction of the dam.

However, there is some uncertainty with how well the first component (upstream creek section) will become reestablished in the original stream channel. It is expected, based on the 1948 air photos, that some sections the creek will have a very low gradient and high sinuosity, which provides the possibility for the stream flow to cut a new channel. This could result in the formation of sections of unstable channel. However, preliminary indications suggest that the

water will likely find the old stream channel. This will be a focus of follow up monitoring in the spring/summer of 2004.

7.2.4 Fish Habitat Compensation Program

The compensation activities incorporated into the project currently include:

- planting of willows and conifers along the stream channels to establish riparian habitat
- evaluating and implementing a plan to restore the original creek channel immediately downstream of the channel that will be constructed through the breach.

An adaptive management approach will be taken to further evaluate the fish and fish habitat conditions in Rose Creek such as the assessment and removal of any barriers to fish movement that were created as a result of the presence of the reservoir. If surveys in the spring/summer of 2004 indicate that there are ongoing residual impacts within the aquatic or terrestrial habitats because of this project, compensation plans will be developed for approval from the agencies.

7.3 Construction Effects and Mitigation

7.3.1 General

The potential environmental effects of the construction phase include:

- Sedimentation from the construction areas (during the breach work and stream channel work downstream of the dam).
- Accidents and malfunctions associated with heavy equipment working near fish habitat.
- Disturbance of riparian vegetation and in stream habitat in the existing channel below the valve house.
- The development of spoil area(s).

The construction is scheduled to take place over the winter months when there is very little water flow. Therefore, the potential for erosion and sedimentation is very low during construction. This will be further minimized through diverting any stream flow that collects upstream of the cofferdam around the construction area. Hydrologic projections estimate that the flow in the South Fork of Rose Creek between December and March is approximately 0.11 m^3/s, which can be easily managed by pumping. The hydrologic assessment also indicates that the risk of a flood event during the construction period is near negligible.

The greatest source of erodible material in the construction area is the material used to construct impervious core of the dam which extends out to the downstream edge of the cofferdam. Drainage collection and sediment control measures will include pumping water out of the

construction area, as necessary. The water will be pumped to a closed system to the north of the fresh water channel, as described in Section 7.3.2.

7.3.2 Water Management

A preliminary water management plan is presented in Section 5.2. The plan will ensure that there is a continuous flow of water into the South Fork of Rose Creek below the work site. Execution of the water management plan will have to be done in a way that ensures that water stays under the ice. Once water begins to flow over the ice it is very difficult to get it back into the channel until the ice melts. This could impact fish habitat downstream of the project if it occurs.

Water management of the construction water was outlined in Section 5.2.1. It is anticipated that the small quantities of water that get into the construction area will be pumped to an upland area where it will be allowed to seep into the snow or vegetation. A berm will be built downslope of the discharge point to collect any pumped water that stays on the surface. Any water collecting behind the berm will be pumped back to the creek, provided it meets the Canadian Council of Ministers of the Environment (CCME, 2002) guidelines for suspended sediment. The pumps will be appropriately sized to handle the expected water quantities. Fish screens will not be required on these pumps, as fish will not be able to get into the construction area, and most fish will be salvaged from the construction area before construction begins.

7.3.3 Fuel Handling and Accidents and Malfunctions

Accidents and malfunctions provide the greatest risk to water quality and sediment contamination. Any accident or malfunction with the potential with environmental consequences will be immediately reported to the site supervisor and the environmental monitor. If the Environmental Monitor determines that a work stoppage is required to minimize further environmental impact, such an order will be issued immediately. The appropriate authorities will also be informed as soon as practical. Section 6.2.6 summarizes the potential accidents and malfunctions. The most critical malfunction would be the breakdown of the pumps used to pass the water in the South Fork of Rose Creek around the work site. A suitably sized back-up pump will be on site to minimize the risk of this event happening. Delay in completing the project due to equipment failure should not result in a delay that would end up with a partially completed breach at the start of freshet. The proposed dewatering plans anticipate that it will be possible to start excavating the breach of the dam in November 2003, which will allow ample time to complete the breach even if additional equipment needs to be brought on site to cover for broken equipment.

Refueling will be confined to a designated site adjacent to the access road on the downstream side of the dam located a minimum of 100 m from any watercourse. The area will be set up so that any fuel spill remains contained in the area. Bulk fuel storage will be at the mine site and a truck designed for fuel transfer will be used to refuel equipment at the designated refueling spot. A fully equipped spill kit will be on site at the refueling site and each piece of heavy equipment will have an appropriately equipped spill kit on board. The drainage collection features would also serve to contain any significant fuel spill that might occur during the construction phase. Any soils contaminated by a fuel spill will be collected and properly disposed of in a manner acceptable to the Environmental Monitor and any applicable regulations. The operators will be educated and aware of the requirements of the workplan and how to react in the event of a spill. In order to reduce the risk and the impact of spills:

1) The contractor will provide an oil spill response plan.
2) Biodegradable/environmentally friendly hydraulic fluid will be used on all equipment (i.e. loaders, excavators and dozers) using hydraulics within the creek channel below the high water level. An exception to this condition may be necessary depending on the air temperatures during construction and the temperature operating range of the biodegradable hydraulic fluid.
3) All machinery employed for in-stream work will be steam cleaned prior to arrival at the site.
4) All machinery employed will be inspected for leaks or worn hoses, fittings and all repairs will be made prior to access onto the site.
5) Oil sorbent sheets and/or containers will be placed under leaking vehicles and equipment immediately upon discovery.
6) Place oil sorbent sheets and/or containers under vehicles and equipment parked in high risk areas i.e., adjacent to watercourses) for longer than 2 hours or immediately under any vehicle or equipment that is leaking.
7) Refueling areas will be enclosed so that any spills can be contained and easily cleaned up and prevent oil and fuel from entering the water. Maintenance of refueling areas (such as removal of rainwater) must be carried out such that no oil and fuel enters the environment. After the project is completed, any contaminated soils within the refueling area must be removed and disposed of properly.
8) To minimize the release of grease to the environment, excavators will not sit in water that is deep enough to cause the rotational table to be below the water level.
9) All clean-up materials and equipment, including sorbent pads, and leak proof waste containers, will be readily available on site in the quantities required for the type of equipment being used. The contractor is required to develop an appropriate list of equipment and materials that will be available at the work site.
10) Waste containers will be labeled appropriately and stored in a secure location, protected from weather until removal and disposal can be arranged.

11) Any waste oil or materials will be removed from the site as soon as possible in accordance with applicable Waste Management Standards, Transportation of Dangerous Good requirements and Special Waste Regulations.
12) In the event of a spill, 200L containment drums will be used to temporarily store material for shipment off site for disposal.
13) Fuel storage areas will be supplied with:
    - 2 open-top type, leak-proof, empty 45 gal drums with sealable lids
    - 2 packages (400 sheets) of absorbent pads (polypropylene – oil only)
    - 2 polypropylene sorbent socks (3"x 4' – oil only)
    - 1 polypropylene sorbent sock (3"x 10' – oil only)
    - 1 bag treated oil only cellulose particulate
    - 1 roll poly plastic sheet 110'x 6'x 6 mil thickness
    - 1 neoprene drain cover
    - 6 poly disposal bags and ties (45 gal drum size, 6 mil)
    - 2 pair nitrite gloves (large)
    - 1 rake
    - 1 shovel
    - 1 utility knife
    - blank labels / indelible maker
    - oil sorbent sheets and/or containers will be placed under leaking vehicles and equipment immediately upon discovery

7.3.4 Spoil Site

Three spoil areas have been identified (Drawing 13). Prior to freshet, appropriate erosion and sediment control measures will be implemented to ensure that sediment laden water from the spoil area does not enter any watercourses. As noted in Section 5.3.2, the spoil pile will revegetated as part of the Phase 2 revegetation in spring/summer 2004. Depending on the results of post-construction monitoring, a granular berm may be placed at the downstream toe of the spoil pile to contain sediment from erosion of the spoil pile surface.

7.4 Environmental Monitoring Plan

7.4.1 General

It is assumed that the field team responsible for the execution of the environmental monitoring will comprise a Resident Engineer, Site Supervisor (Contractor), and Environmental Monitor (Monitor).

The Resident Engineer will be on-site daily during all construction work related to the breach. The Resident Engineer will be responsible for day to day environmental monitoring (during active construction) and ensuring the works are performed in accordance with the EMP.

The Monitor is not expected to be on-site daily throughout the construction period. However, the Monitor will be on-site daily during project startup, the construction of the sump, construction of the inlet structure for the channel and construction of the rehabilitated channel (the work conducted either in or adjacent to the channel). The Monitor will also be on site on an as needed basis, depending on the nature of the work being undertaken and discussions between the Monitor and the Resident Engineer. As noted above, the Monitor is not on site, the Resident Engineer will be responsible for the execution of the environmental monitoring. The Monitor will conduct a site visit prior to the commencement of the construction phase of the project, during any shut-down stages of the project, and as required during any of the key stages of the project. More details on the schedule of the Monitor will be provided as the final construction schedule is developed. The Monitor will have the authority to order the shutdown of the operation if environmental protection is compromised (i.e. water quality criteria are exceeded, a fuel spill occurs, etc).

The Environmental Monitor will be on-site during activities both prior to the main construction activities (i.e. fish salvage) and to perform follow up monitoring of the effects of the construction (i.e. fish sampling). A list of aspects to monitor is provided in Sections 7.4.3 and 7.4.5.

7.4.2 Responsibilities

The Resident Engineer, Construction Manager, the Contractor's Site Supervisor, and Environmental Monitor for each component of the work are responsible for ensuring that the EMP has been reviewed and understood by all personnel, including contractors, involved with the project. Environmental issues will be covered in pre-job and on-site meetings with the crews to ensure that environmental risks have been identified and adequately addressed. Any subcontractors will be issued a copy of the EMP and will be required to sign a "Contractor Orientation Record" form. The contractor will ensure that all staff is familiar with the relevant components of the EMP. Any changes to the work plan shall be brought to the attention of the Site Supervisor and Environmental Monitor so that the EMP can be amended and agencies contacted, if necessary.

Prior to the start of the construction project, the reporting structure for the environmental monitoring will be clearly identified. The Environmental Monitor will report issues of concern directly to the site supervisor who will coordinate any corrective action with equipment

operators. The Environmental Monitor will work closely with the Resident Engineer and Contractor's senior site representative to review project schedules and issues of concern and to anticipate environmental issues ahead of time so that contingency plans are in place to ensure good environmental stewardship throughout the project.

7.4.3 Aspects to Monitor

- Monitor state of fish left to recolonize the channel after dewatering. Develop plan to minimize stranding during final days of dewatering.
- Set up of construction area including laydown areas, fueling site, establishment of drainage and sediment control measures for construction
- Initial monitoring of construction activities on a daily basis.
- Advise on layout of stream channel features, especially the section below the dam. Daily monitoring of the stream channel rehabilitation work below the dam, the stream channel through the breach and any compensation habitat required.
- Monitor water discharge from construction area and stream restoration work areas for turbidity
- Monitor downstream pools in Reach 2 of the South Fork of Rose Creek for turbidity and dissolved oxygen during all construction phases
- Be on site during initial snow melt to evaluate turbidity levels and assess the need for additional practical sediment control to minimize sedimentation of streams (i.e. locate and stabilize or isolate sources of erosion)
- Monitor seeding success in early spring and determine the need for additional seeding.

7.4.4 Monitoring Total Suspended Sediment and Turbidity

The water management program, Section 5.3.1, indicates how water monitoring within the construction area will be handled. If settling basins or some other form of treat and pump is used to remove the sediment then any water discharged into the South Fork of Rose Creek will meet criteria set by the CCME, which stipulates that total suspended solids (TSS) levels should not exceed 25 mg/L above the background levels in Rose Creek (or 10% above background if background TSS exceeds 250 mg/L). The laboratory facilities on site include the capability to measure TSS. It is expected that results for TSS tests would be available within a few hours of sampling and could be tested on a daily basis as necessary. This testing could be supplemented with NTU testing at the site on a more frequent basis. The frequency of TSS testing should allow a useful TSS/NTU relationship to be used on an ongoing basis.

7.4.5 Post-Construction Monitoring and Follow-up Monitoring

- Seed germination success rate in mid-summer. Additional seeding required in areas of poor germination or cover.
- Evaluate channel stability (in built areas and the upstream areas) after the 2004 freshet (late August, September). To be evaluated in conjunction with the Resident Engineer (Section 5.5.3). Prepare a report on channel conditions with, recommendations for stream work that could be carried out, depending on access and logistics, prior to the 2005 freshet
- Monitor vegetation survival at the end of the growing season. In areas of poor survival (i.e. less that 80%) new plants will be added. This can be done in late fall when the plants have become dormant or can be carried out in the spring while they are still dormant.
- 2005 assessment of revegetation success and stream habitat conditions. Stream assessment should include channel stability, riparian condition, and availability of spawning and rearing habitat, fish sampling to determine densities and determine if there is any evidence of spawning and spawning success. Control sites should be established in another area of Rose Creek for comparison.
- Annual evaluation of areas planted with willows and conifers, on going mitigation or compensation measures for the re-establishment of instream habitat through 2008. The results will be reported annually with recommended maintenance or corrective actions.
- After 2008 the mine reclamation and closure plan will be complete and approved and will take over the requirements for maintaining and rehabilitating fish habitat affected by mining in the Rose Creek drainage. The mine closure plan will include a comprehensive plan for restoring fish habitat through out Rose Creek, including the area of the FWSD.

7.5 Reporting

- Environmental Monitor (supported by the Resident Engineer) will be required to maintain suitable records and photographs throughout the construction phase. Weekly reports that summarize work activities and incidents or issues will be submitted to the Interim Receiver, DIAND and DFO (and, possibly, Yukon Department of Environment).
- Any significant environmental issues will be reported immediately (the protocols for reporting will be defined as part of final design and the development of an Environmental Management Plan QA/QC program).
- Any significant changes in construction methods (detailed in the final design report), to habitat rehabilitation, stream channel design, monitoring procedures, etc. will be presented to the Interim Receiver, DFO, DIAND and the Yukon Department of Environment, along with justification for the changes.

- A report on the construction phase is required within 6 months of the completion of the construction work and should include photo documentation of the construction activities, summary of significant incidents.
- A report on the assessment of the success of revegetation program after the first full growing season and the condition of the stream channel after the first freshet along with recommendations for additional work or any remedial action taken will be submitted by December 2004.
- Annual reports on the condition of the stream habitat annually until 2008 including degree of utilization of the fish habitat, success of the revegetation, etc.

8 CLOSURE

An engineering team, under the direction of SRK Consulting, has completed the detailed design of a breach of the FWSD at the Faro Mine, Yukon Territory. However, additional field work that could not be performed over the winter, including fish and vegetation studies and detailed reconnaissance of the area downstream of the dam, will be undertaken in the coming months. Based on this information, refinements will be made to the environmental management plan and the fish habitat mitigation and compensation plan. In addition, technical specifications will be prepared and the detailed design drawings contained in this report will be advanced to construction drawings.

This report "**Final Breach Design, Fresh Water Supply Dam, Faro Mine**" has been prepared by:

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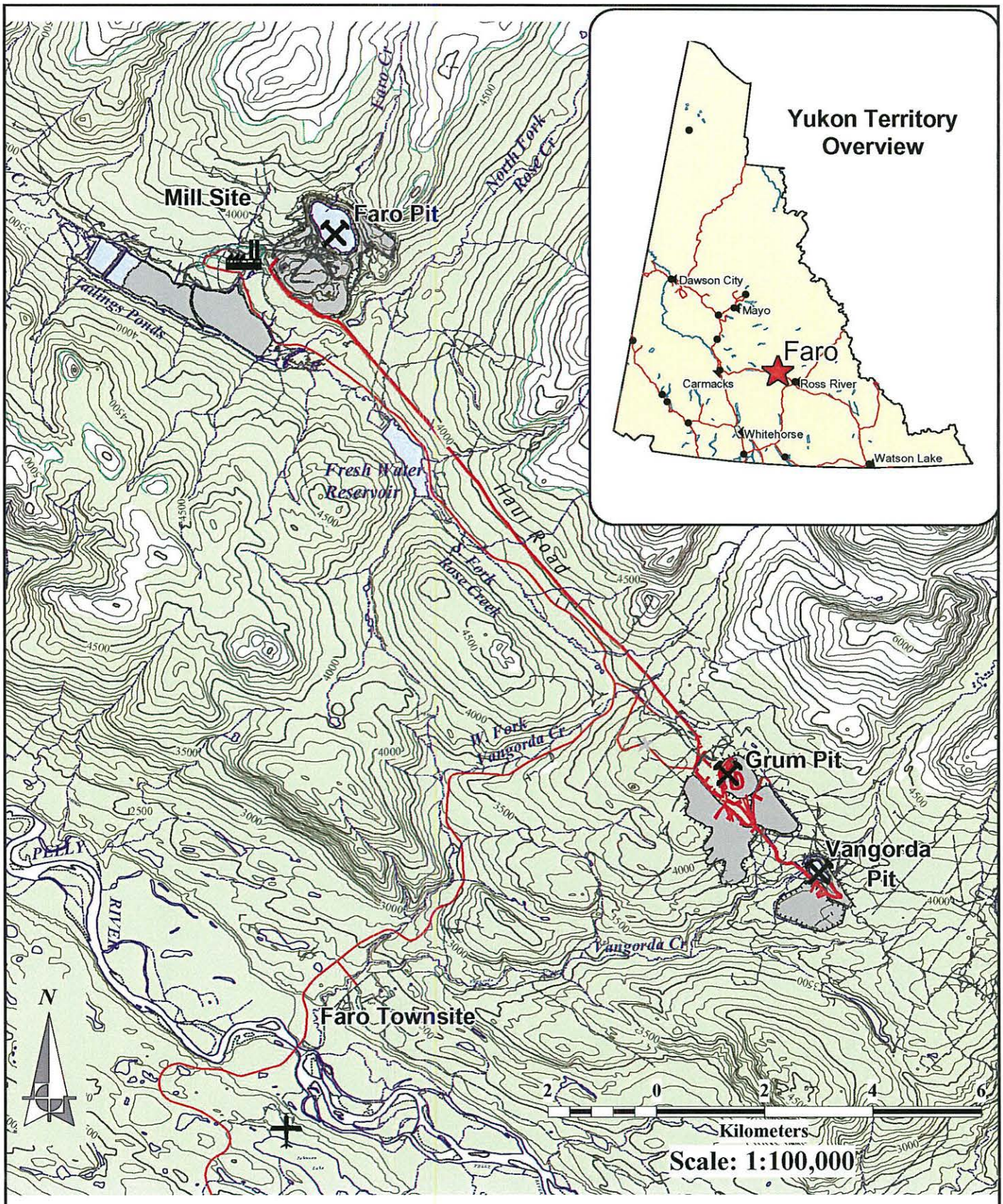
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Figures



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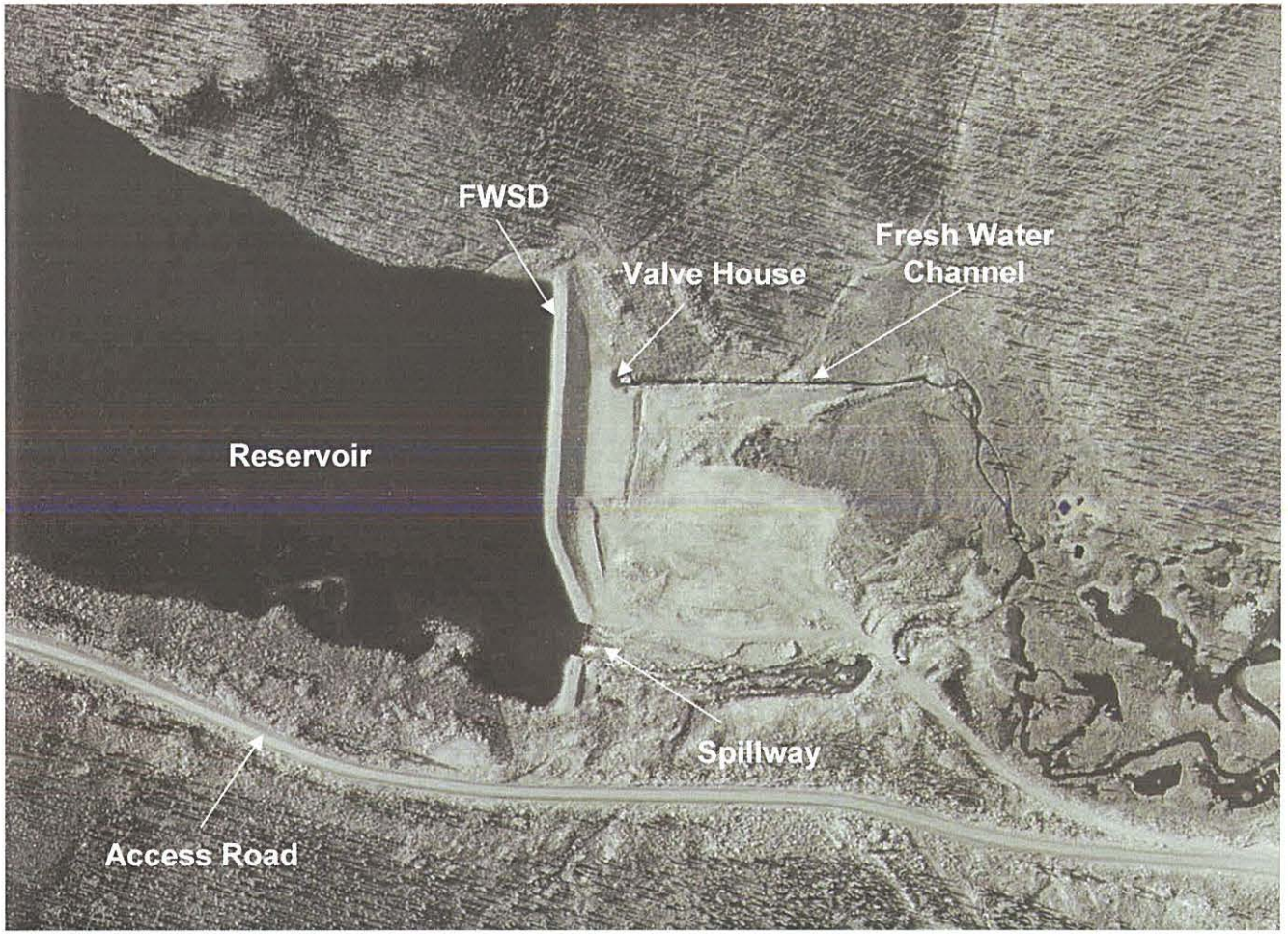
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FWSD BREACH FARO MINE, YUKON TERRITORY

LOCATION MAP

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.22	APRIL, 2003	GWF	2.1

Dwg Ref: Figure 1.1.dwg



Source: Airphoto – OS9009015-1-12 & -13, Scale 1:10,000 Line 1-SE (1-15) 8700 ASL, September 17, 1990

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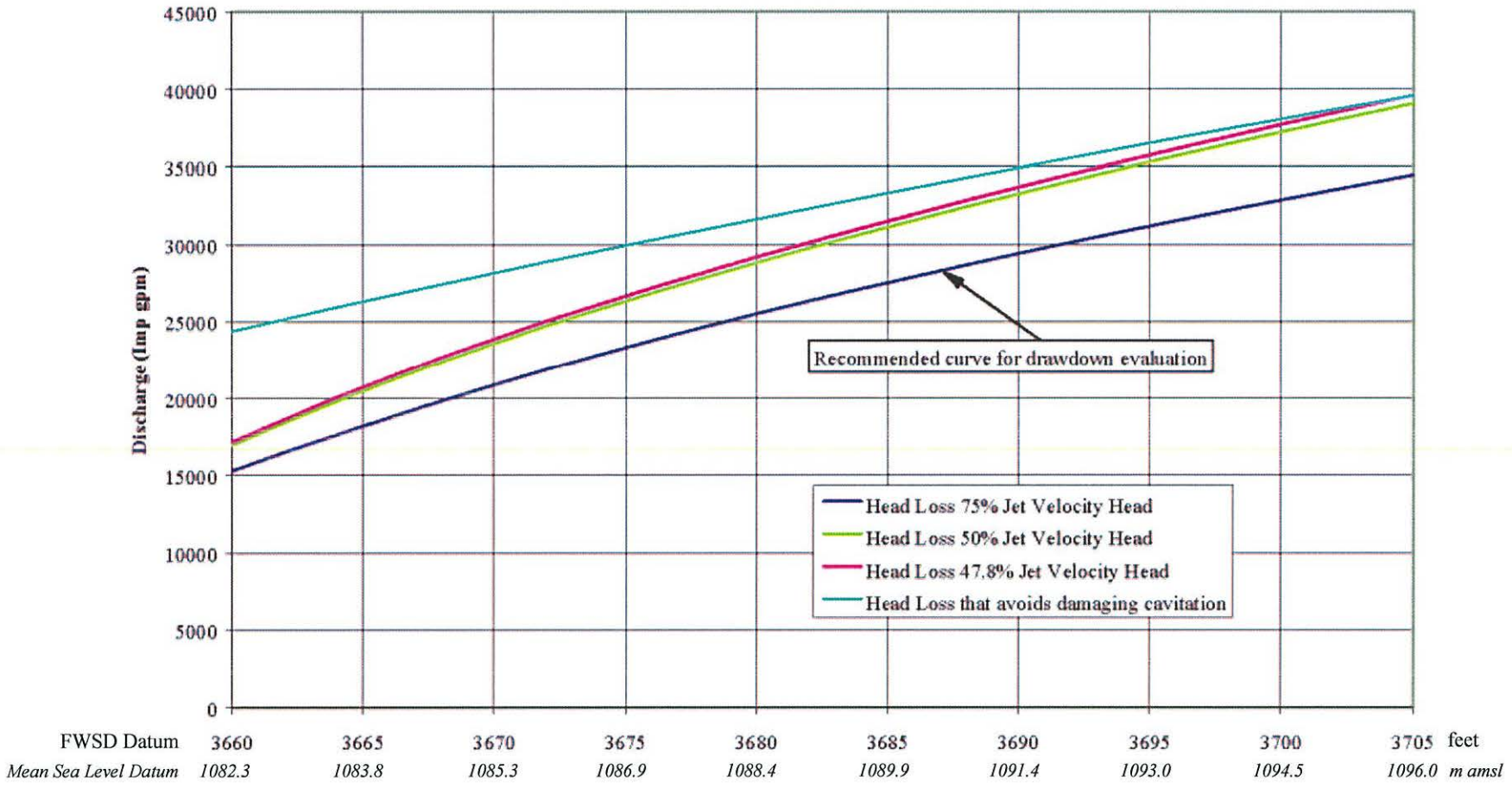
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FWSD Breach
Faro Mine, Yukon Territory

FWSD Features

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**2.2**



Source: Klohn Crippen, 2003 Anvil Range Mine, Water Supply Dam, Low-Level Outlet Assessment

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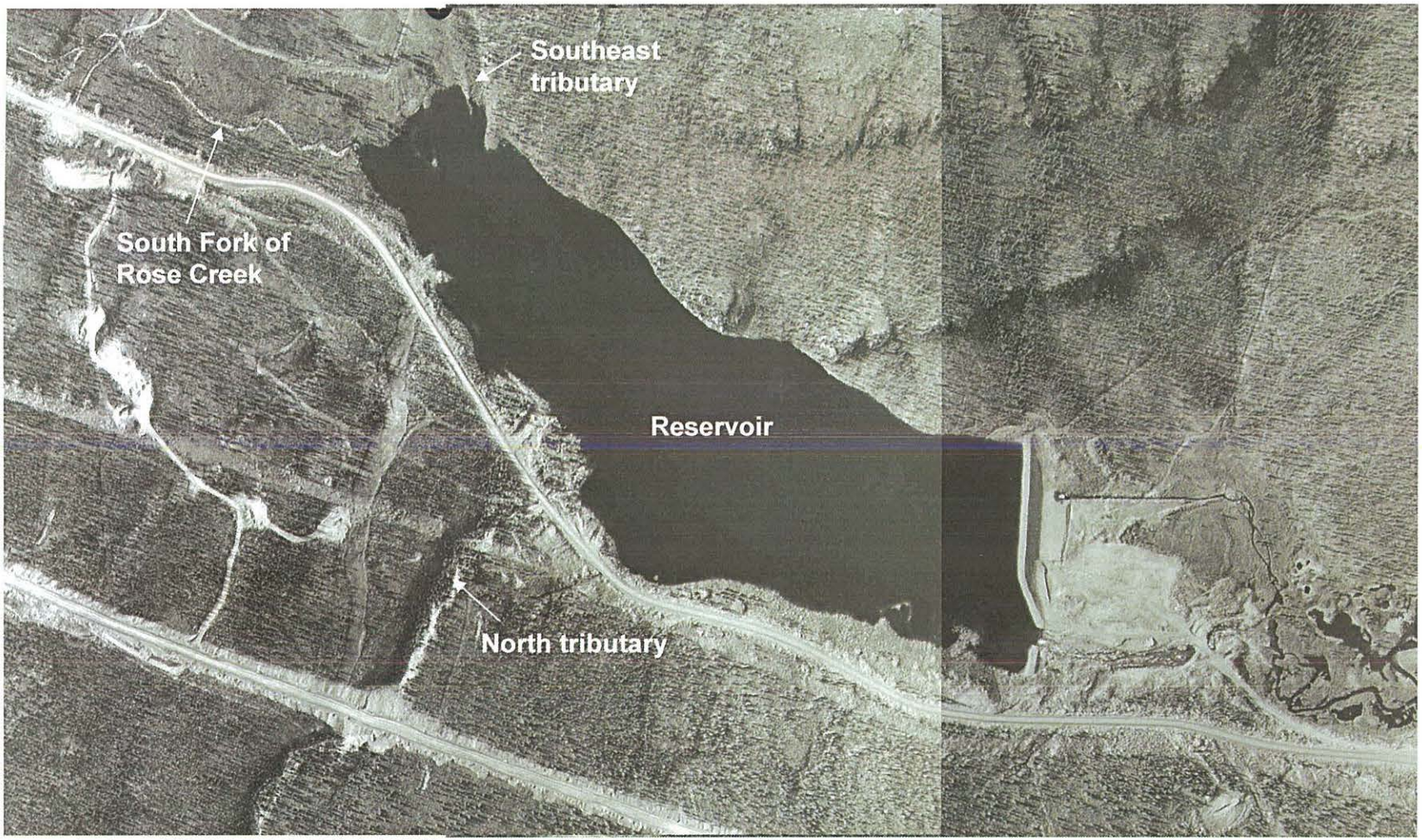
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FWSD Breach
Faro Mine, Yukon Territory

Low Level Outlet Rating Curves

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**2.3**



Source: Airphoto – OS9009015-1-12 & -13, Scale 1:10,000 Line 1-SE (!-15) 8700 ASL, September 17, 1990

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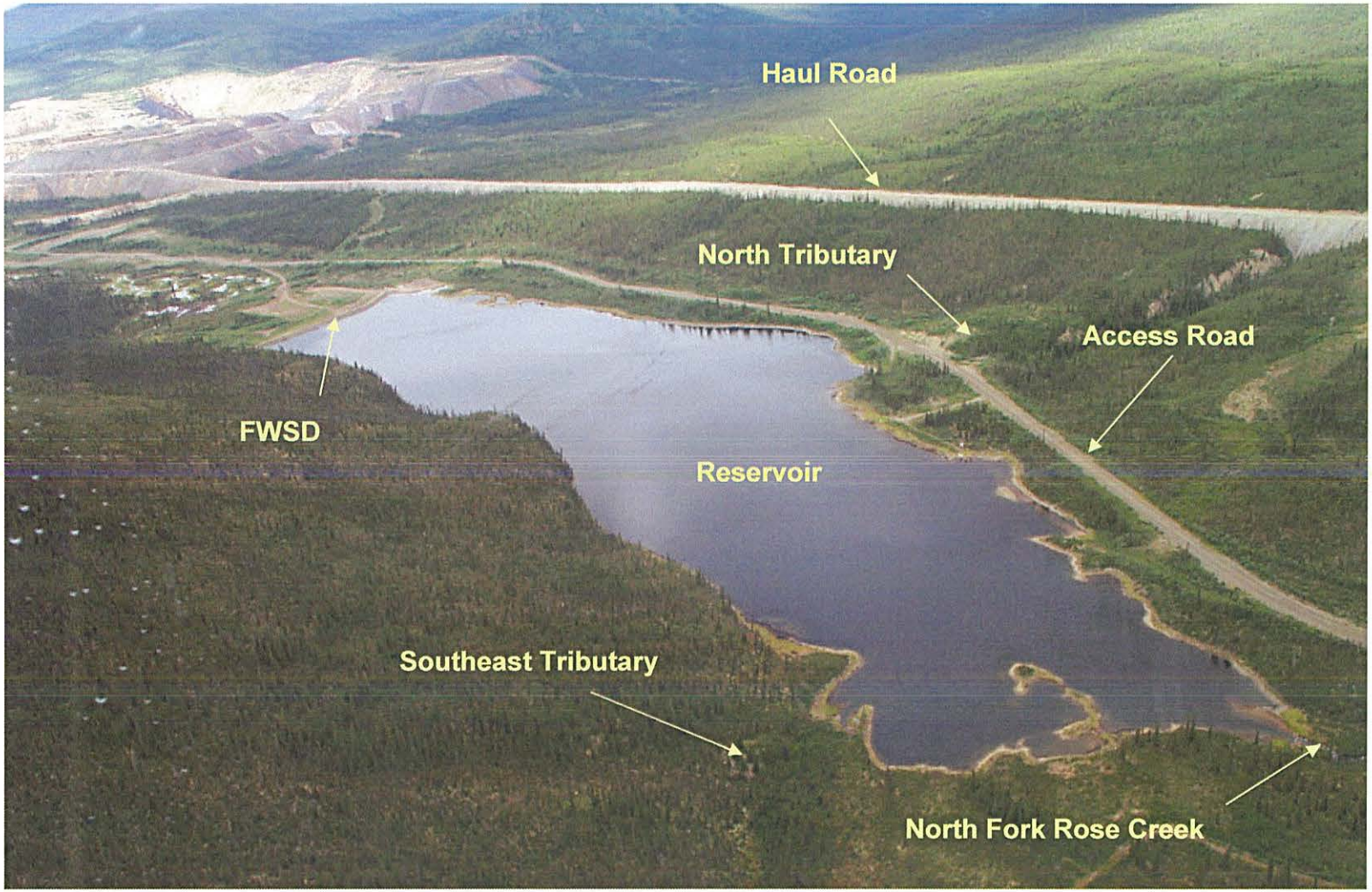
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FWSD Breach
Faro Mine, Yukon Territory

Air Photo of Reservoir

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**2.4**



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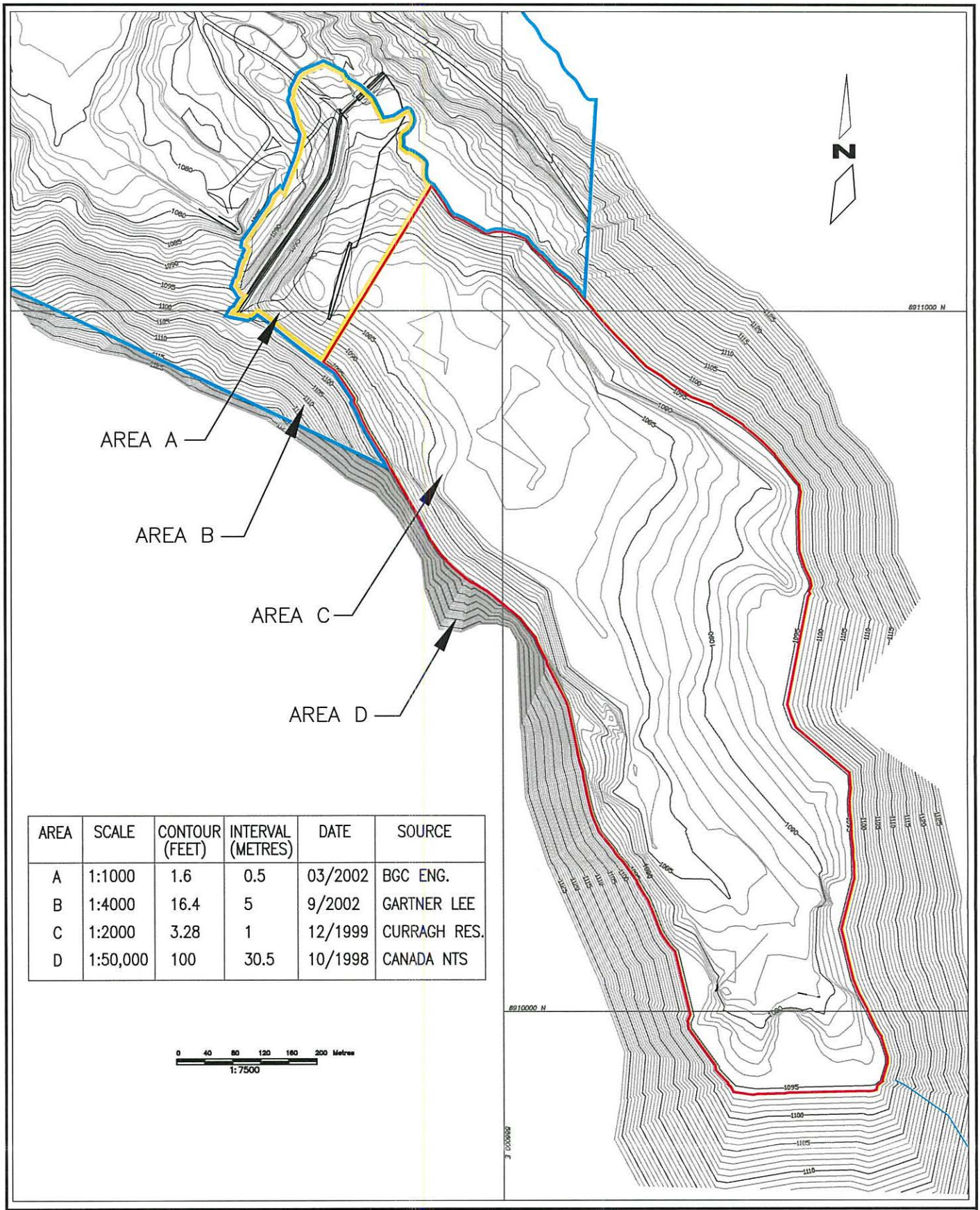
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FWSD Breach
Faro Mine, Yukon Territory

Oblique Photo of Reservoir

PROJECT:	DATE:	APPROVED:	FIGURE
1CD003.22	April 2003	GWF	2.5



AREA	SCALE	CONTOUR (FEET)	INTERVAL (METRES)	DATE	SOURCE
A	1:1000	1.6	0.5	03/2002	BGC ENG.
B	1:4000	16.4	5	9/2002	GARTNER LEE
C	1:2000	3.28	1	12/1999	CURRAGH RES.
D	1:50,000	100	30.5	10/1998	CANADA NTS

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FWSD BREACH FARO MINE, YUKON TERRITORY

AVAILABLE SURVEY DATA FOR PROJECT AREA

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.22	APRIL, 2003	GWF	2.6

Dwg Ref: Figure 1.2.dwg

ACCESS ROAD

ESTIMATED LOCATION OF CREEK
(PRE-CONSTRUCTION)

FRESH WATER CHANNEL

DAM CREST

APPROXIMATE OUTLINE OF
RESERVOIR AT FULL SUPPLY

1080
1085
1090
1095
1100
1105
1110

691200 N

585000 E

LEGEND

- LOCATION OF SURVEY DATA POINT
- CREEK OUTLINE FROM 1999 SURVEY
- ESTIMATED CREEK OUTLINE

SOURCE: AS BUILT DRAWING NO. D1575-058-002, REV.05 PARSONS-JURDEN CORPORATION, OCT. 1968

CONTOUR INTERVAL = 1m
NAD 27 DATUM, ZONE 8
ELEVATIONS (m amsl)

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D/APP'D	DATE
REVISIONS			

REV.	ISSUE PURPOSE	AUTH. BY	DATE
B	FINAL DESIGN	GWF	APRIL, 2003
A	PRELIMINARY DESIGN	GWF	FEB 3/03
ISSUE AUTHORIZATION			

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FINAL DESIGN

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: March 2003	DATE:
CHECKED BY:	DISCIP. ENGR.
DATE:	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:800
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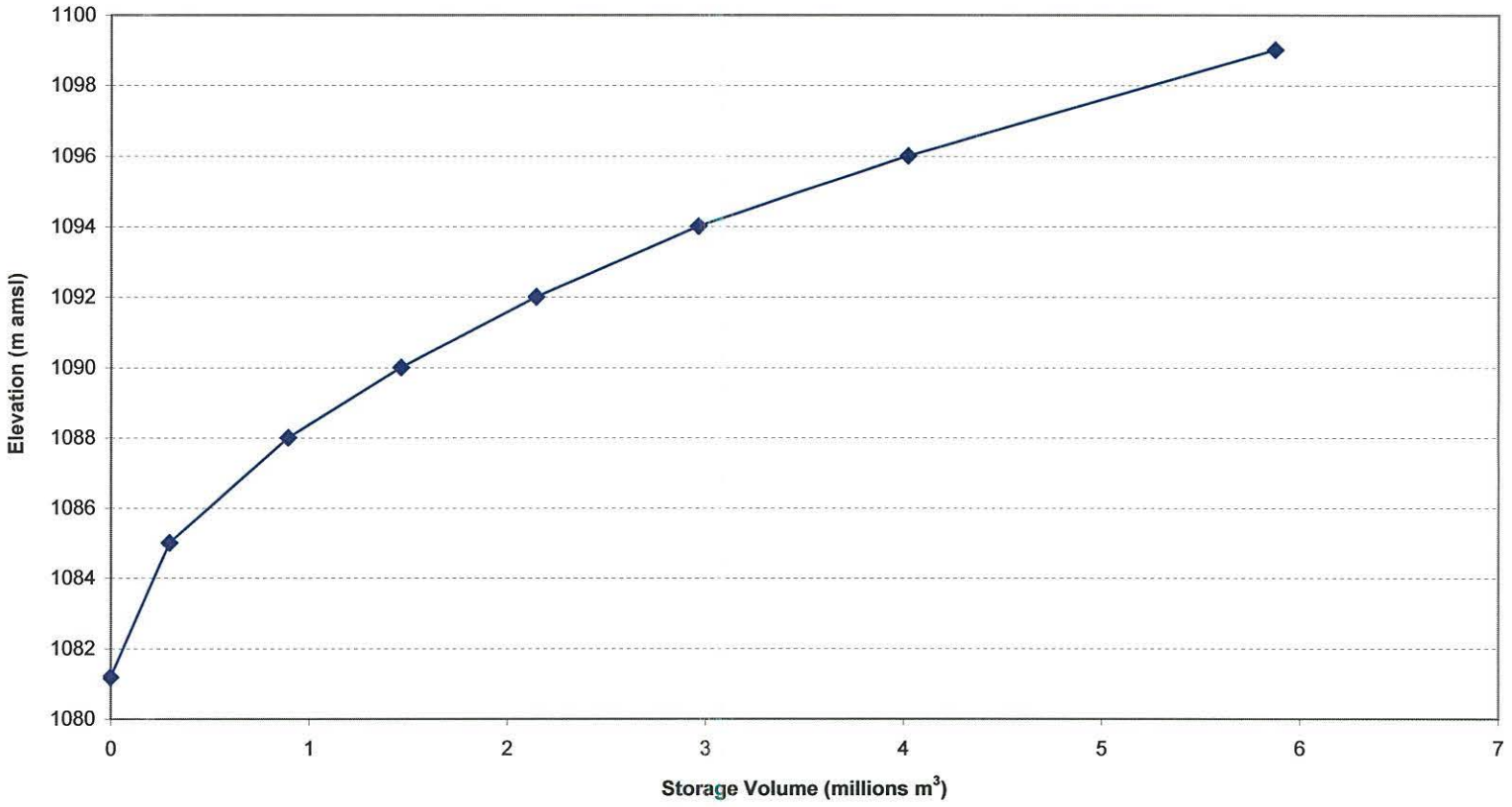
SURVEY LOCATIONS
FWSD

FIGURE NUMBER 2.7

REV. B

FILE NAME: F:\Deloitte_Touche\Good drawings-Fero\Fero FWSD\Figure 4.dwg

FILE REF: Figure 2.8-final.xls



Based on Bathymetric Survey performed August 6-7, 2002

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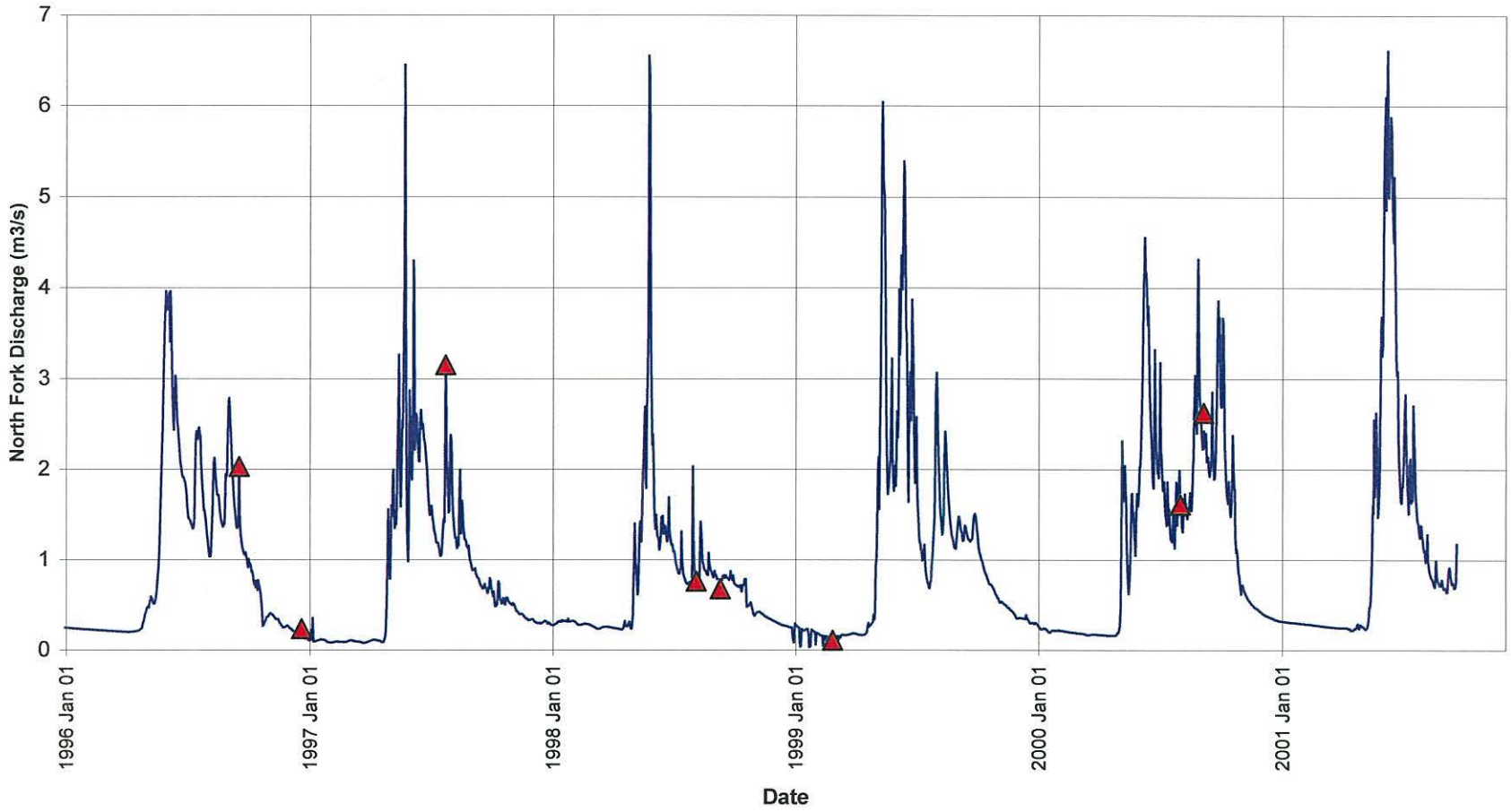
Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

FWSD Height Capacity Curve

PROJECT	DATE	APPROVED	FIGURE
1CD003.22	April 2003	GWF	**2.8**

FILE REF: Figure 2.9-final.xls



Source: Gartner Lee Limited

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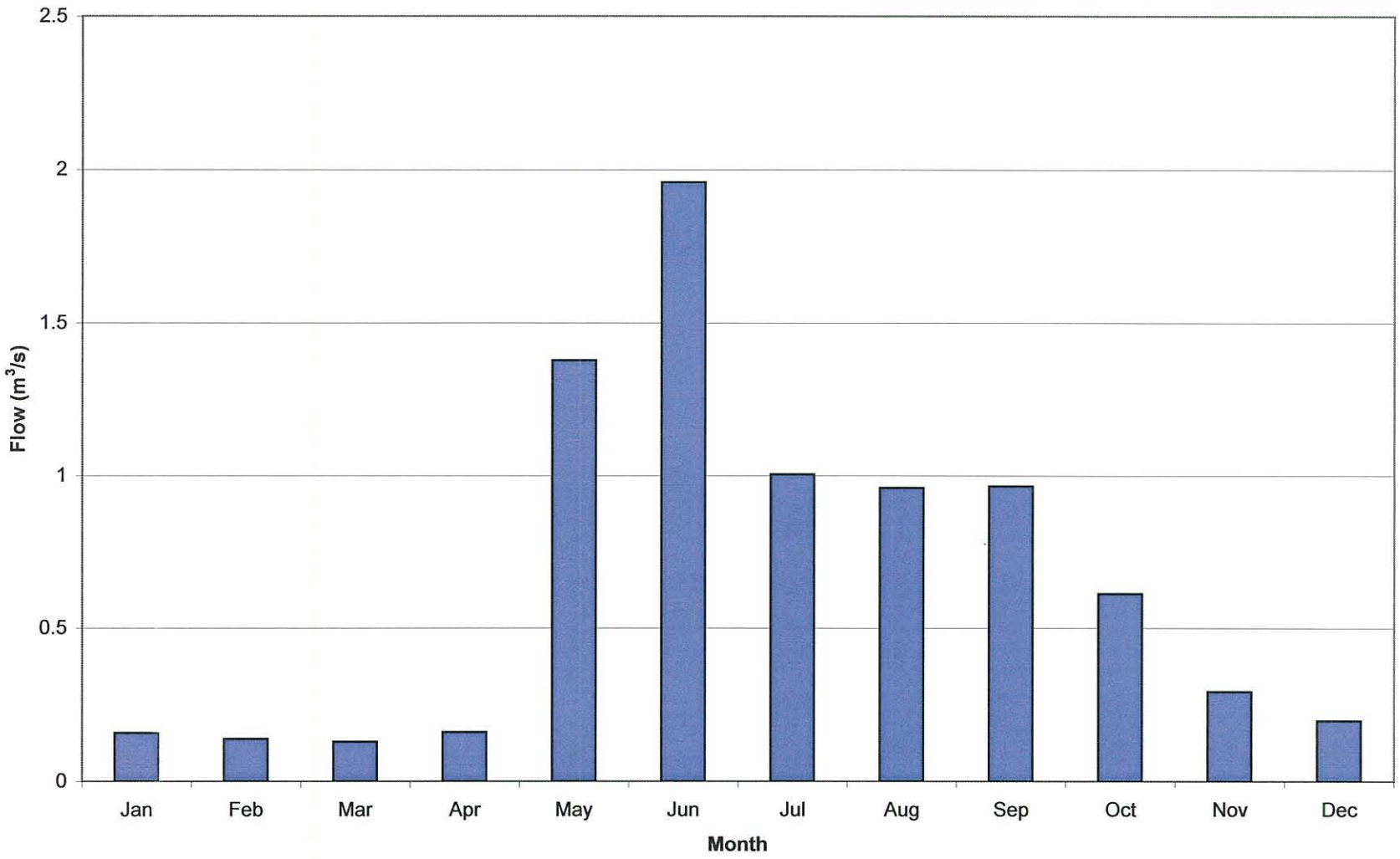
Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

Flow Measurement
R7 - North Fork of Rose Creek

PROJECT	DATE	APPROVED	FIGURE
1CD003.22	April 2003	GWF	**2.9**

FILE REF: Figure 2.10-final1-pb.xls



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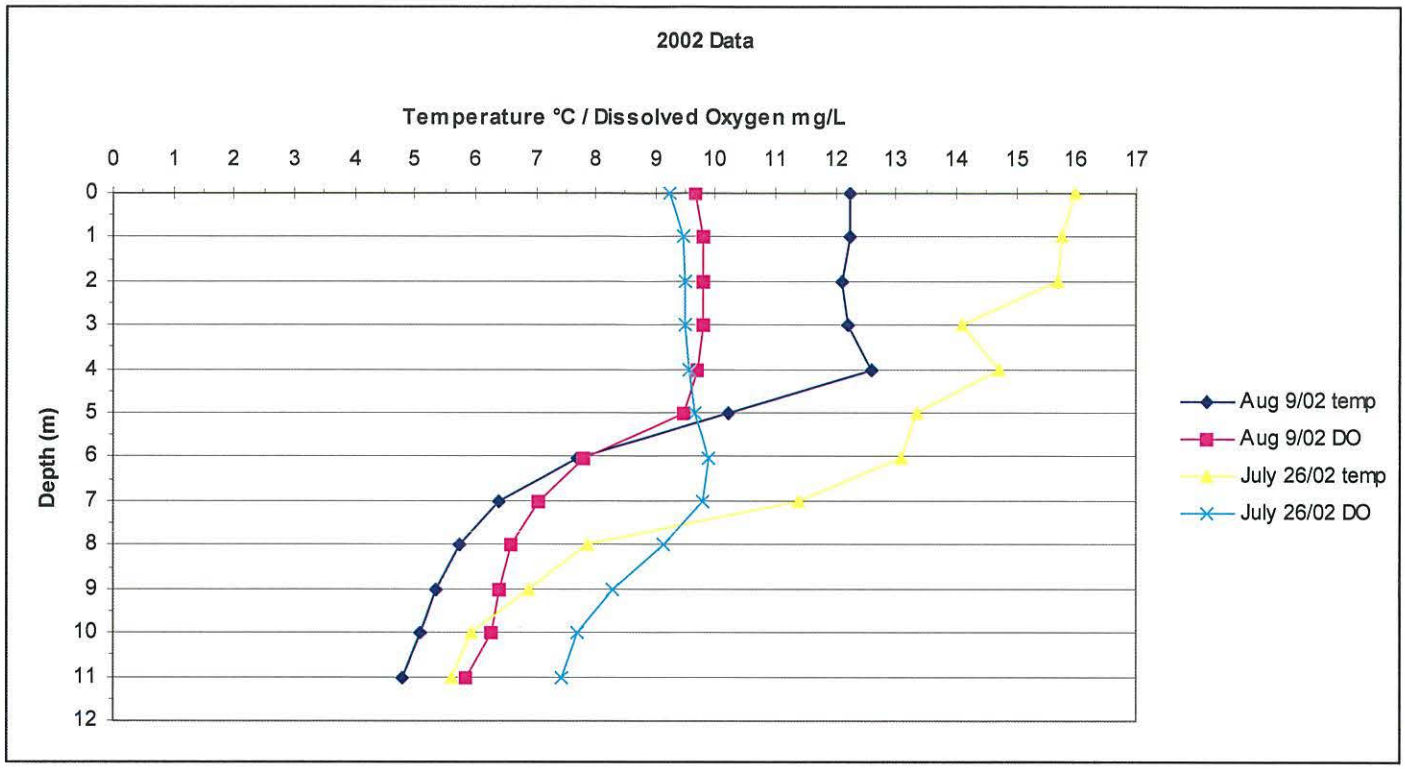
SRK Consulting Engineers and Scientists

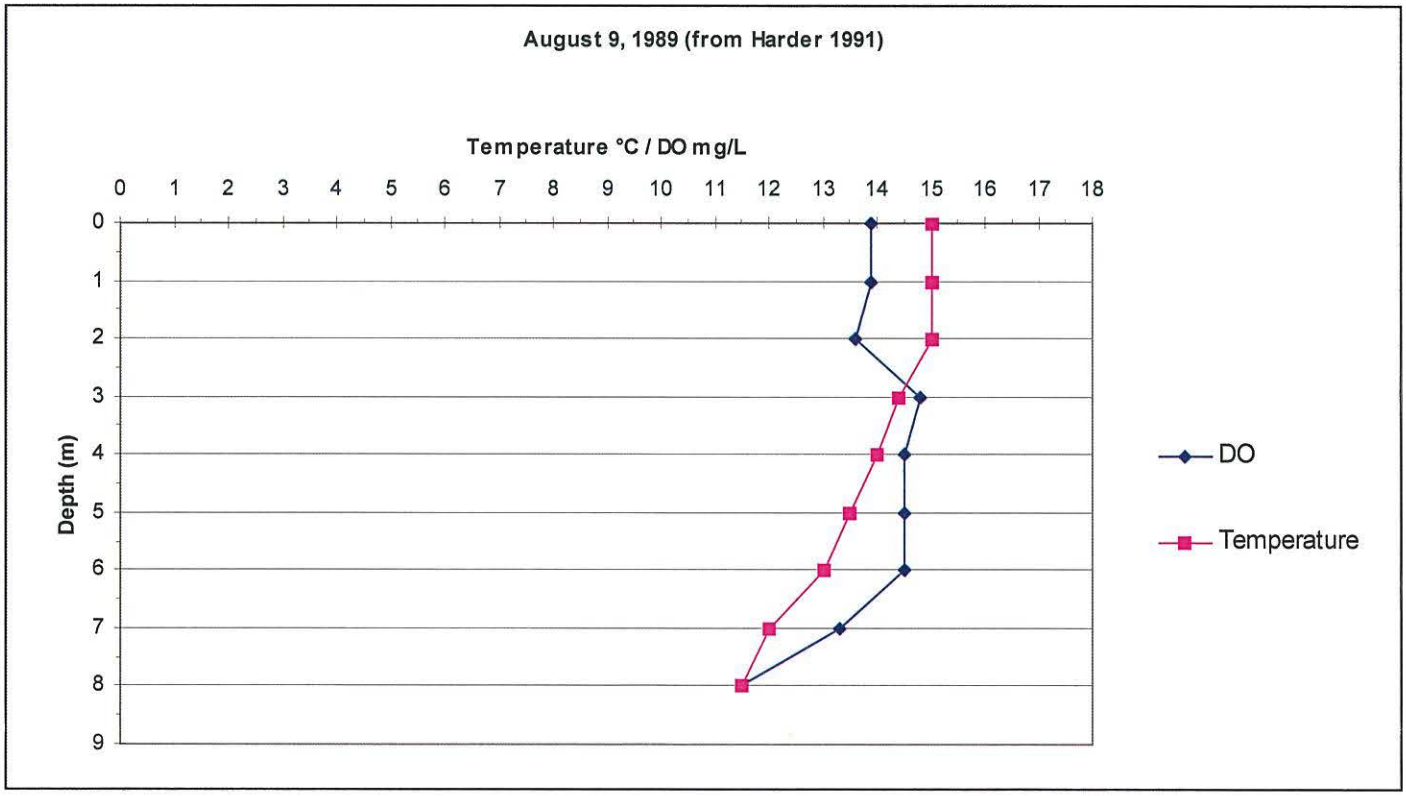
Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

Hydrograph of Average Flow Conditions for FWSD

PROJECT	DATE	APPROVED	FIGURE
1CD003.22	APRIL 2003	GWF	**2.10**





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FWSD Breach
Faro Mine, Yukon Territory

Temperature/Dissolved Oxygen Profiles of the FWSD Reservoir

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**2.11**

LEGEND

WATER SAMPLING SITE

Notes:

Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour Interval 100 m
Universal Transverse Mercator Projection
Map is a composite of 9 basemaps,

Faro Ck
INTERCEPTOR
FARO VALLEY
FARO VALLEY ROCK DUMPS
FARO CREEK DIVERSION
R7
Rose Creek
North Fork
UPPER GUARDHOUSE CREEK
MAIN PIT
Water Level
NORTHEAST ROCK DUMP
NORTHWEST ROCK DUMPS
TAILINGS PIPELINE
MAIN ROCK DUMP
INTERMEDIATE ROCK DUMP
FLOW THROUGH ROCK DRAIN (FISH BARRIER)
HAUL ROAD
NEXT CREEK
NORTH WALL INTERCEPTOR DITCH (MINE LEG)
Guardhouse CK
WATER SUPPLY PIPELINE
NORTH FORK DIVERSION
MINE ACCESS ROAD
CROSS VALLEY DAM
INTERMEDIATE DAM
ORIGINAL TAILINGS IMPOUNDMENT
SECOND IMPOUNDMENT
SOUTH FORK ROSE CREEK
X3
X14
Rose Creek
X10
INTERMEDIATE IMPOUNDMENT
ROSE CREEK DIVERSION
PUMPHOUSE POND
FRESH WATER SUPPLY DAM
FRESH WATER SUPPLY RESERVOIR
FUSE PLUG
ROSE CREEK DIVERSION
1400
1300
1500
1200
1100

DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D/APP'D	DATE

REVISIONS

REV.	ISSUE PURPOSE	AUTH. BY	DATE
C	ISSUED TO WATER BOARD	GWF	APR. 17/03
B	FINAL DESIGN	GWF	APR 03/03
A	PRELIMINARY DESIGN	GWF	FEB 3/03

ISSUE AUTHORIZATION

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

FINAL DESIGN

DESIGNED BY: GWF	DRAWN BY: DMC
DATE: JAN. 2003	DATE: JAN. 2003
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE:
PROJ. MGR:	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FWSD BREACH
FARO MINE, YUKON TERRITORY

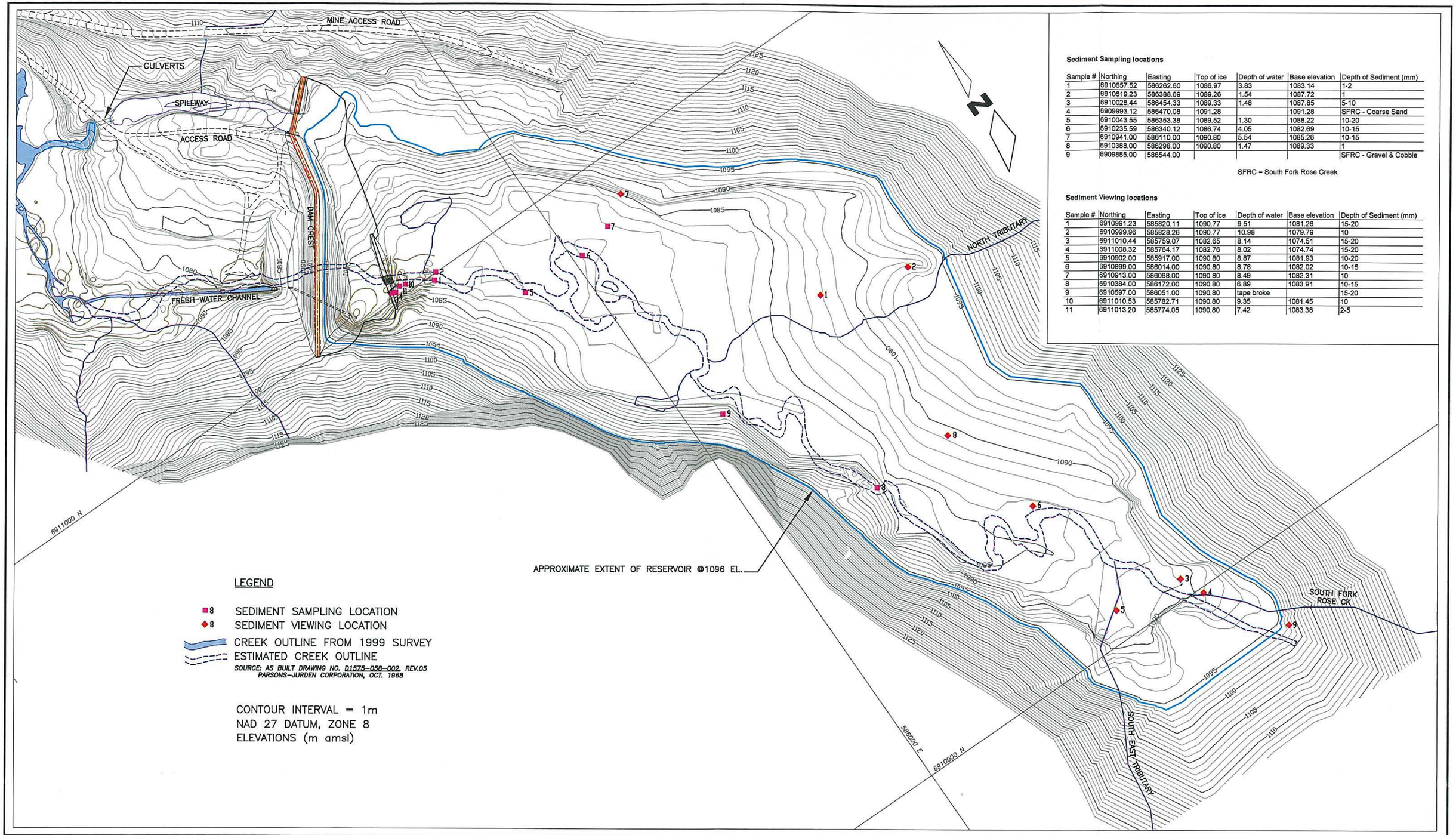
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WATER SAMPLING LOCATIONS

FIGURE NUMBER 2.12

REV. C

FILE NAME: F:\Deloitte_touche\Acad drawings-Faro\Geo FWSD\Figure GL-2.4.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

LEGEND

- ■8 SEDIMENT SAMPLING LOCATION
- ◆8 SEDIMENT VIEWING LOCATION
- CREEK OUTLINE FROM 1999 SURVEY
- ESTIMATED CREEK OUTLINE

SOURCE: AS BUILT DRAWING NO. D1575-058-002, REV.05 PARSONS-JURDEN CORPORATION, OCT. 1968

CONTOUR INTERVAL = 1m
NAD 27 DATUM, ZONE 8
ELEVATIONS (m amsl)

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE

REFERENCE DRAWINGS

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B	FINAL DESIGN	GWF	APRIL, 2003
A	PRELIMINARY DESIGN	GWF	FEB 3/03

REVISIONS

ISSUE AUTHORIZATION

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

FINAL DESIGN

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: March 2003	DATE:
CHECKED BY:	DISCIP. ENGR.
DATE:	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE

SRK PROJECT NUMBER: 1CD003.22

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

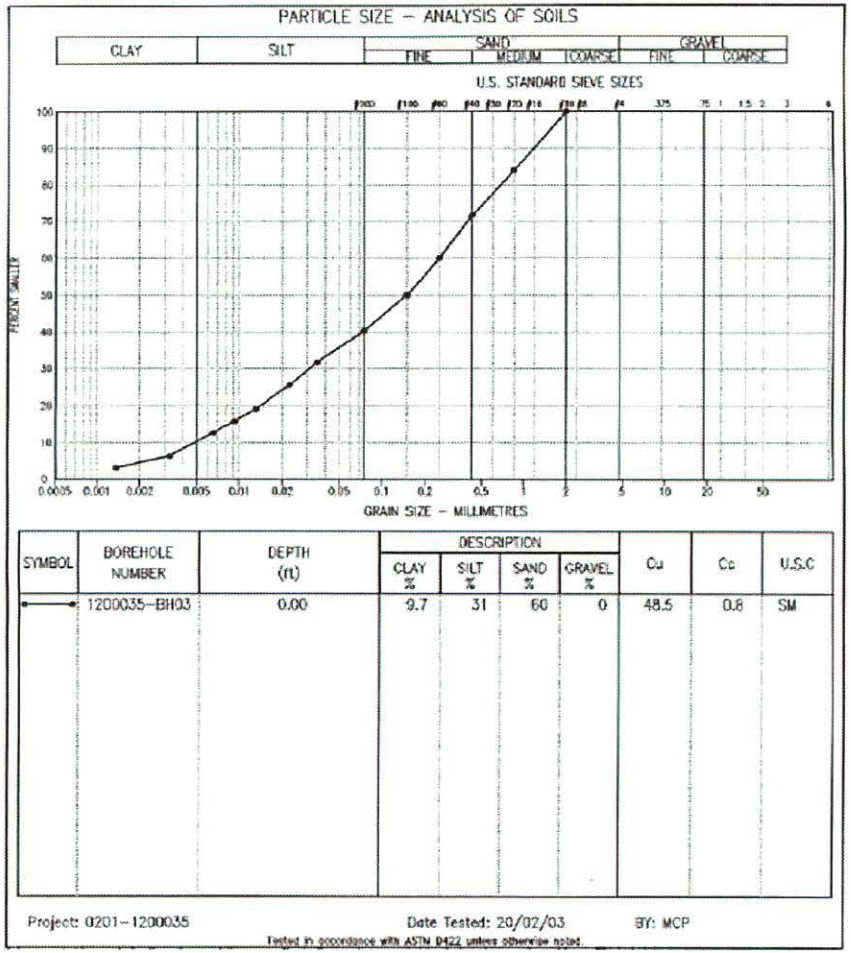
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SEDIMENT SAMPLING LOCATIONS

FIGURE NUMBER 2.13

REV. B

FILE NAME: P:\Deloitte_touche\Acad drawings-Fare\fare FIG02\Figure 4.dwg

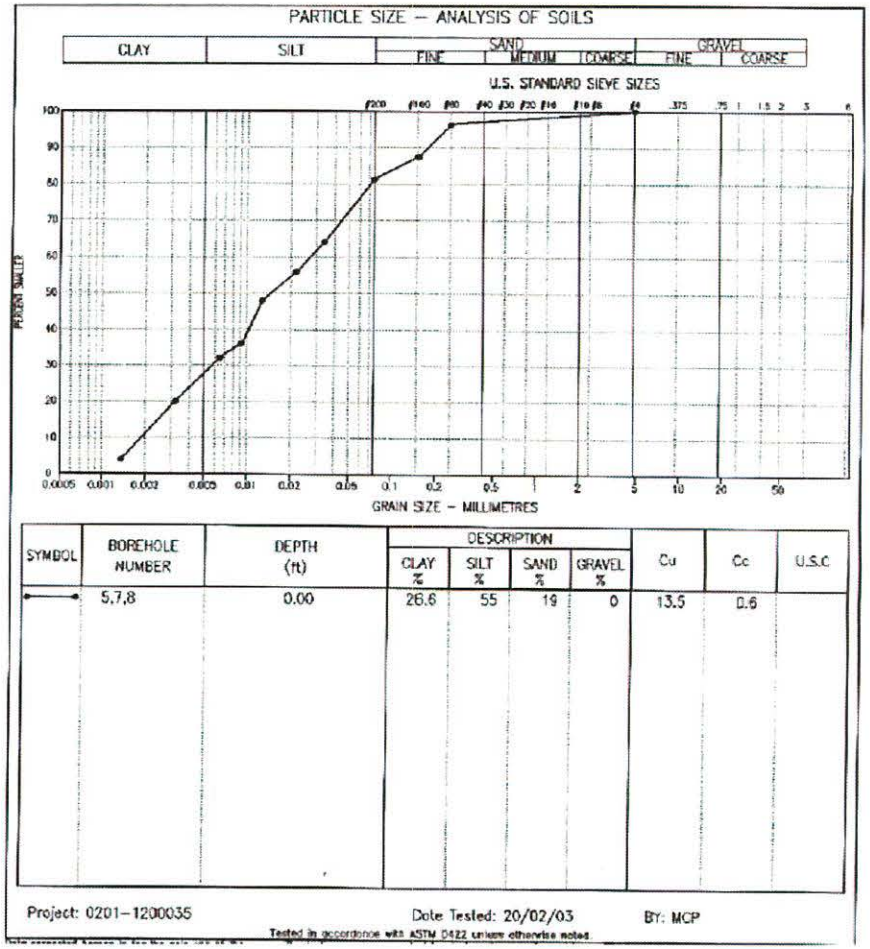


SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
	1200035-BH03	0.00	9.7	31	60	0	48.5	0.8	SM

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



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

Source: EBA Engineering Consultants Ltd., Fax dated January 14, 2003, Re: Intake Sediment Sample Grain Size

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BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

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Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

Grain Size Testing

PROJECT:	DATE:	APPROVED:	FIGURE
1CD003.22	April 2003	GWF	**2.14**



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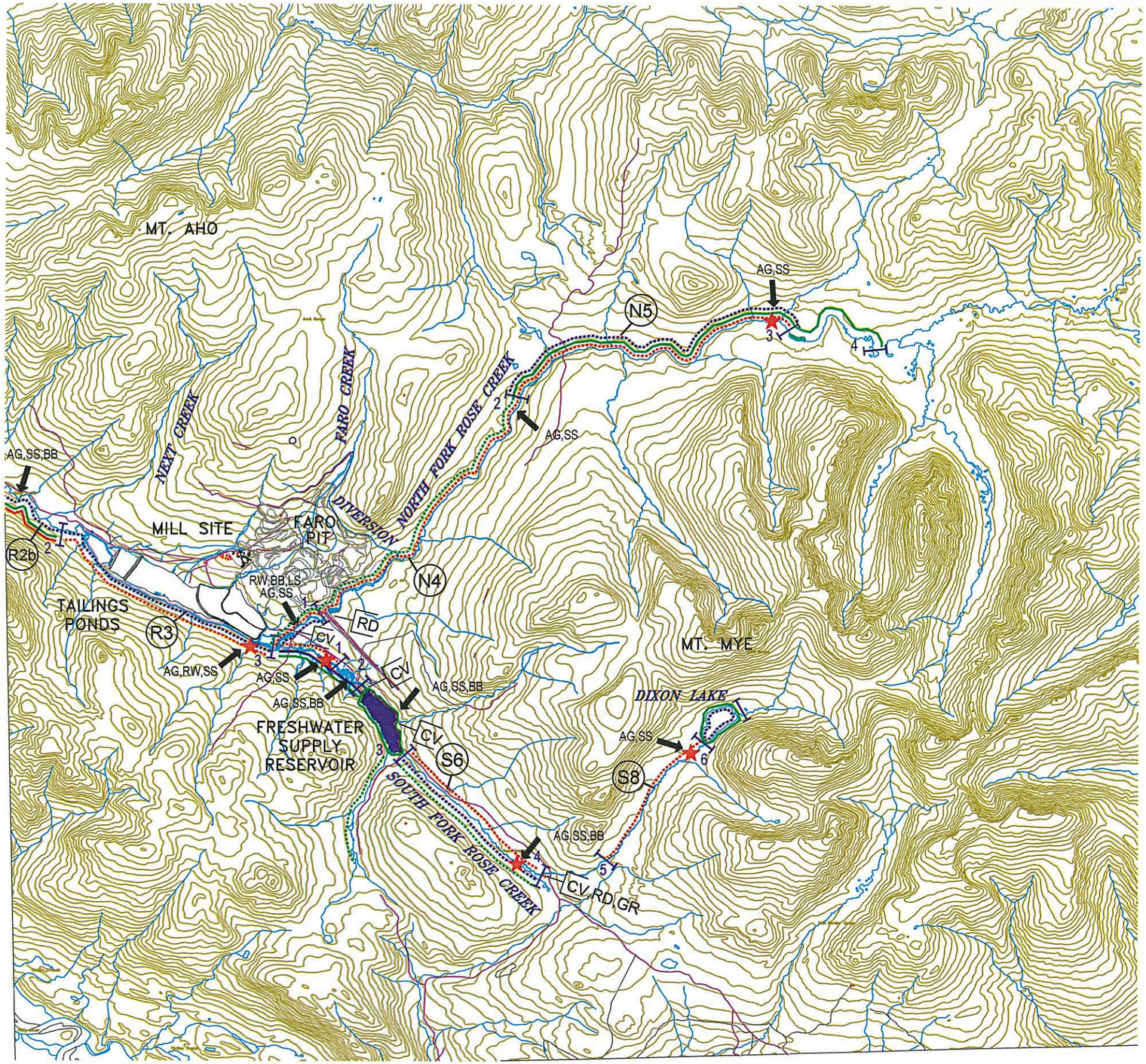
SRK Consulting
Engineers and Scientists

Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

South Fork of Rose Creek Downstream of FWSD

PROJECT:	DATE:	APPROVED:	FIGURE
1CD003.22	April 2003	GWF	**2.15**



LEGEND:

- ROAD
- SURFACE DRAINAGE
- 1 — REACH BREAK
- (BC) FISH SAMPLING LOCATION (2002)
- ★ KNOWN SPAWNING IN STREAM REACH
- → FISH SPECIES PRESENT (KNOWN) IN STREAM REACH
  - AG ARCTIC GREYLING
  - SS SLIMY SCULPIN
  - BB BURBOT
  - RW ROUND WHITEFISH
  - CH CHINOOK SALMON
  - LS LONGNOSE SUCKER
- CV POTENTIAL OR KNOWN BARRIER TO FISH PASSAGE
  - CV CULVERT
  - RD HAUL ROAD
  - GR GRADIENT
  - CANYON

ARCTIC GREYLING HABITAT VALUE IN ROSE WATERSHED

- HIGH REARING
- MODERATE REARING
- HIGH SPAWNING
- MODERATE SPAWNING
- HIGH OVER-WINTERING
- MODERATE OVER-WINTERING

Notes:

Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour Interval 100 m
Universal Transverse Mercator Projection
Map is a composite of 9 basemaps,
it was redigitized to simplify planimetric features.

SOURCE OF FIGURE:

DRAWING NO. 4.1 "OVERVIEW OF FARO MINESITE"
DIAND WASTE MANAGEMENT PROGRAM BY GARTNER LEE LIMITED
03/16/01 ADAPTED FROM ROBERTSON GEOCONSULTANTS INC.

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D/APP'D	DATE
REVISIONS			

REV.	ISSUE PURPOSE	AUTH. BY	DATE
C	ISSUED TO WATER BOARD	GWF	APR. 17/03
B	FINAL DESIGN	GWF	APR 03/03
A	PRELIMINARY DESIGN	GWF	FEB 3/03
ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

FINAL DESIGN

DESIGNED BY: BF/LH	DRAWN BY: CPW
DATE: JAN. 2003	DATE: JAN. 2003
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE:
PROJ. MGR:	PROJ. ENGR.
DATE	DATE

SRK PROJECT NUMBER: 1CD003.22

Deloitte & Touche Inc.

FWSD BREACH
FARO MINE, YUKON TERRITORY

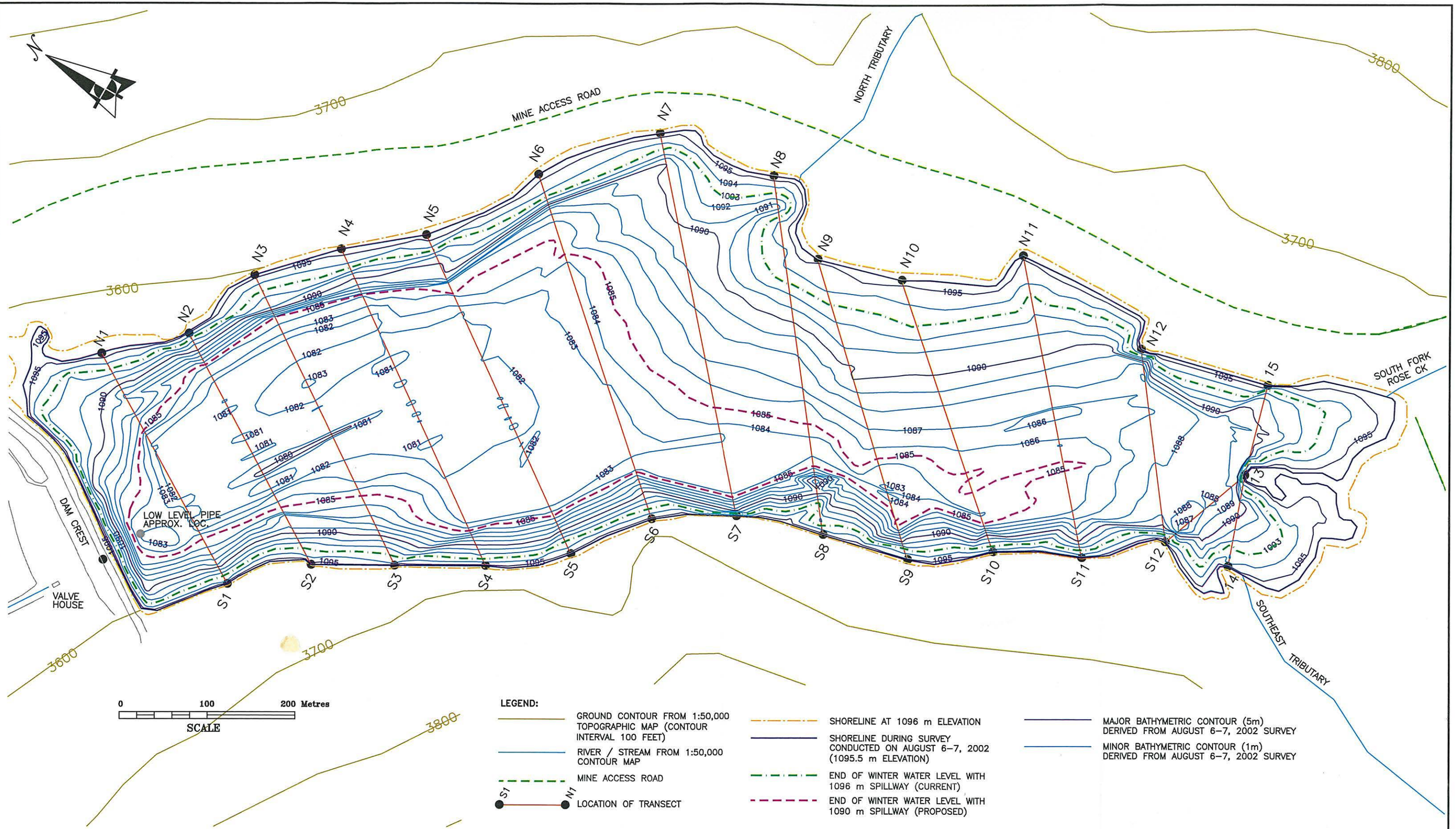
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FISH HABITAT IN THE ROSE CREEK WATERSHED

FIGURE NUMBER 2.16

REV. C

FILE NAME: P:\Deloitte_touche\Acad drawings-Faro\Faro FWSD\Figure GL2.16.dwg



DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D	APP'D	DATE
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SRK Consulting Engineers and Scientists

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DATE: JAN. 2003	DATE: JAN. 2003
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE:
PROJ. MGR:	PROJ. ENGR.
DATE	DATE

SRK PROJECT NUMBER: 1CD003.22

Deloitte & Touche Inc.

FWSD BREACH
FARO MINE, YUKON TERRITORY

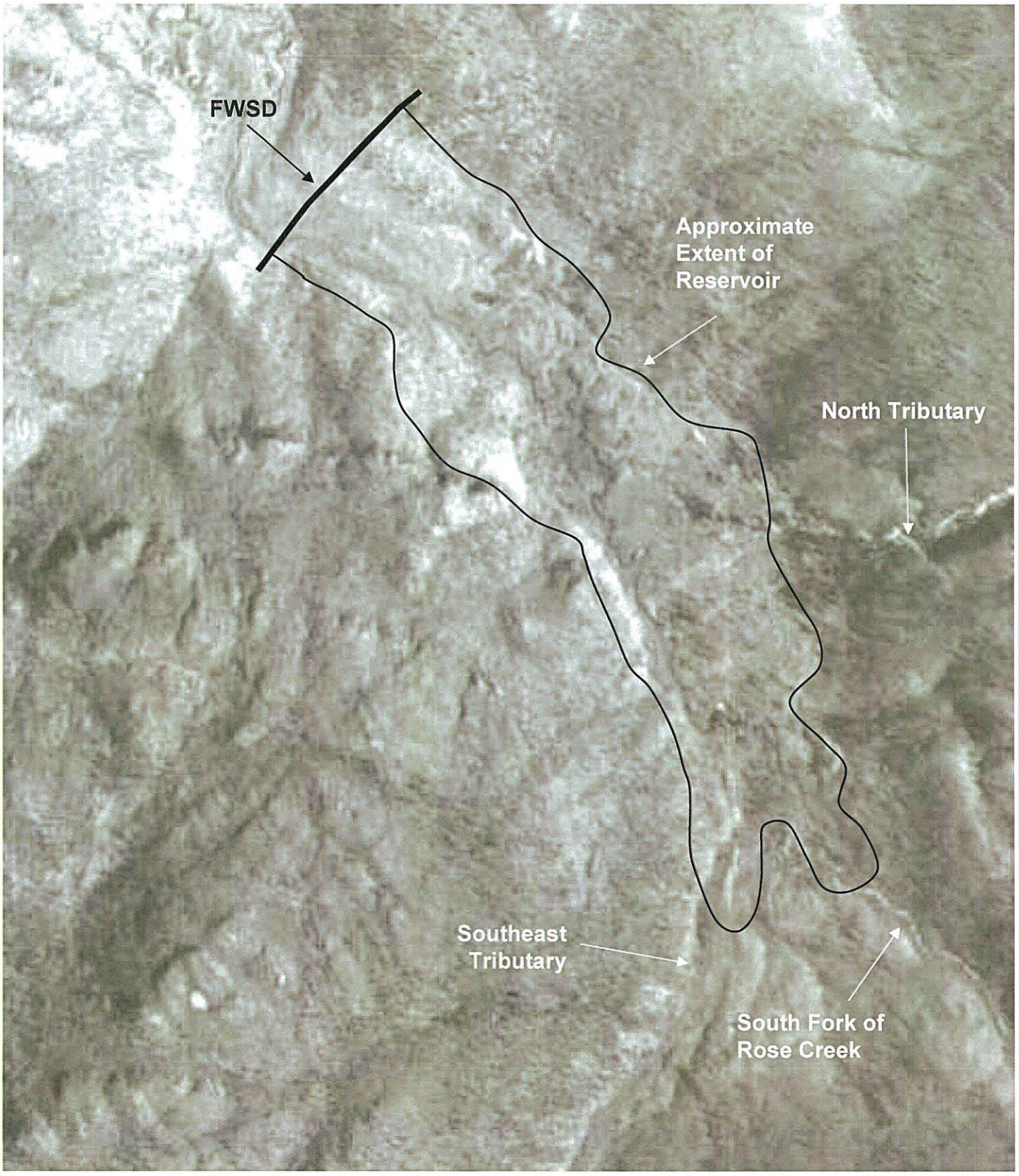
SCALE: AS SHOWN

BATHYMETRIC MAP OF FRESHWATER SUPPLY RESERVOIR

FIGURE NUMBER 2.17

REV. C

FILE NAME: F:\Deloitte_touche\Used drawings-Faro\dwg FWSD\Figure 2.17.dwg



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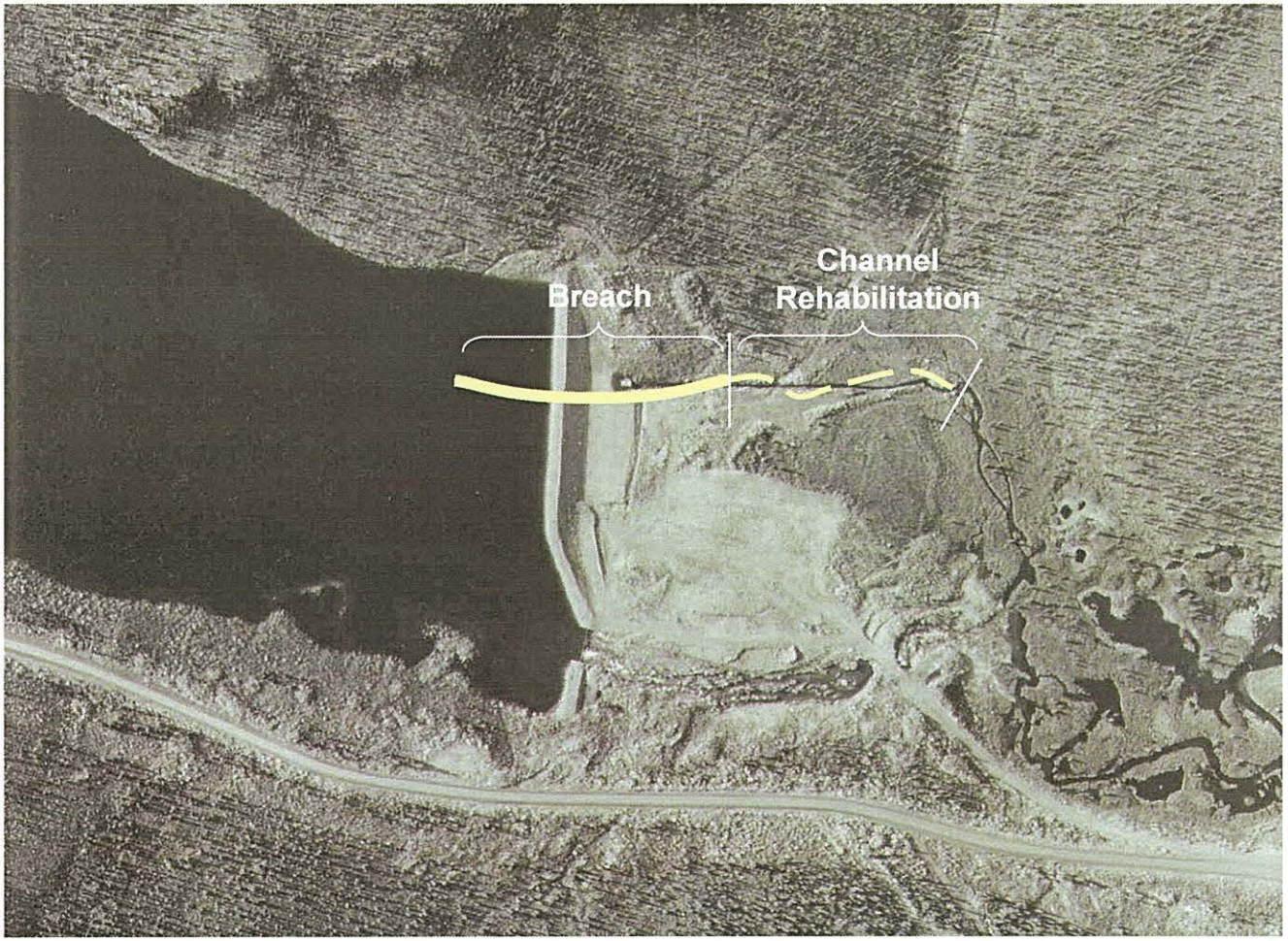
SRK Consulting Engineers and Scientists

Deloitte & Touche Inc.

FWSD Breach
Faro Mine, Yukon Territory

1948 Air Photo of Reservoir

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**2.18**



Source: Airphoto – OS9009015-1-12 & -13, Scale 1:10,000 Line 1-SE (1-15) 8700 ASL, September 17, 1990

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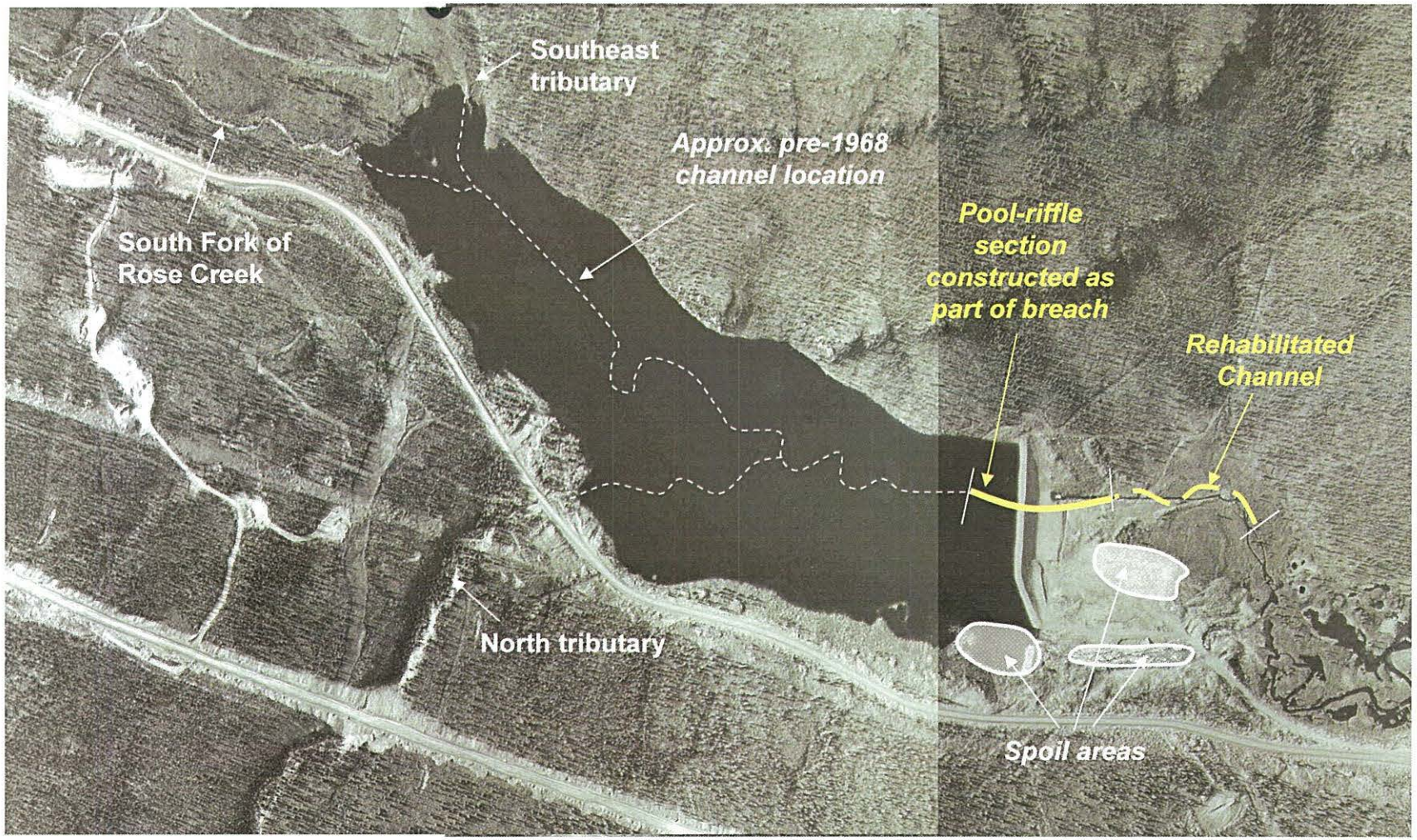
SRK Consulting Engineers and Scientists

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FWSD Breach
Faro Mine, Yukon Territory

Breach & Rehabilitated Channel Approximate Locations

PROJECT:	DATE:	APPROVED:	FIGURE::
1CD003.22	April 2003	GWF	**5.1**



Source: Airphoto – OS9009015-1-12 & -13, Scale 1:10,000 Line 1-SE (1-15) 8700 ASL, September 17, 1990

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FWSD Breach
Faro Mine, Yukon Territory

Approximate Post Breach Channel Configuration

PROJECT:	DATE:	APPROVED:	FIGURE
1CD003.22	April 2003	GWF	**5.2**

FWSD BREACH PROJECT CONSTRUCTION SCHEDULE

ID	Task Name
1	**Tender Process**
2	Issue contract
3	**Lower the reservoir**
4	lower the reservoir
5	Perform Phase I revegetation
6	Complete lowering
7	**Construction**
8	Mobilization
9	Prepare Borrow area / fish exclusion elements
10	Prepare flume
11	Create sump area
12	Continued pumping
13	Complete Notch Excavation
14	Decommission low level pipe
15	Place habitat elements in notch
16	Create downstream mitigation
17	Backfill sump area and perform clean up
18	Freshet 2004 (early start date)
19	Freshet 2004 (earilies measured)
20	Freshet 2004 (latest measured)

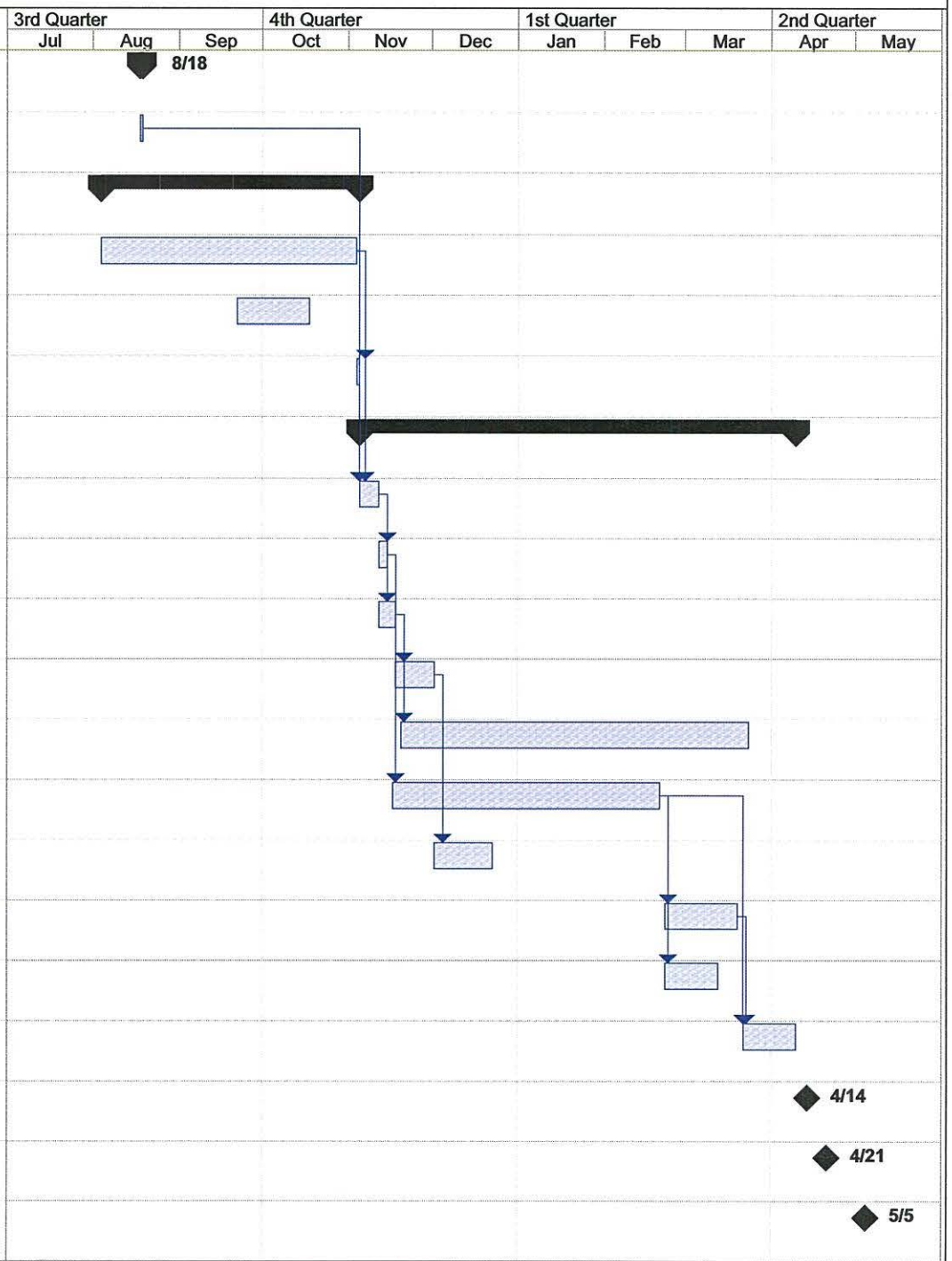


Fig. 5.3

Photos



Photo 1: FWSD



Photo 2: Spillway near North Abutment of FWSD

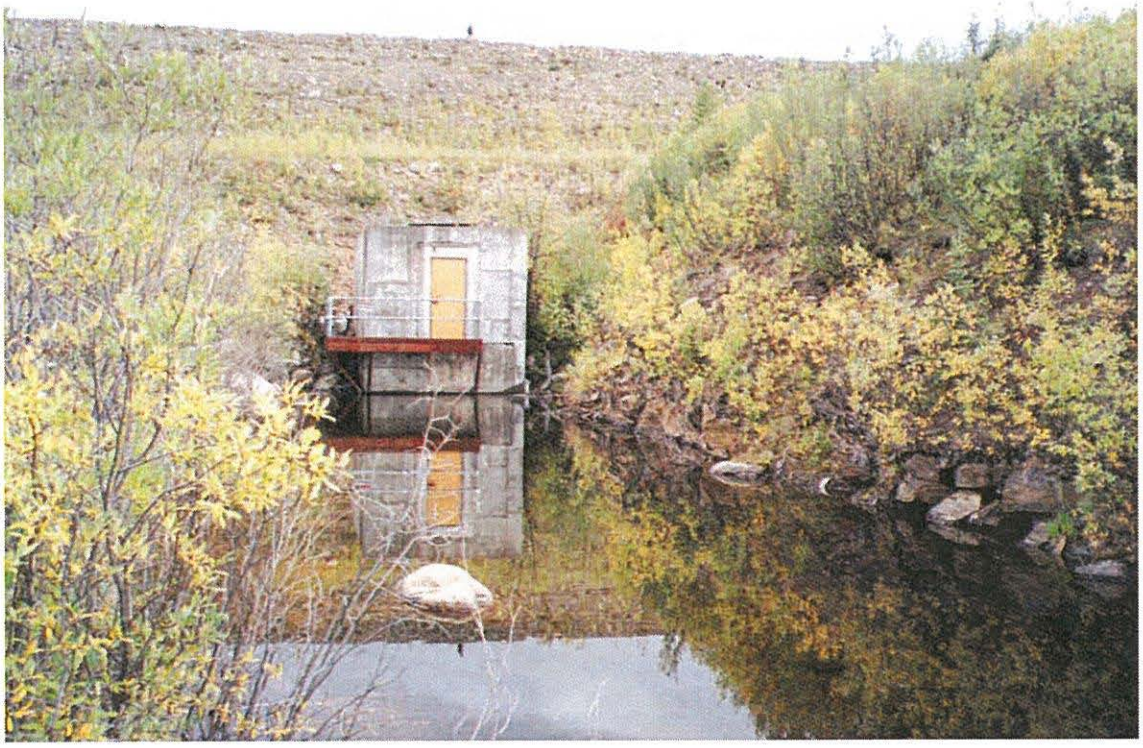


Photo 3: Valve House and portion of Fresh Water Channel



Photo 4: Fresh Water Channel



Photo 5: Culvert Discharge at downstream end of spillway



Photo 6: Cracking on the crest of the FWSD



Photo 7: South Fork of Rose Creek – upstream from the FWSD reservoir



Photo 8: North Tributary as it enters the FWSD Reservoir



Photo 9: Southeast Tributary at the entrance to the FWSD reservoir



Photo 10: South Fork of Rose Creek, downstream of reservoir



Photo 11: View of the exposed reservoir base near the south abutment of the FWSD



Photo 12: View of the exposed reservoir base, near the spillway



Photo 13: Exposed reservoir base



Photo 14: Exposed reservoir base

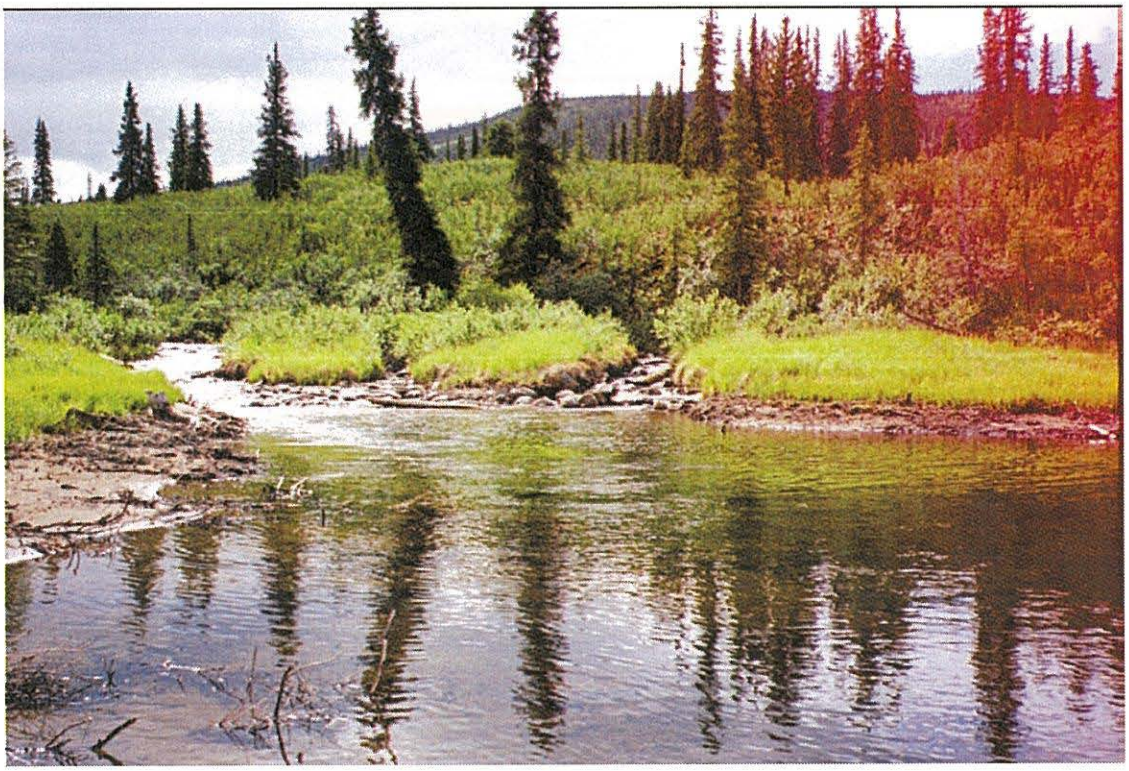


Photo 15: South Rose Creek inlet (July 26/02)

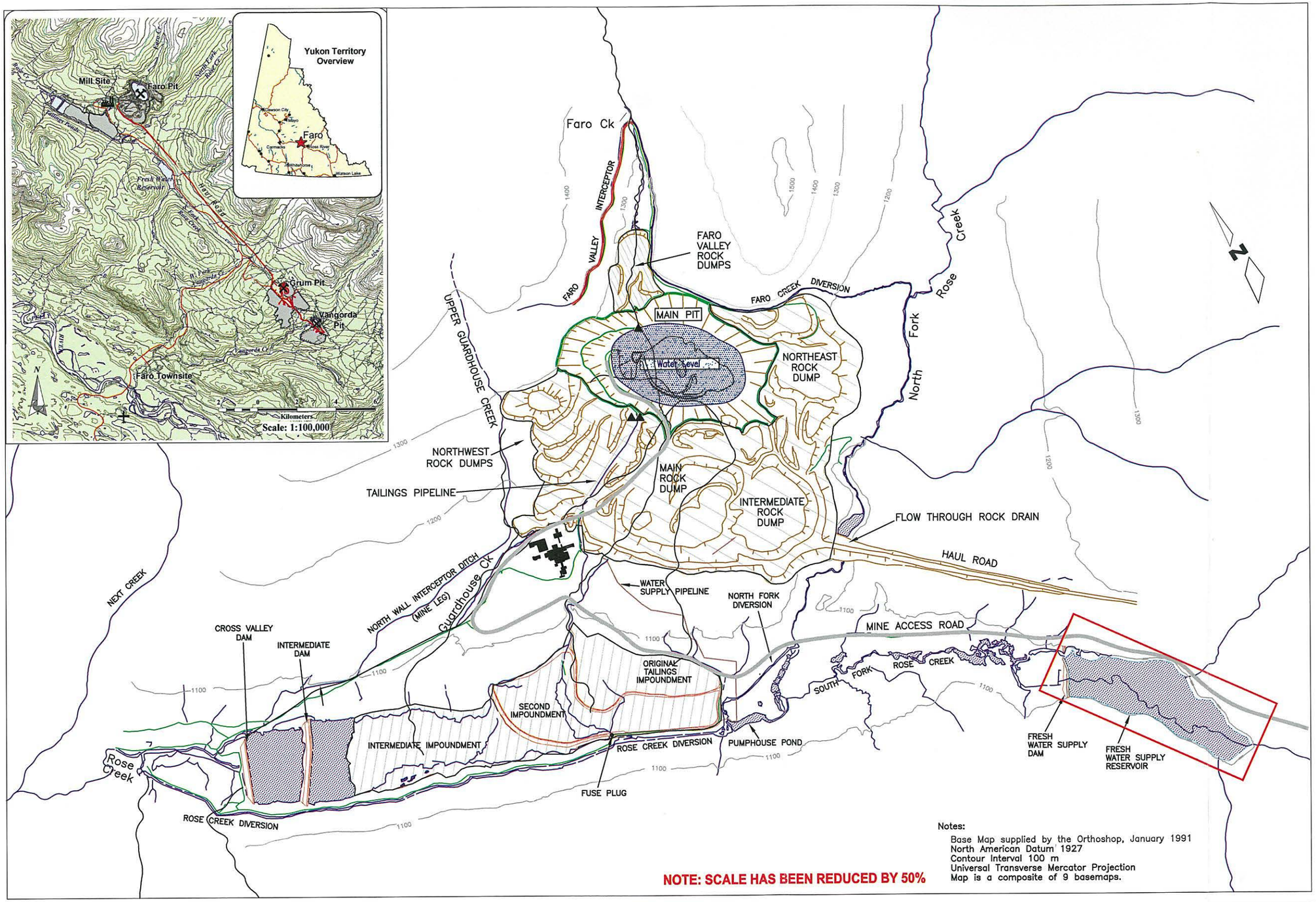


Photo 16: New inlet of Southeast Tributary



Photo 17: Near inlet of South Fork of Rose Creek

Reduced Drawings



DRAWING INDEX:

DRAWING 1.: COVER SHEET
DRAWING 2.: FWSD EXISTING CONDITIONS
DRAWING 3.: FWSD DETAILS: EXISTING CONDITIONS
DRAWING 4.: RESERVOIR SITE PLAN
DRAWING 5.: FWSD BREACH GENERAL ARRANGEMENT
DRAWING 6.: FWSD BREACH SECTIONS
DRAWING 7.: FWSD BREACH PLAN AND PROFILE
DRAWING 8.: REHABILATED CHANNEL PLAN & PROFILE
DRAWING 9.: FWSD INLET DETAILS
DRAWING 10.: FWSD CHANNEL DETAILS
DRAWING 11.: LOW LEVEL OUTLET ABANDONMENT
DRAWING 12.: WATER MANAGEMENT
DRAWING 13.: CONSTRUCTION AREA AND REVEGETATION PLAN

Notes:

Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour Interval 100 m
Universal Transverse Mercator Projection
Map is a composite of 9 basemaps.

NOTE: SCALE HAS BEEN REDUCED BY 50%

REFERENCE DRAWINGS

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Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

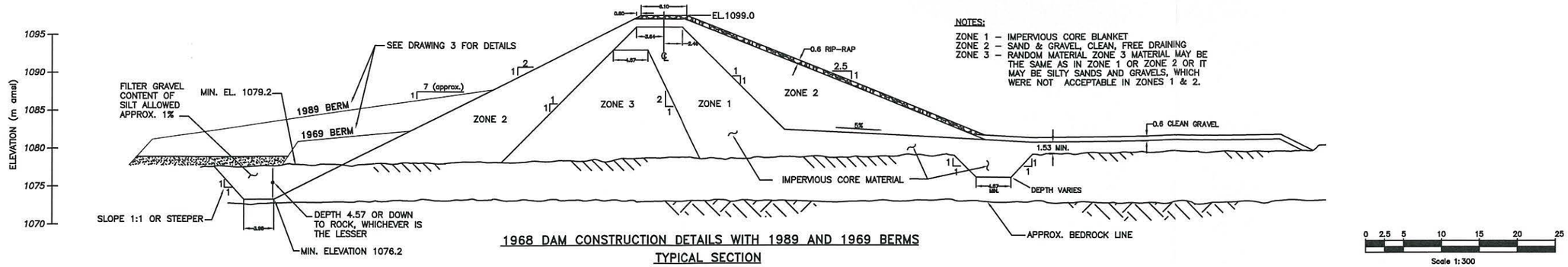
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COVER SHEET

DRAWING NUMBER: 1

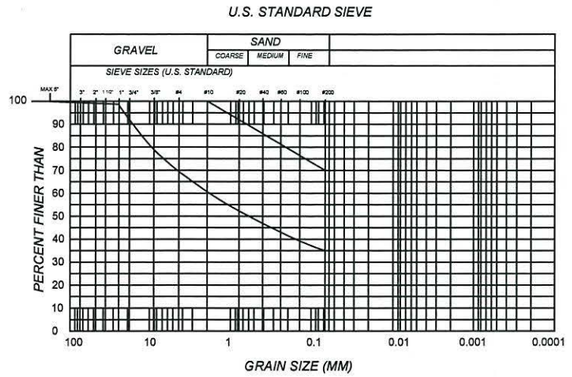
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FILE NAME: P:\Deloitte_Inc\dwg\Last drawings-Faro\Faro FWSD\Figure 1.dwg



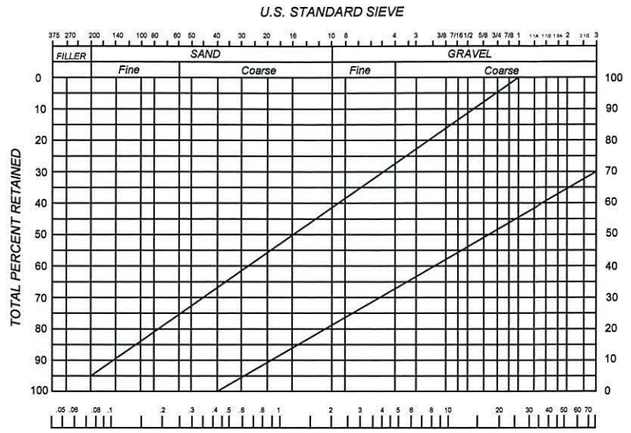
1968 DAM CONSTRUCTION DETAILS WITH 1989 AND 1969 BERMS
TYPICAL SECTION

SOURCE: AS BUILT DRAWING NO. D1575–058–006, REV.06
PARSONS–JURDEN CORPORATION, OCT. 1968



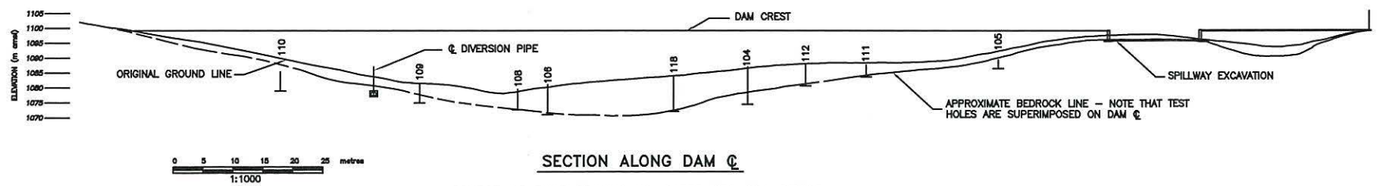
DESIGN GRADATION CURVE LIMITS - ZONE 1

SOURCE: AS BUILT DRAWING NO. D1575–058–006, REV.06
PARSONS–JURDEN CORPORATION, OCT. 1968



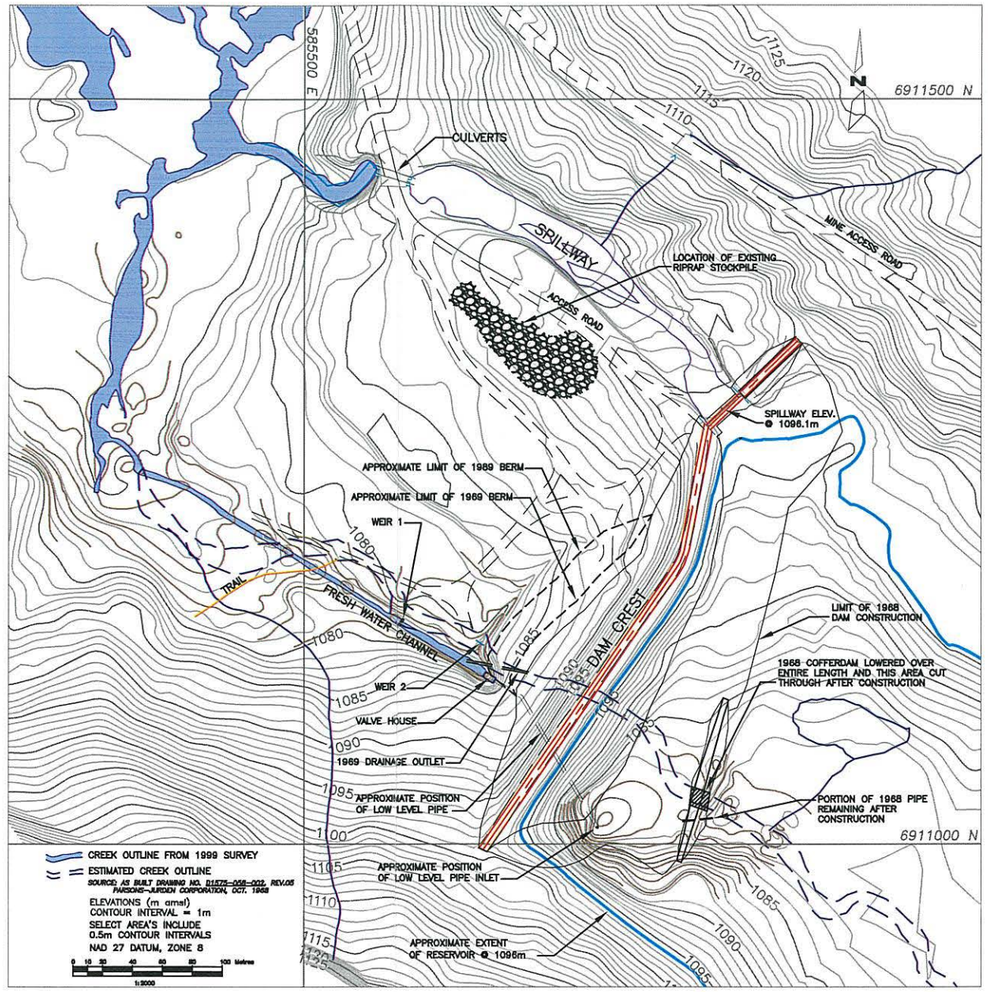
DESIGN GRADATION CURVE LIMITS - ZONE 2

SOURCE: AS BUILT DRAWING NO. D1575–058–006, REV.06
PARSONS–JURDEN CORPORATION, OCT. 1968



SECTION ALONG DAM ℄

SOURCE: AS BUILT DRAWING NO. D1575–058–004, REV.05
PARSONS–JURDEN CORPORATION, OCT. 1968



NOTE: SCALE HAS BEEN REDUCED BY 50%

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C	ISSUED TO WATER BOARD	GWF	APR. 17/03
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ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: JAN. 2003	DATE:
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

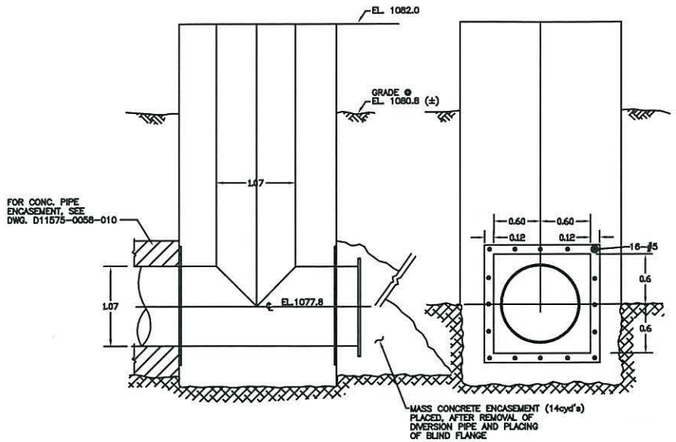
SCALE: AS SHOWN

FWSD EXISTING CONDITIONS

DRAWING NUMBER 2

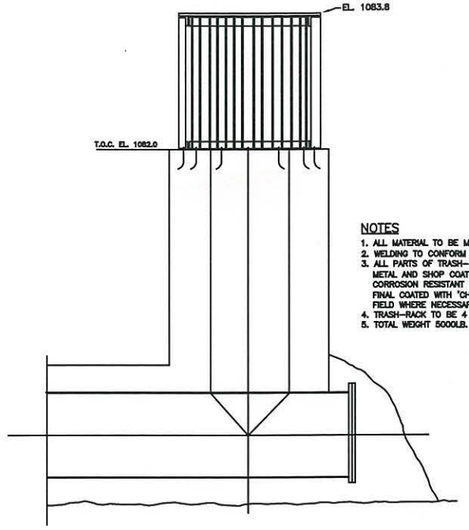
REV. C

FILE NAME: P:\Deloitte_touche\Acad drawings-Fors\fors FWSD\Figure 2.dwg



LOW-LEVEL PIPE INLET
SECTION ELEVATION
CONCRETE OUTLINE

SOURCE: AS BUILT DRAWING NO. D1575-058-013, REV.04
PARSONS-JURDEN CORPORATION, OCT. 1968

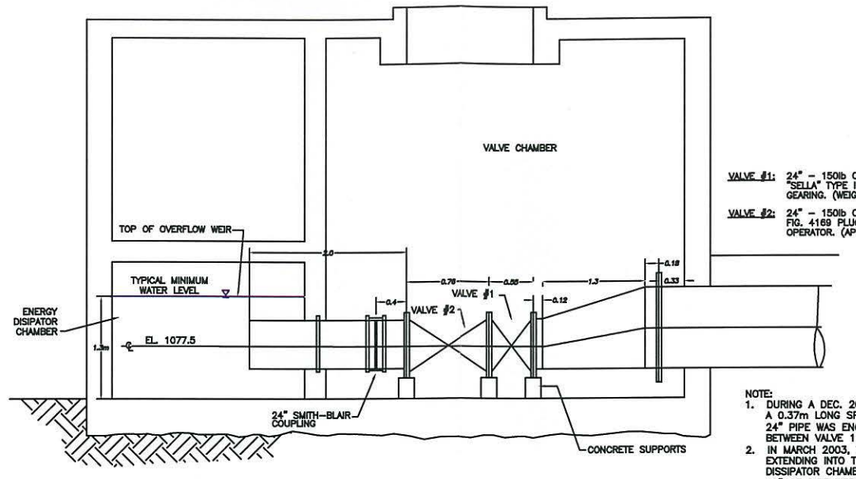


NOTES
1. ALL MATERIAL TO BE MILD STEEL.
2. WELDING TO CONFORM TO CSA STANDARDS. S16-1965.
3. ALL PARTS OF TRASH-RACK TO BE SAND-BLASTED TO WHITE METAL AND SHOP COATED WITH PCE-414 'FLINTGUARD' CORROSION RESISTANT COATING TO 20 MIL. THICKNESS AND FINAL COATED WITH 'CHEMROX' VINYL ENAMEL. TOUCH UP IN FIELD WHERE NECESSARY.
4. TRASH-RACK TO BE 4 PANELS AS SHOWN
5. TOTAL WEIGHT 5000LB.

TRASH RACK DETAILS

SOURCE: AS BUILT DRAWING NO. D1575-058-017, REV.04
PARSONS-JURDEN CORPORATION, OCT. 1968

0 .5 1 1.5 2 2.5 Metres
1:40



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

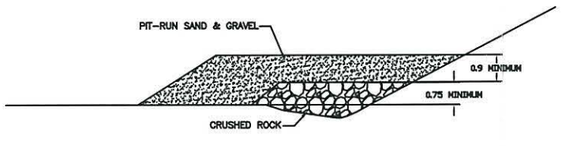
VALVE #2: 24" - 150lb CAST STEEL "ROCKWELL-NORDSTROM" FIG. 4169 PLUG VALVE WITH WORM GEAR OPERATOR. (APPROX. WEIGHT: 3,500lb.)

NOTE:
1. DURING A DEC. 2002 SITE VISIT, A 0.37m LONG SPOOL PIECE OF 24" PIPE WAS ENCOUNTERED BETWEEN VALVE 1 AND VALVE 2
2. IN MARCH 2003, THE 24" PIPE EXTENDING INTO THE ENERGY DISSIPATOR CHAMBER WAS CUT, 12" OF PIPE WERE REMOVED, AND A HUB FLANGE AND ORIFACE PLATE WERE INSTALLED. A THRUST PLATE WAS INSTALLED ON THE UPSTREAM SIDE OF THE ENERGY DISSIPATOR CHAMBER WALL AND NEW SUPPORTS FOR THE VALVES WERE INSTALLED WITHIN THE VALVE CHAMBER.

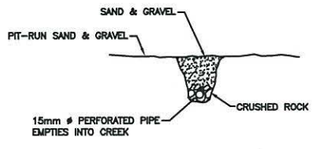
VALVE HOUSE ARRANGEMENT

SOURCE: AS BUILT DRAWING NO. D1575-058-014, REV.05
PARSONS-JURDEN CORPORATION, OCT. 1968

0 2 Metres
1:125



TYPICAL SECTION THROUGH DRAIN AND BERM

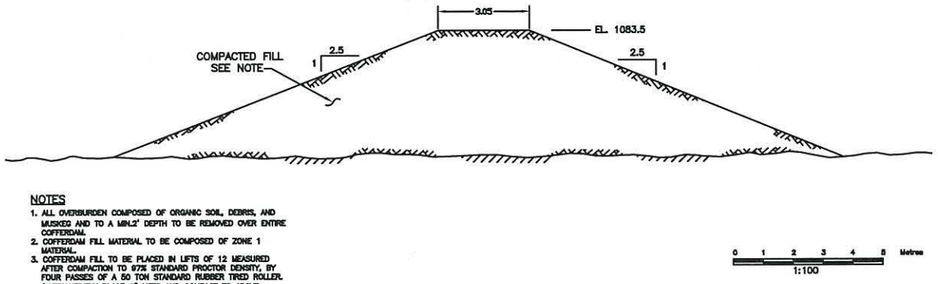


TYPICAL SECTION THROUGH
1969 DRAINAGE OUTLET DITCH

1969 TOE BERM CONSTRUCTION DETAILS

RECOMMENDED TOE DRAINAGE DRAWING D-1223-C
ACCOMPANING LETTER OF JUNE 18, 1969
SOURCE: RIPLEY,KLOHN & LEONOFF INTERNATIONAL LTD.

0 1 2 3 4 5 Metres
1:100

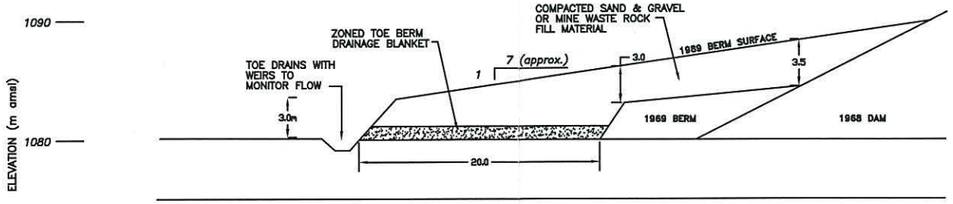


NOTES
1. ALL OVERBURDEN COMPOSED OF ORGANIC SOIL, DEBRIS, AND MUSKEG AND TO A MIN.2' DEPTH TO BE REMOVED OVER ENTIRE COFFERDAM.
2. COFFERDAM FILL MATERIAL TO BE COMPOSED OF ZONE 1 MATERIAL.
3. COFFERDAM FILL TO BE PLACED IN LIFTS OF 12 MEASURED AFTER COMPACTION TO 97% STANDARD PROCTOR DENSITY, BY FOUR PASSES OF A 50 TON STANDARD RUBBER TIRED ROLLER. (ALTERNATIVELY PLACE 8" LIFTS AND COMPACT TO ABOVE DENSITY USING A "SHEEP'S FOOT ROLLER"

0 1 2 3 4 5 Metres
1:100

UPSTREAM COFFERDAM TYPICAL DETAIL

SOURCE: AS BUILT DRAWING NO. D1575-058-011, REV.06
PARSONS-JURDEN CORPORATION, OCT. 1968



TYPICAL SECTION - 1989 TOE BERM CONSTRUCTION DETAILS

SOURCE: 1988 ANNUAL INSPECTION OF THE FARO MINE.
GOLDER ASSOCIATES LTD.

0 4 8 12 16 20 Metres
1:250

NOTE: SCALE HAS BEEN REDUCED BY 50%

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SRK Consulting Engineers and Scientists

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DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

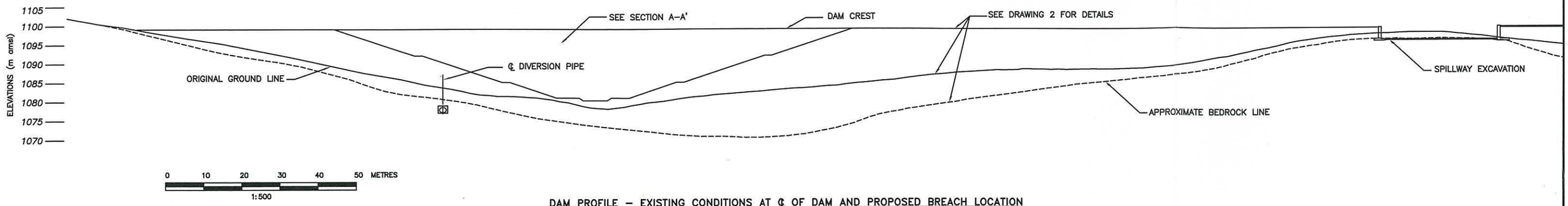
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FWSD DETAILS: EXISTING CONDITIONS

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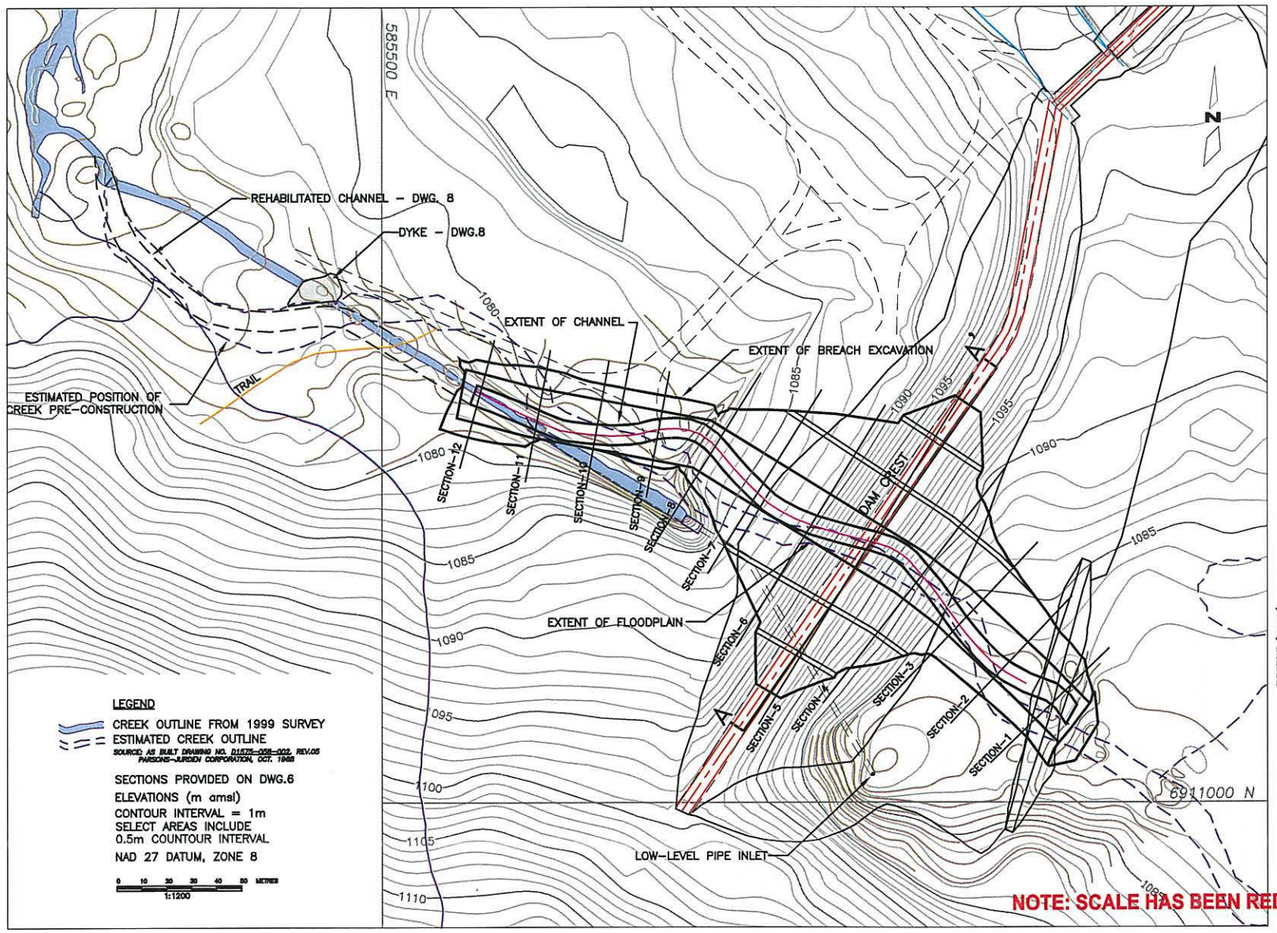
REV. C

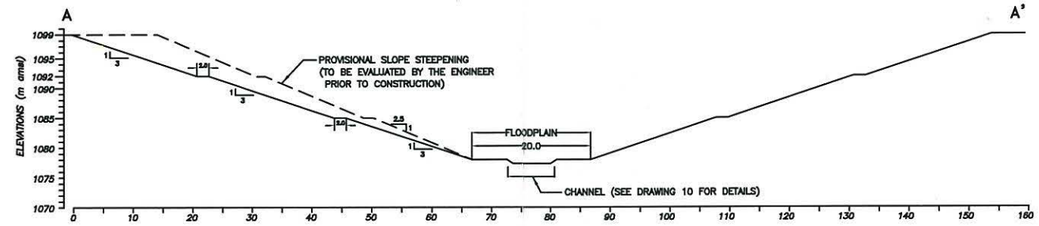
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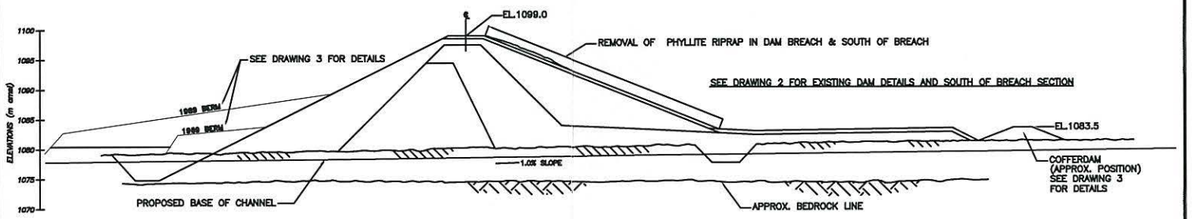
DAM PROFILE – EXISTING CONDITIONS AT ℄ OF DAM AND PROPOSED BREACH LOCATION

SOURCE: AS BUILT DRAWING NO. D1575–058–004, REV.05
PARSONS–JURDEN CORPORATION, OCT. 1968





SECTION A–A' – PROPOSED BREACH GENERAL EXCAVATION DETAIL



TYPICAL DAM SECTION PROPOSED CHANNEL BASE

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE
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NO.	DESCRIPTION	CHK'D/APP'D	DATE
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ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

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PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

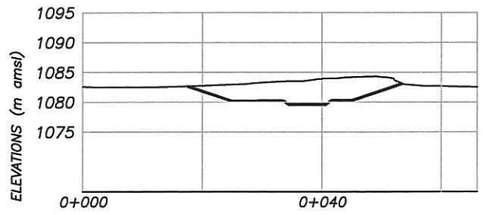
SCALE: AS SHOWN

FWSD BREACH GENERAL ARRANGEMENT

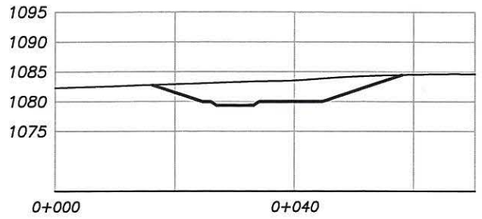
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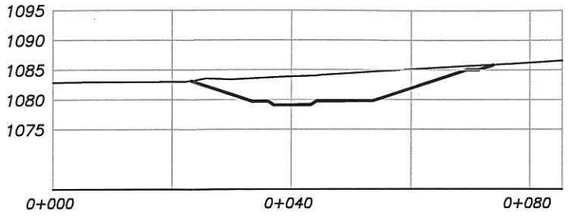
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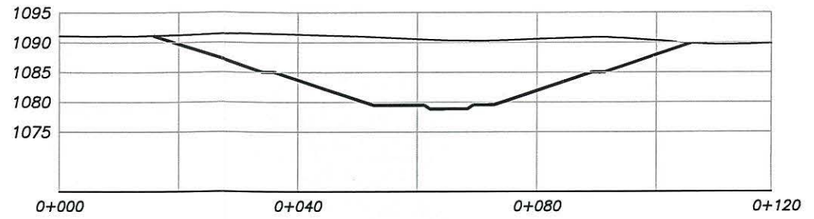
Section–1



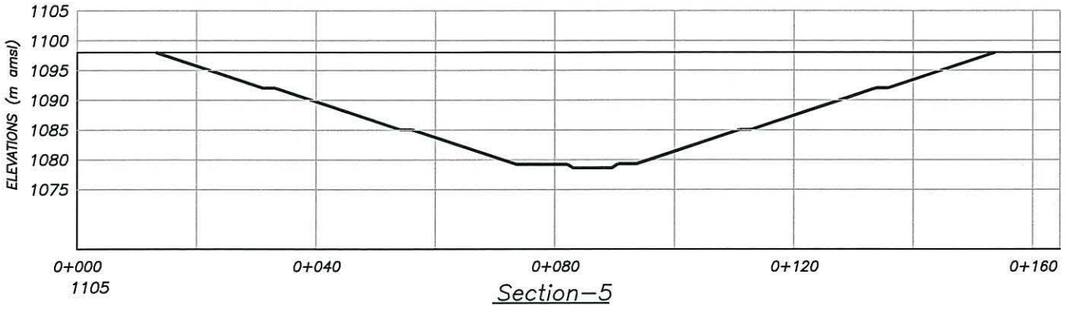
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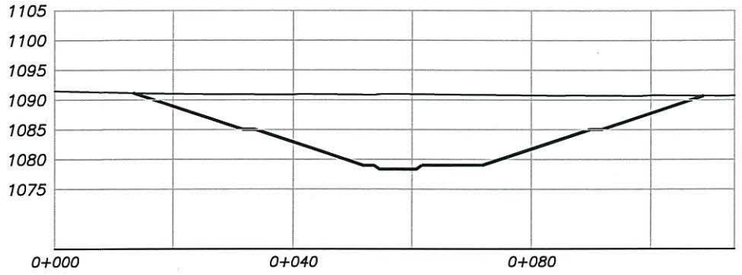
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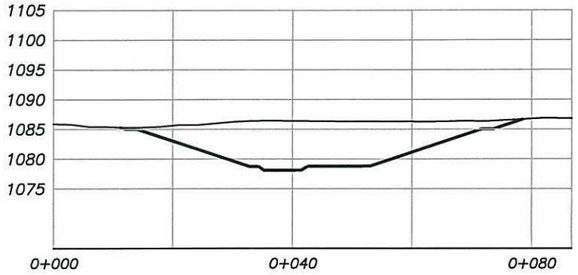
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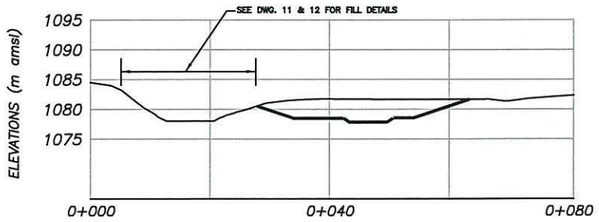
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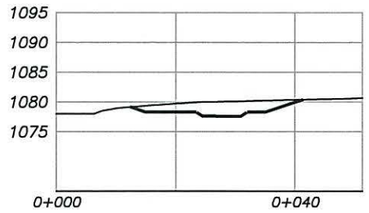
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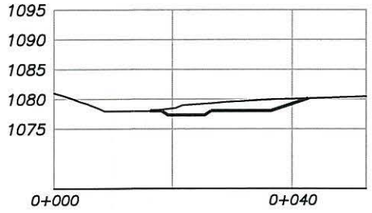
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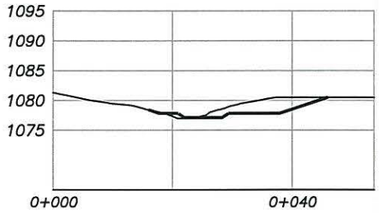
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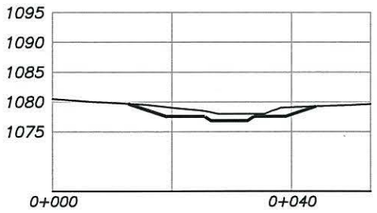
Section–9



Section–10



Section–11



Section–12

LEGEND

EXISTING SURFACE

FINISHED DESIGN GRADE

NOTE: SCALE HAS BEEN REDUCED BY 50%

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NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

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Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

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PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE

SRK PROJECT NUMBER: 1CD003.22

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:750

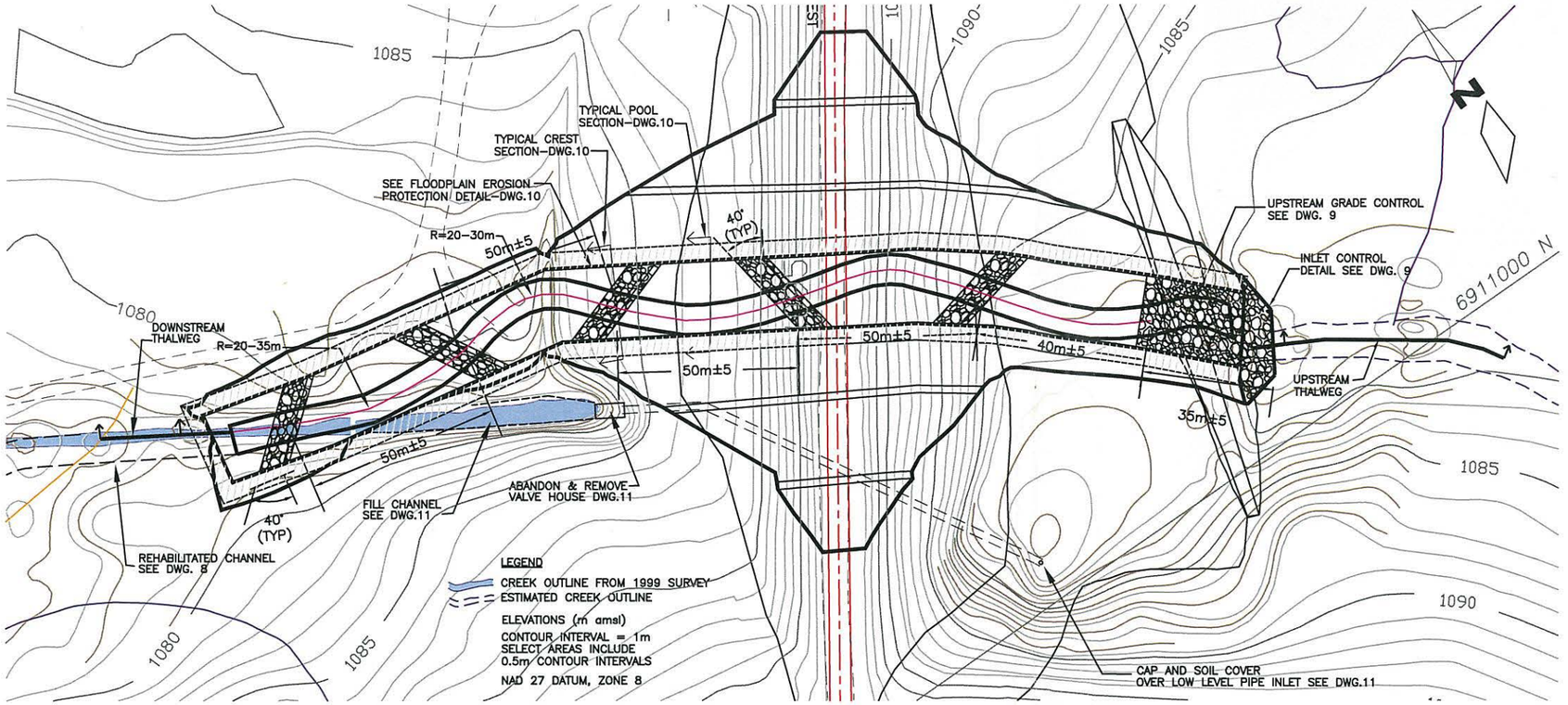
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Metres

FWSD BREACH SECTIONS

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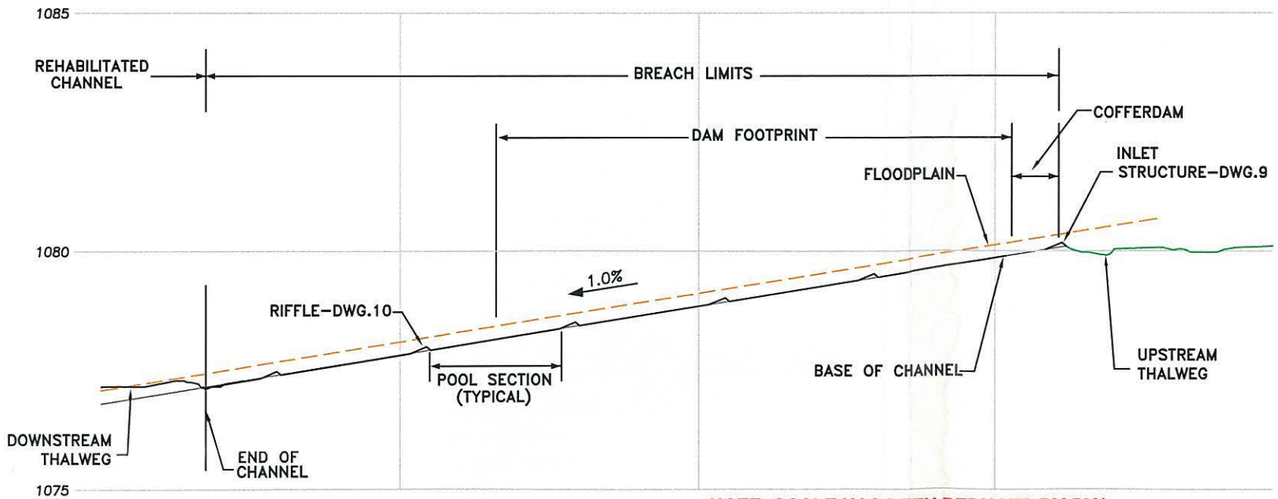
REV. C

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RIFFLE STRUCTURE STARTING AT UPSTREAM END	ELEVATION OF RIFFLE CREST (EXCLUDING THE SLOPE TO THE RIFFLE CENTRE)
INLET STRUCTURE	1080.50
RIFFLE	1079.92
RIFFLE	1079.32
RIFFLE	1078.72
RIFFLE	1078.12
RIFFLE	1077.50

NOTE: DETAILED COORDINATES TO BE PROVIDED PRIOR TO CONSTRUCTION



HORIZONTAL SCALE – 1:1000
VERTICAL SCALE – x2

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE
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FRESH WATER SUPPLY DAM BREACH
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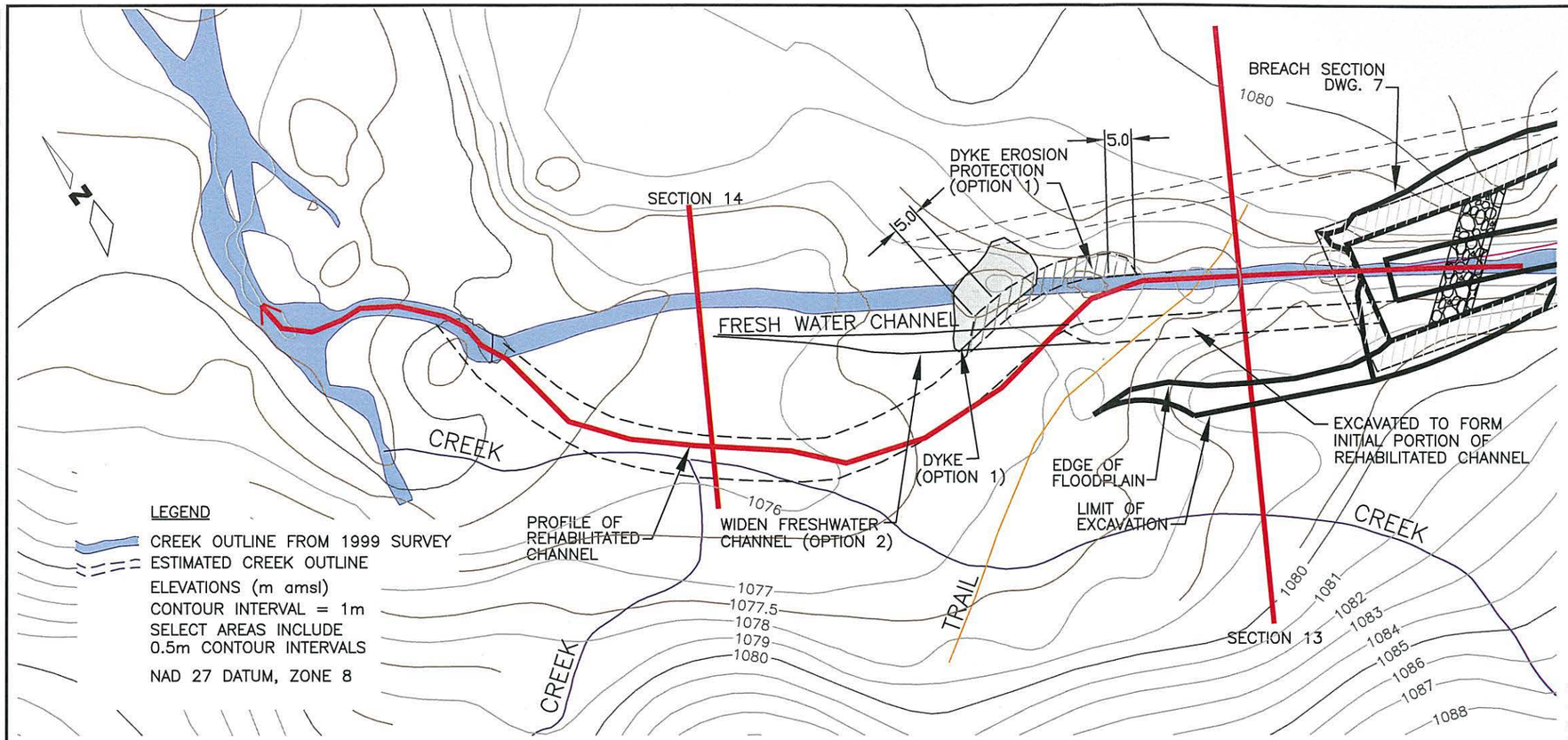
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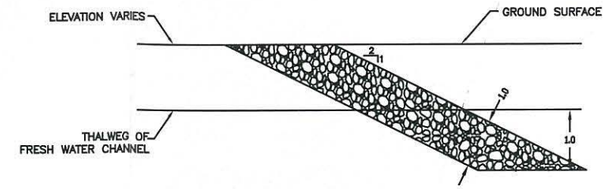
FWSD BREACH PLAN AND PROFILE

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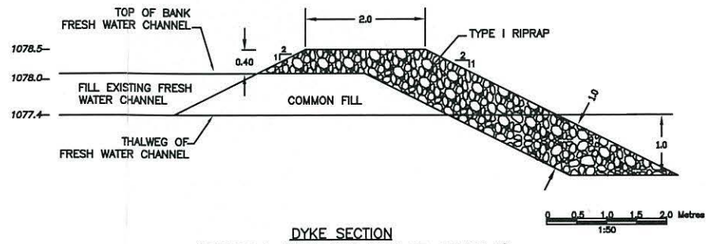
REV. C

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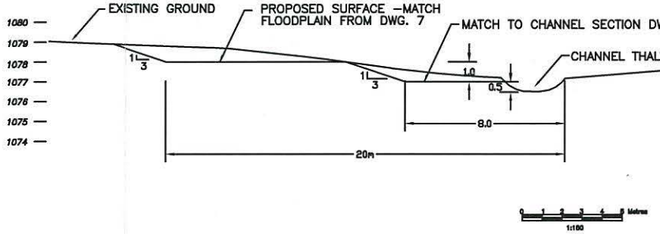




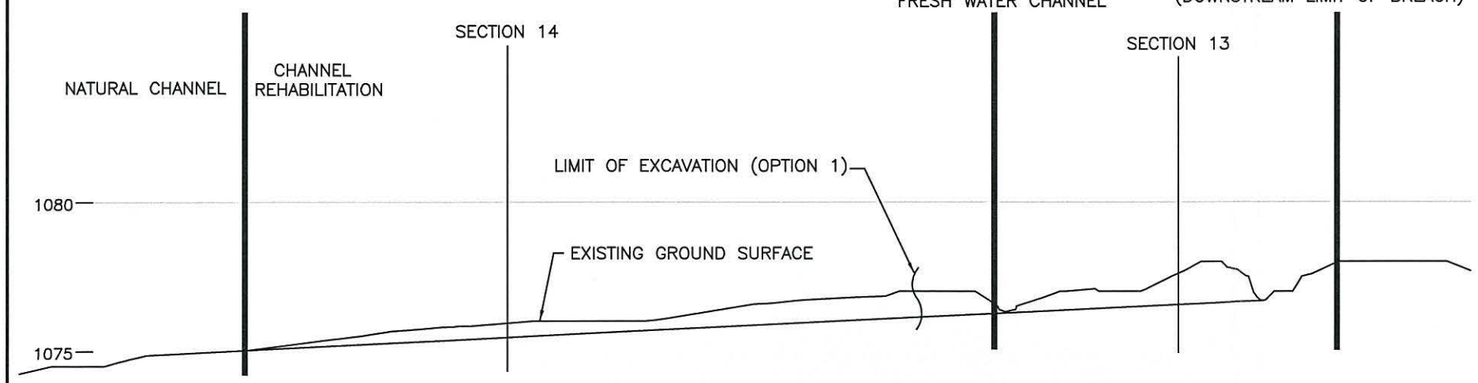
DYKE EROSION PROTECTION DETAIL
(OPTION 1 ONLY, NOT PART OF OPTION 2)



DYKE SECTION
(OPTION 1 ONLY, NOT PART OF OPTION 2)



SECTION 13 – REHABILITATED CHANNEL



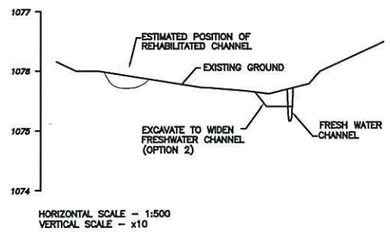
PROFILE OF REHABILITATED CHANNEL

NOTE: SCALE HAS BEEN REDUCED BY 50%

Note:
Downstream of the breach is the segment of the works referred to as the rehabilitated channel. The rehabilitated channel shall be constructed by either Option 1 or Option 2, described below. Option 1 is preferred, but final selection will be made following detailed inspection in summer 2003.

Option 1 to consist of installing dyke erosion protection, dyke and excavation of the initial position of the rehabilitated channel. These elements direct water into the location of the creek prior to 1968.

Option 2 to consist of widening the existing fresh water channel to accommodate 2–yr flood event.



SECTION 14 – REHABILITATED CHANNEL

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

REV.	ISSUE PURPOSE	AUTH. BY	DATE
C	ISSUED TO WATER BOARD	GWF	APR. 17/03
B	FINAL DESIGN	GWF	APR. 03/03
A	PRELIMINARY DESIGN	GWF	FEB 3/03
ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

DESIGNED BY: GWF | DRAWN BY: DC/JM
DATE: Jan. 2003 | DATE:
CHECKED BY: CCS | DISCIP. ENGR.
DATE: JAN. 2003 | DATE
PROJ. DES. COORD. | PROJ. ENGR.
DATE | DATE
SRK PROJECT NUMBER: 1CD003.22

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:500
0 10 20 30 40 50 Metres

REHABILITATED CHANNEL PLAN & PROFILE

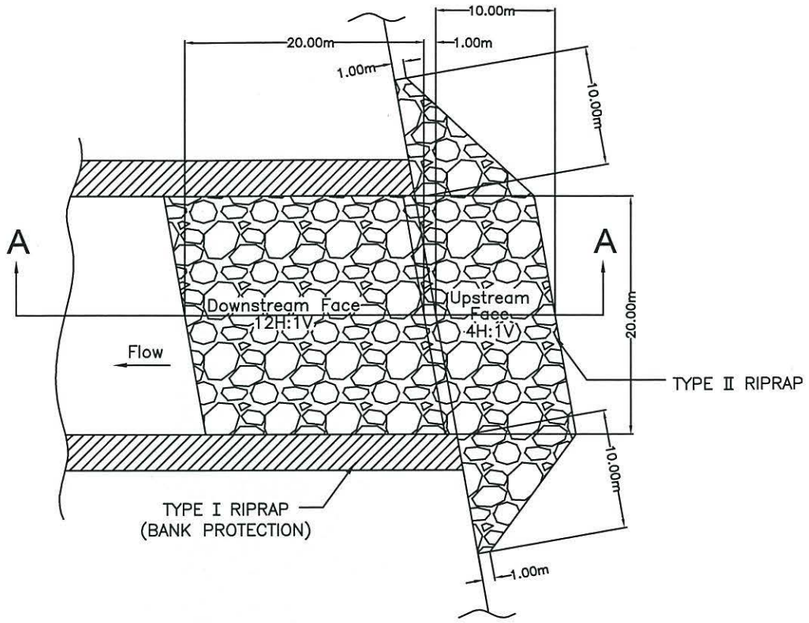
DRAWING NUMBER 8

REV. C

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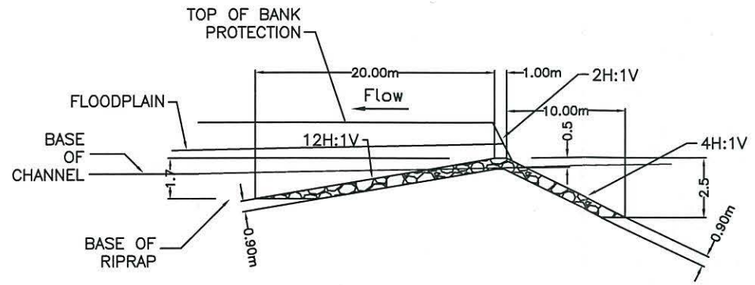
Plan

SCALE: 1:500



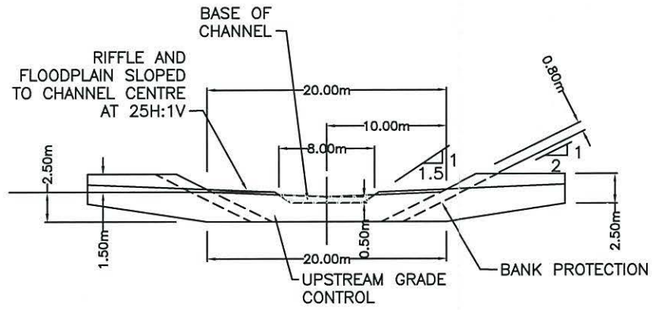
Profile A-A

SCALE: 1:500 HORIZ. 1:250 VERT.



Front View

SCALE: 1:500



Construction Notes:

1) Inlet structure constructed of Type II riprap. (See Dwg.10)
2) Floodplain erosion protection constructed of Type I riprap. (See Dwg.10)
3) Key riffle 2.5 m into channel bed and extend to floodplain erosion protection.
4) Concentrate flow in centre third of channel by sloping rock up towards top of banks (4%) and leaving gaps between the rocks of the middle third of the riffle crest.
5) Concentrate larger stones at riffle crest and space 0.2m to 0.3m apart on downstream slope to dissipate energy.
6) Construct riffle with crest 0.5 m above channel bed elevation.
7) Align face of inlet structure with face of existing Cofferdam.

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D	APP'D	DATE
REVISIONS				

REV.	ISSUE PURPOSE	AUTH. BY	DATE
C	ISSUED TO WATER BOARD	GWF	APR. 17/03
B	FINAL DESIGN	GWF	APR. 03/03
A	PRELIMINARY DESIGN	GWF	FEB. 3/03
ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: Jan. 2003	DATE:
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:250

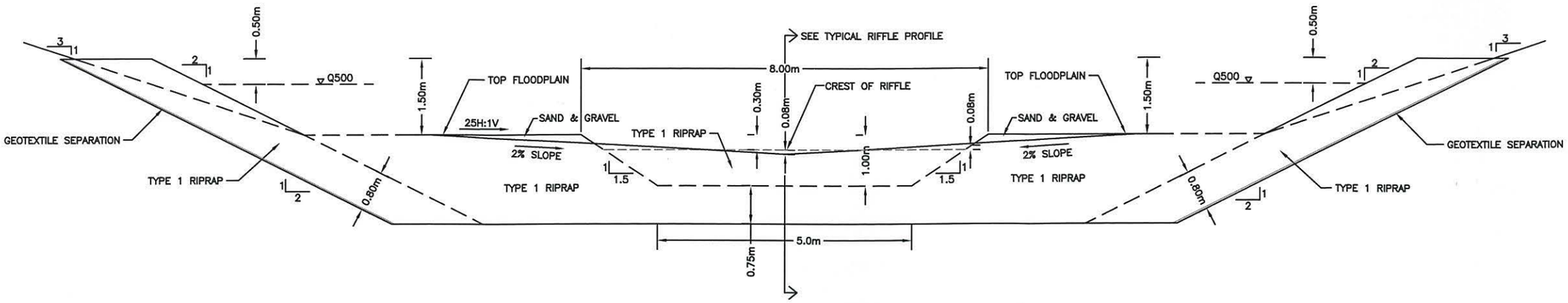
0 1 2 3 4 5 METRES

FWSD INLET DETAILS

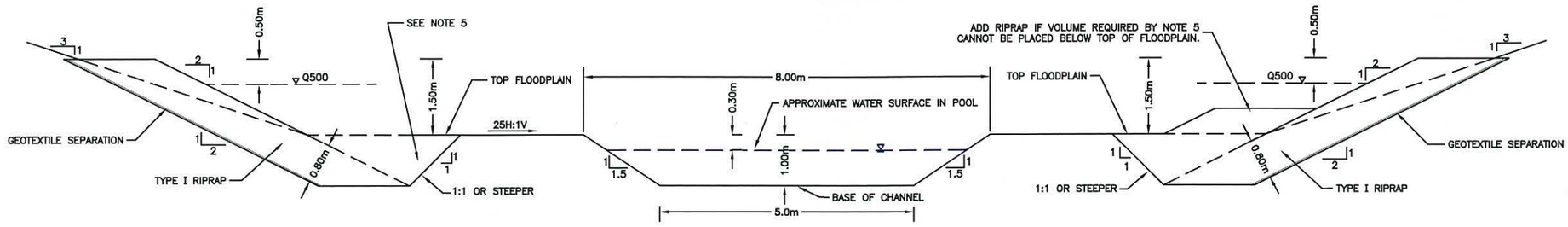
DRAWING NUMBER 9

REV. C

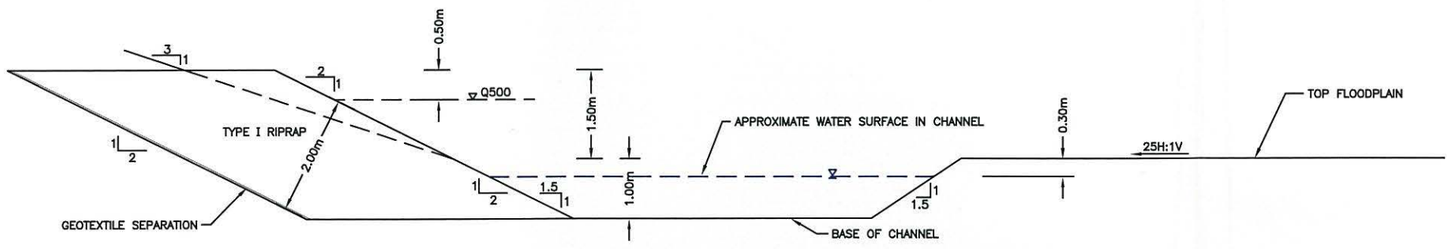
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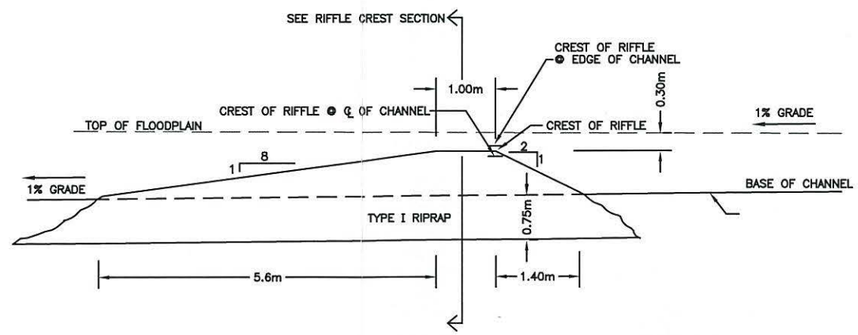
TYPICAL RIFFLE CREST SECTION



TYPICAL FLOODPLAIN EROSION PROTECTION BETWEEN RIFFLES (POOL SECTION)



TYPICAL FLOODPLAIN EROSION PROTECTION WITH CHANNEL AT FLOODPLAIN LIMIT (POOL SECTION)



TYPICAL RIFFLE PROFILE

Construction Notes:

1) Type I riprap – D50 = 0.40m.
2) Type II riprap – D50 = 0.45m.
3) Riffles to be constructed from Type I riprap.
4) Floodplain erosion protection to be constructed from Type I riprap.
5) Maintain a minimum volume of 4.5m^3 per lineal m of floodplain erosion protection below the top of floodplain.
6) Over excavated areas beyond the lines and grades shown can be backfilled with common fill.
7) Geotextile to be used to separate Type I riprap from excavated soils on backslope of floodplain erosion protection.
8) Over excavated areas beyond the lines and grades shown can be backfilled with common fill. If available, the backfill on the upstream side of the riffles should consist of 150 mm minus alluvial gravels.
9) The channel sideslopes may be constructed with a parabolic shape rather than the straight lines shown in the sections.

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D/APP'D	DATE	REV.	ISSUE PURPOSE	AUTH. BY	DATE
						C	ISSUED TO WATER BOARD	GWF	APR. 17/03
						B	FINAL DESIGN	GWF	APR. 03/03
						A	PRELIMINARY DESIGN	GWF	FEB. 3/03
REFERENCE DRAWINGS		REVISIONS				ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: Jan. 2003	DATE:
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

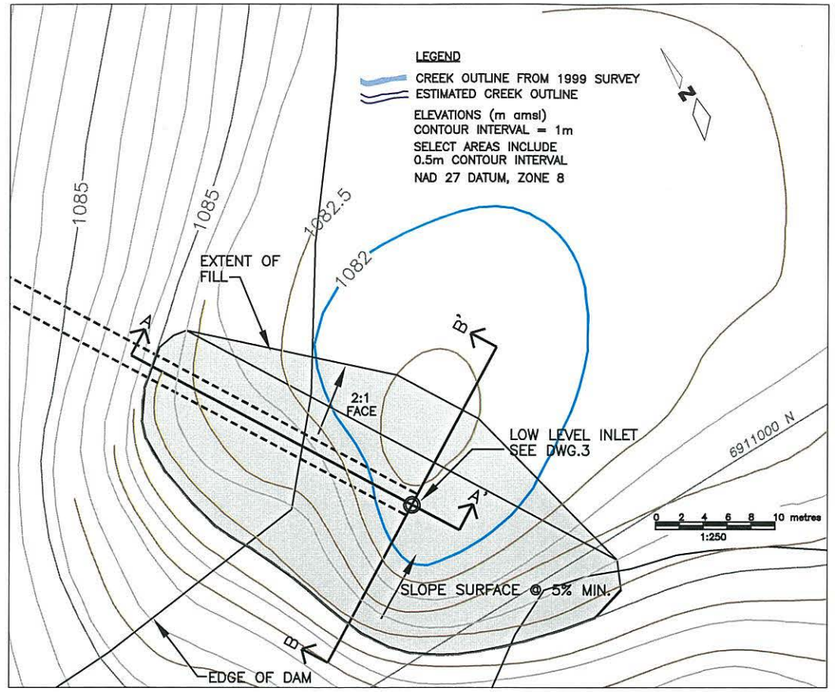
SCALE: 1:50 — 0 1 2 3 4 5 METRES

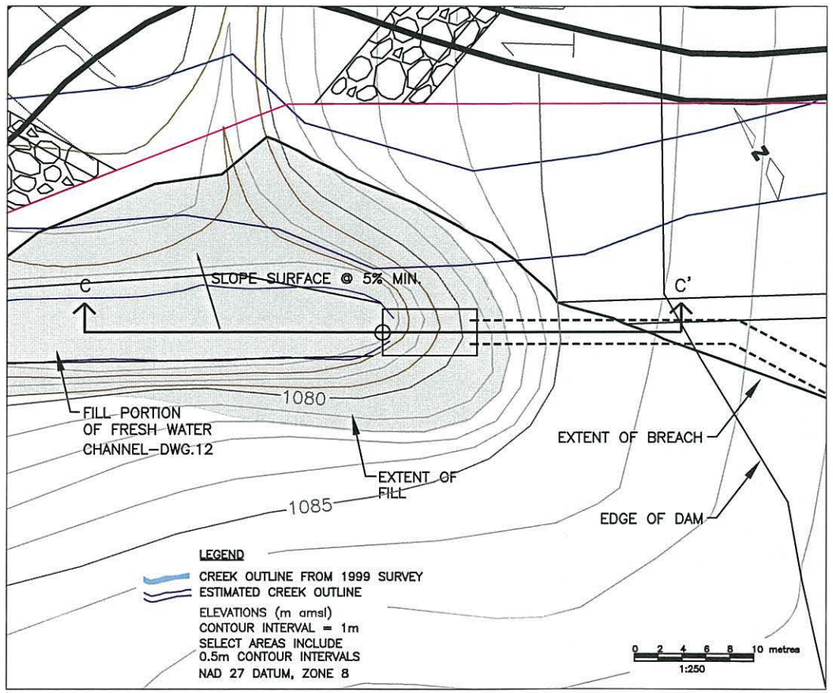
FWSD CHANNEL DETAILS

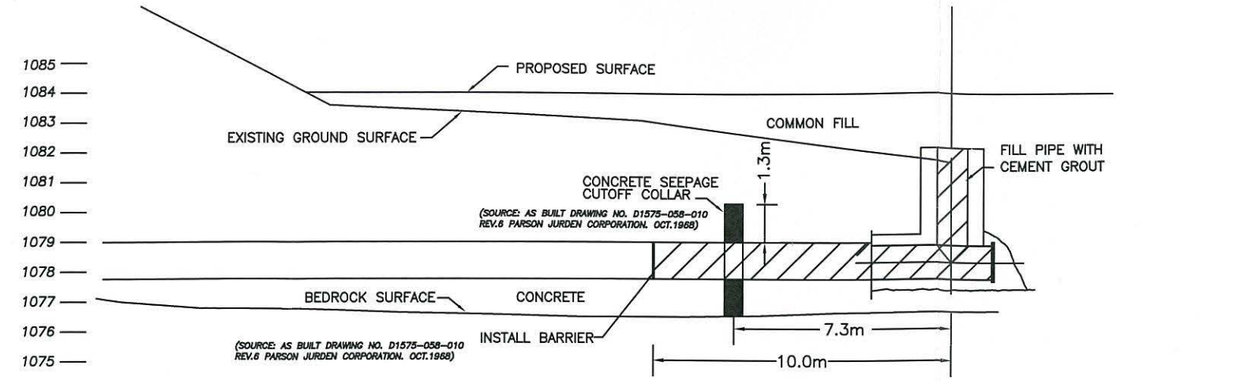
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REV. C

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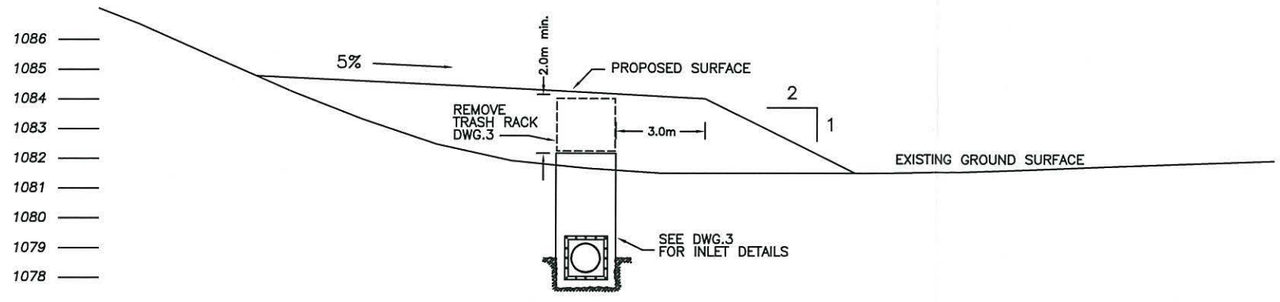






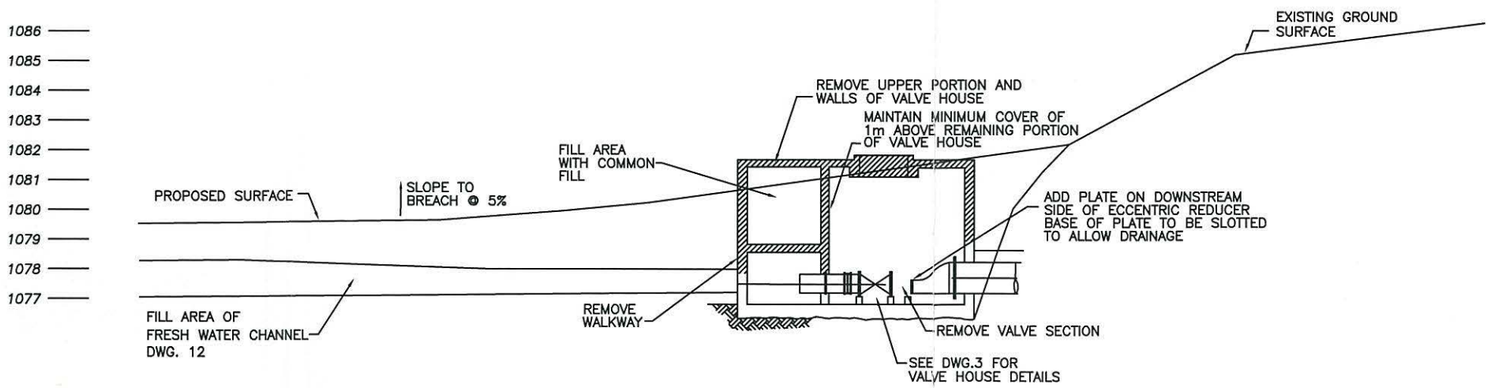
SECTION A – A' INLET – GROUT BACKFILL DETAIL

0 1 2 3 4 5 Metres
1:100



SECTION B – B' INLET – CROSS SECTION DETAIL

0 1 2 3 4 5 Metres
1:100



SECTION C – C' OUTLET – LONGITUDINAL SECTION

0 1 2 3 4 5 Metres
1:100

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D/APP'D	DATE	REV.	ISSUE PURPOSE	AUTH. BY	DATE
						C	ISSUED TO WATER BOARD	GWF	APR. 17/03
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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

FINAL DESIGN

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: Jan. 2003	DATE:
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	DATE
PROJ. DES. COORD.	PROJ. ENGR.
DATE	DATE
SRK PROJECT NUMBER: 1CD003.22	

Deloitte & Touche Inc.

FRESH WATER SUPPLY DAM BREACH
ANVIL RANGE MINING COMPLEX, YT

SCALE: 1:750

0 10 20 30 40 50 Metres

LOW LEVEL OUTLET ABANDONMENT

DRAWING NUMBER 11

REV. C

FILE NAME: P:\Deloitte_touche\Acad drawings–Fare\fare FW00\Figure 11.dwg

HAUL ROAD

MINE ACCESS ROAD

LOCATION OF EXISTING RIP RAP STOCKPILE

FORM SURFACE TO ALLOW CREEK DRAINAGE

SPOIL AREA

SPOIL AREA

EXISTING ACCESS ROAD

SPOIL AREA

PROPOSED ACCESS ROAD (Refurbish following construction)

DAM CREST

EDGE OF TREES

DYKE

TRAIL

REHABILITATED CHANNEL

SPOIL AREA

EXTENT OF DAM BREACH

SPOIL AREA

EXPOSED RESERVOIR BASE TO BE REVEGETATED USING APPROPRIATE GRASS SPECIES

PHASE 1 REVEGETATION

PHASE 2 REVEGETATION

NORTH TRIBUTARY

SOUTH FORK ROSE CK

SOUTH EAST TRIBUTARY

REVEGETATION IN RIPARIAN ZONE

EXTENT OF RESERVOIR @1096 EL.

6911000 N

6910000 N

558000 E

568000 E

N

NOTES:

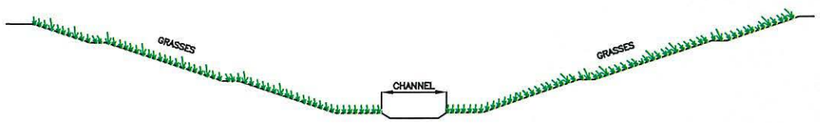
1. PHASE 1 REVEGETATION INCLUDES THE PORTION OF THE RESERVOIR EXPOSED DURING SUMMER 2003.
2. PHASE 2 REVEGETATION INCLUDES ANY AREAS WITHIN THE RESERVOIR THAT WERE NOT REVEGETATED AS PART OF PHASE 1, AS WELL AS THE BREACH SIDE SLOPES AND ANY SPOIL AREAS.
3. REVEGETATE ALL SPOIL SURFACES.
4. RIPARIAN ZONE IS DEFINED AS A 10m STRIP OUTSIDE EDGE OF SOUTH FORK OF ROSE CREEK AND 5m WIDE STRIP ON THE TWO TRIBUTARIES.
5. REVEGETATION OUTSIDE OF CONSTRUCTION AREA SHALL BE COMPLETED WITHOUT MACHINE DISTURBANCE OF EXPOSED RESERVOIR BASE.

LEGEND

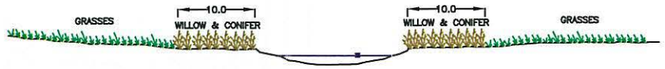
- CREEK OUTLINE FROM 1999 SURVEY
- ESTIMATED CREEK OUTLINE
- EXISTING ACCESS ROAD
- PROPOSED ACCESS ROAD
- EXTENT OF RIPARIAN ZONE

ELEVATIONS (m amsl)
CONTOUR INTERVAL = 1m
SELECT AREAS INCLUDE 0.5m CONTOUR INTERVALS

NAD 27 DATUM, ZONE 8



TYPICAL REVEGETATION IN PROPOSED BREACH ZONE



TYPICAL REVEGETATION IN RIPARIAN ZONE

NOTE: SCALE HAS BEEN REDUCED BY 50%

DRAWING NO.	DRAWING TITLE
REFERENCE DRAWINGS	

NO.	DESCRIPTION	CHK'D/APP'D	DATE
REVISIONS			

REV.	ISSUE PURPOSE	AUTH. BY	DATE
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B	FINAL DESIGN	GWF	APR. 03/03
A	PRELIMINARY DESIGN	GWF	FEB 3/03
ISSUE AUTHORIZATION			

Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

FINAL DESIGN

SRK Consulting Engineers and Scientists

DESIGNED BY: GWF	DRAWN BY: DC/JM
DATE: Jan. 2003	DATE:
CHECKED BY: CCS	DISCIP. ENGR.
DATE: JAN. 2003	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: 1:3000
0 50 100 150 200 250 metres

CONSTRUCTION AREA AND REVEGETATION PLAN

DRAWING NUMBER 13

REV. C

FILE NAME: F:\Deloitte_Touche\Acad drawings-Fare\New FWSD\Figure 13.dwg

APPENDIX A
Summary of December 2 & 3, 2002
Planning Meeting

Planning Meeting for Breach of Fresh Water Supply Dam

Meeting Dates: December 2/3, 2002
Meeting Location: Offices of SRK, Vancouver

Attendees:

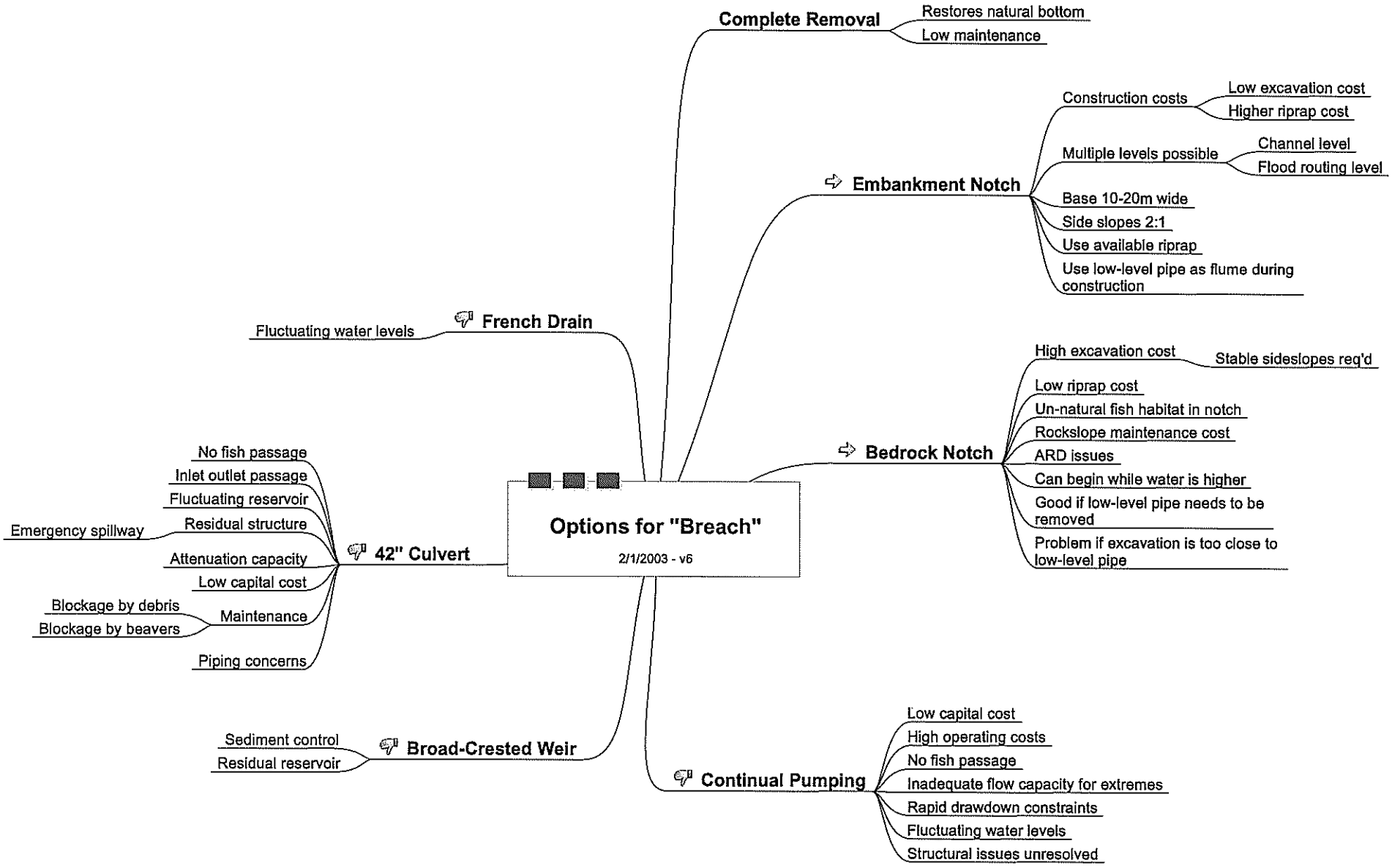
- DFO: Herb Klassen, Sandra Orban
- DIAND: Bud McAlpine, Bill Slater
- Hydroconsult: Wim Veldman
- Geo-Engineering: Milos Stepanek
- BGC: Jim Cassie, Gerry Ferris
- SRK: Daryl Hockley, Peter Healey, Cam Scott

Conclusions:

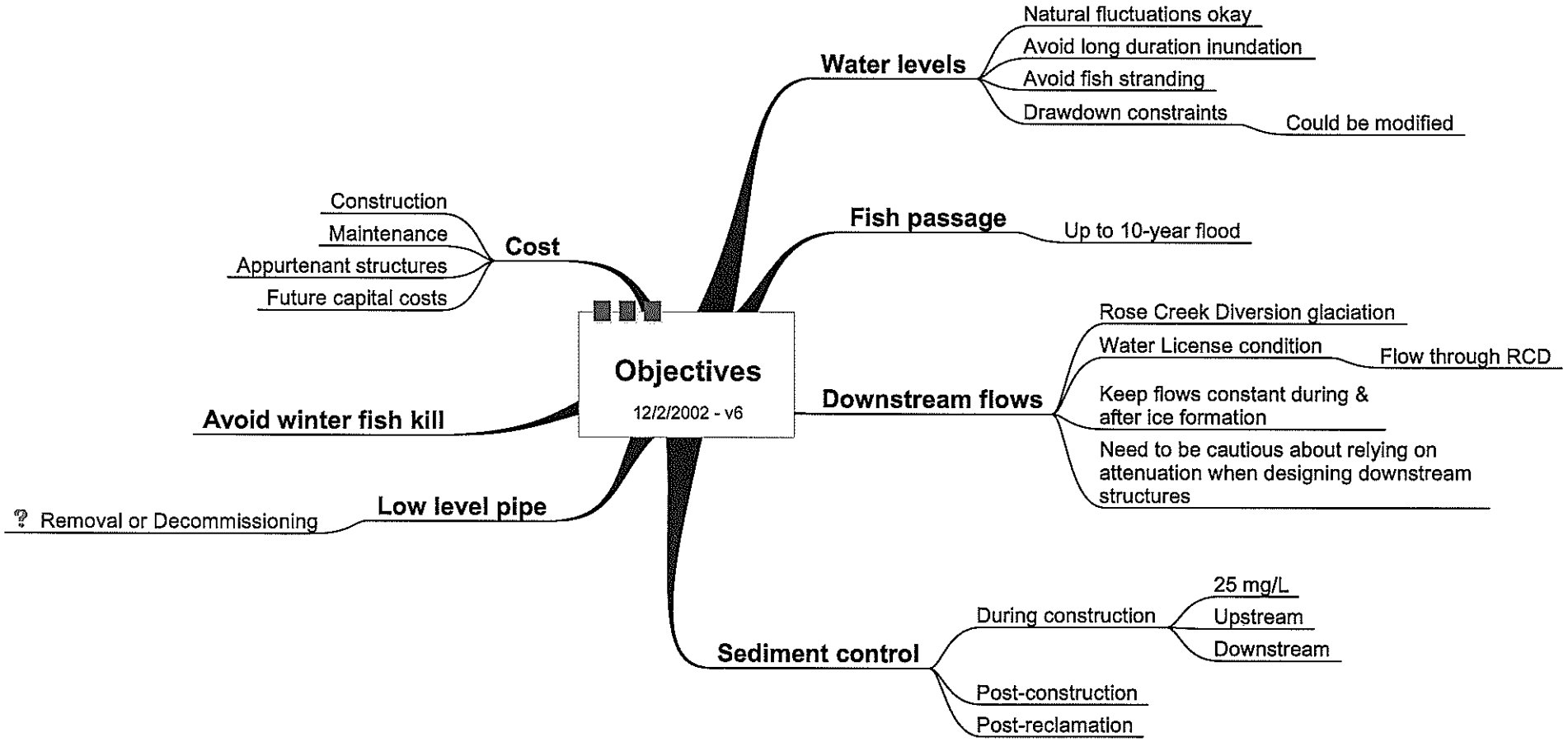
1. Seven options for the breach were considered (see attached Mindmap entitled "Options for Breach"). Four of them ("French drain", "42-inch culvert", "broad-crested weir", and "continual pumping") were rejected. Of the remaining three, "embankment notch" was preferred, "bedrock notch" should remain under consideration, and "complete removal" was judged to be a variant of embankment notch.
2. The objectives for the FWSD breach were clarified (see attached Mindmap entitled "Objectives"), as follows:
    - Keep water levels within the range of natural fluctuations.
    - Avoid long duration inundation.
    - Avoid fish stranding in higher ponds.
    - Respect dam stability constraints on dewatering rates.
    - Provide fish passage for up to 10-year flood.
    - Minimize risk of ice blockages, specifically by avoiding increases in flowrates after ice formation.
    - Control sediment releases.
    - Avoid creation of small volume pond that would result in winter fish kill.
    - Consider construction, maintenance, future construction, and appurtenant costs.
3. Further clarification is required regarding the DFO requests related to "removal" of the low level pipe and "attenuation" of floods.
4. Unnaturally maintaining flows through the Rose Creek Diversion is not an objective of this project. (The Water License requirement specifies the minimum Rose Creek Diversion flow, but does not require the FWSD to be the source of that flow. Furthermore, the License will be outdated prior to the start of construction.)
5. Upstream and downstream requirements associated with the breach were reviewed (see attached Mindmap entitled "Final Configuration"). Specific items to be considered in the design include:
    - Reconnecting streams – Need to remove obstacles to fish passage, including over-steepened delta areas. This work could be delayed until after freshet of 2004.

- Revegetation – Need to assess natural vegetation. Need community input. DFO mandate includes edges of streams, where willow cuttings and grasses/legumes should be considered.
- The channel through the reservoir should be natural, with no constructed flow controls.
- The channel through the breach should match previous gradients, should include roughness elements, and should be hydraulically continuous with downstream reaches.
- The downstream channel should link breach with original downstream alignment, and include fish habitat elements. Habitat creation here will compensate for loss of habitat elsewhere.

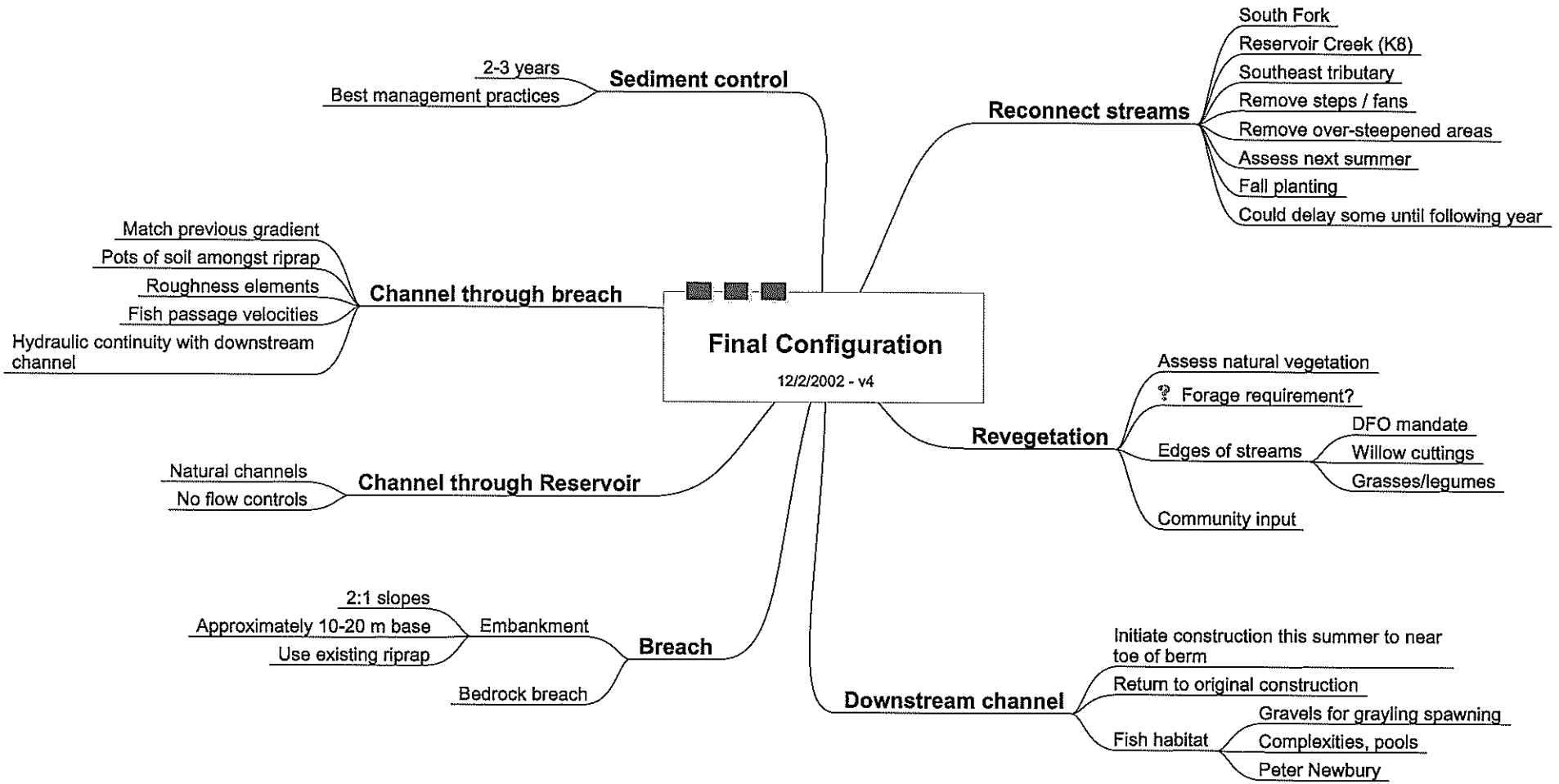
6. Requirements for the Fish Habitat Mitigation and Compensation Plan were reviewed (see attached Mindmap entitled "Construction Issues for Fish Mitigation & Compensation Plan"), and placed additional requirements on the design and construction planning:
    - A fish survey and fish salvage plan will be needed.
    - The plan should include commitments to environmental monitoring and follow-up monitoring and reporting.
    - Details of site preparation, coffer dam construction, in-stream work, spoil disposal, road drainage, water drawdown rates, and outlet point, where relevant to fish habitat will need to be provided.
    - A plan for cleaning, fueling, servicing and inspecting equipment that will be used in-stream will need to be provided.
    - Contingencies for accidents and malfunctions will need to be included.
    - Blasting guidelines will need to be provided.
7. Methods to lower the reservoir were discussed (see attached Mindmap entitled "Methods to Lower Reservoir"). The preference is to use the low level pipe to the maximum extent possible. There is an urgent need to evaluate the conditions of the valve and pump-house. There is no permitting concern with using either the low level pipe or properly screened pumps to lower water levels for one year, as long as there is fish salvage before the pond is completely removed.
8. A project schedule was developed. Key considerations are:
    - The Feb. 3 requirements from the DFO letter
    - Requirement for a Comprehensive Study
    - Requirements for a Water Licence
    - Dry construction and revegetation could be initiated in summer 2003
    - Breach construction should be completed by freshet 2004
    - Upstream construction and revegetation can be completed in summer 2004.
9. The permitting schedule is aggressive. Complications arising from YEAA have not been included in the current schedule.



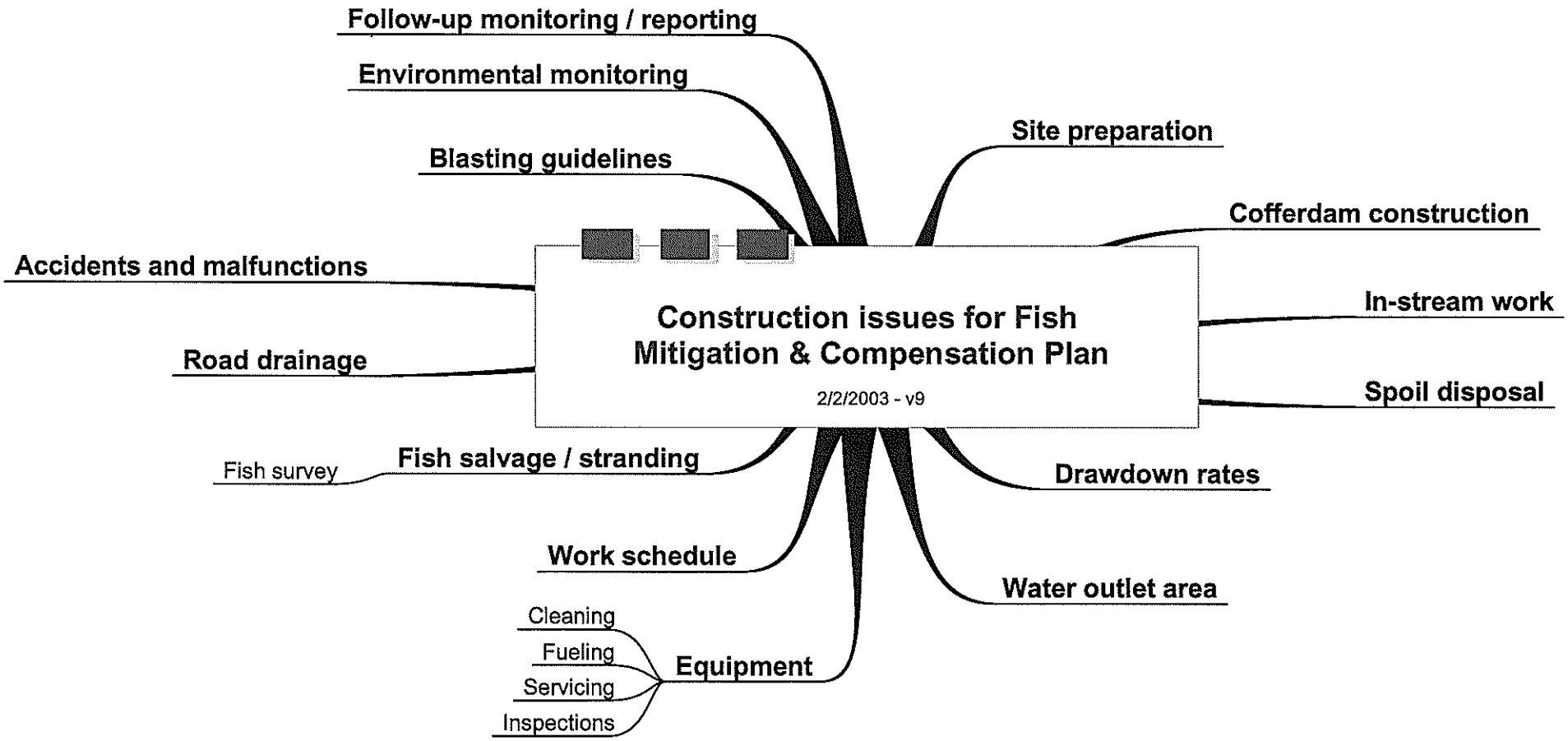
E:\Deloitte_touche\1CD003.20_FWSD_Prelim_Breach_Design\Report\Appendix A\Options for Breach.mmp - 2/1/2003 - Daryl Hockley - dhockley@srk.com



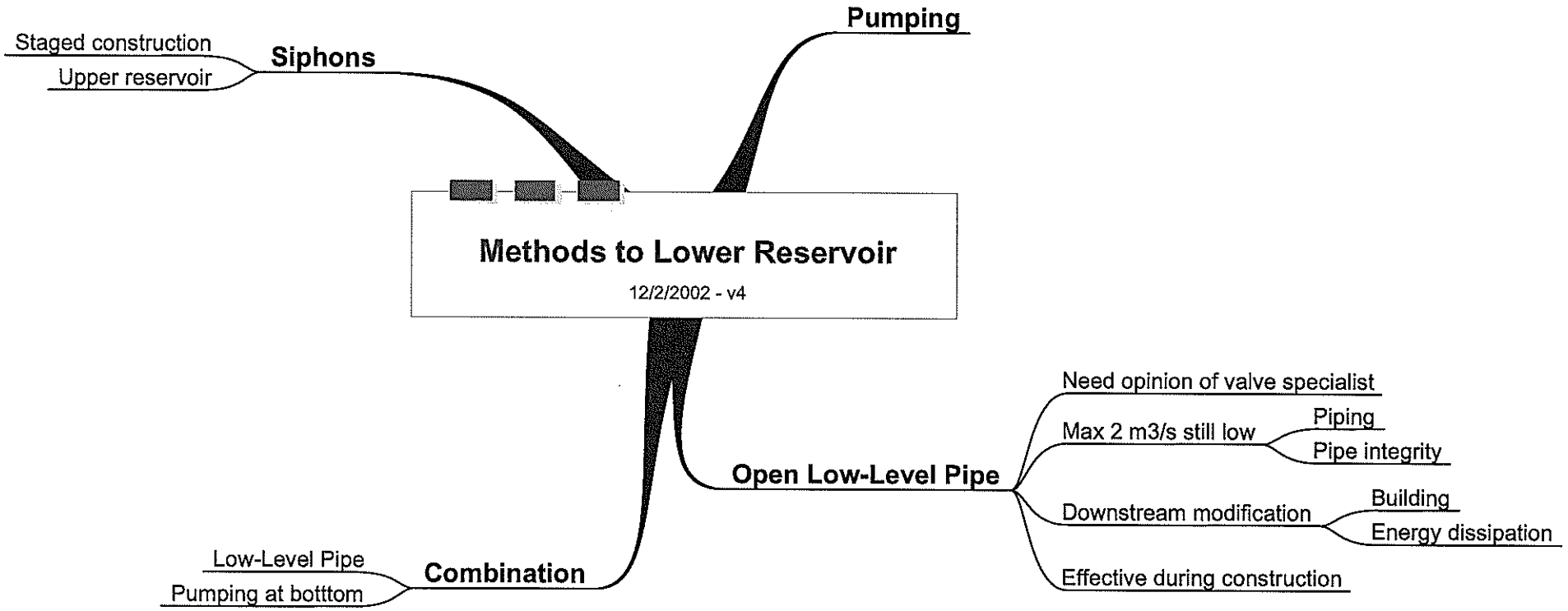
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E:\Deloitte_touche\1CD003.20_FWSD_Prelim_Breach_Design\Report\Appendix A\Reservoir Rehab.mmp - 12/2/2002 - Daryl Hockley - dhockley@srk.com



E:\Deloitte_touche\1CD003.20_FWSD_Prelim_Breach_Design\Report\Appendix A\Construction.mmp - 2/2/2003 - Daryl Hockley - dhockley@srk.com



E:\Deloitte_touche\1CD003.20_FWSD_Prelim_Breach_Design\Report\Appendix A\Methods to Lower Reservoir.mmp - 12/2/2002 - Daryl Hockley - dhockley@srk.com

APPENDIX B
Modifications to the LLO

SRK Consulting
Engineers and Scientists

Steffen Robertson and Kirsten (Canada.) Inc.
Suite 800, 1066 West Hastings St.
Vancouver, BC.
V6E 3X2

email: vancouver@srk.com
URL: http://www.srk.com
Tel: 604.681.4196
Fax: 604.687.5532

MEMORANDUM

DATE: April 11, 2003

TO: File 1CD003.22

FROM: Gerry Ferris

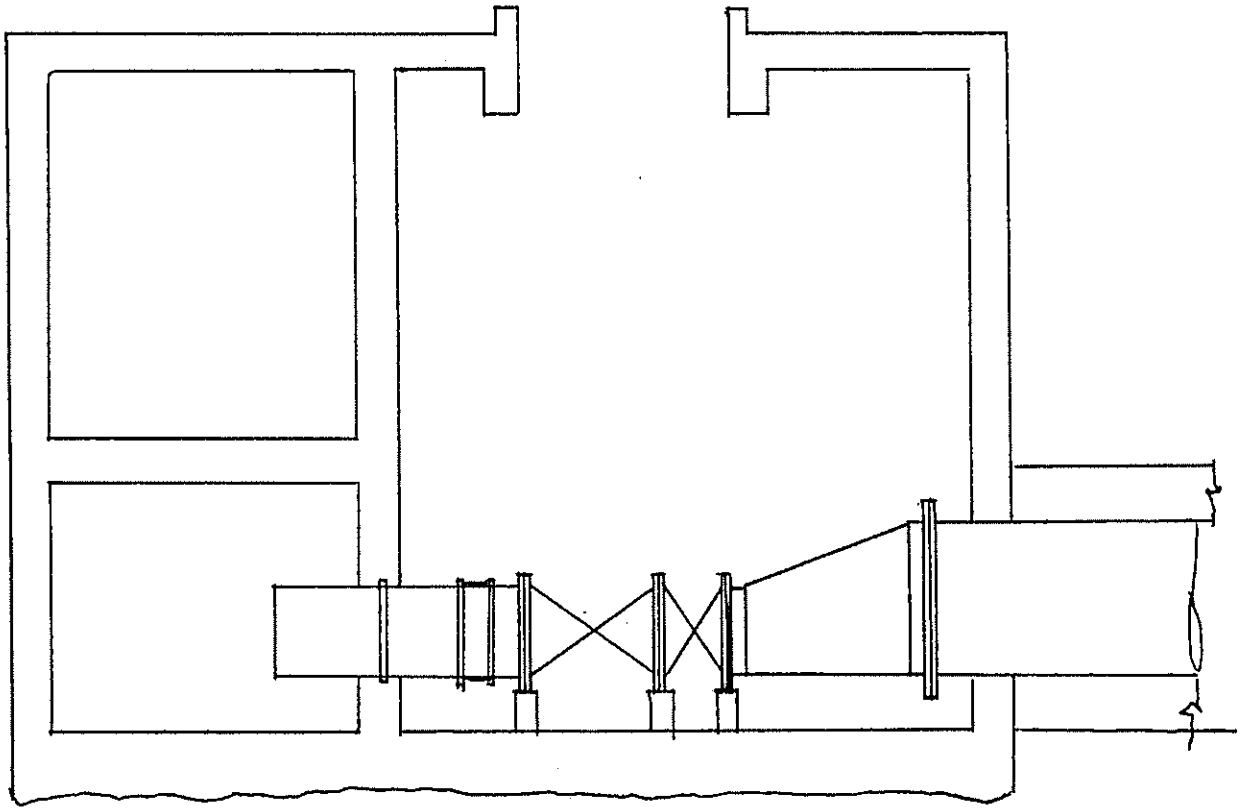
RE: Modifications to the LLO Pipe

The LLO pipe was recently (March 2003) modified to increase its discharge capacity and eliminate potential concerns related to vibration caused by cavitation. The modifications were recommended by Klohn Crippen, in response to a request by the interim receiver, as the most appropriate way to increase the safe discharge capacity of the LLO[1]. The modifications consisted of installing an orifice plate and providing additional support for the piping in the valve chamber. Site staff completed the modifications under the supervision of the on-site managers. Successful testing in early April confirmed that the modified LLO can safely discharge the flows when the valves are fully opened.

Attached to this memorandum are the following:

- The detailed construction plans prepared by the site staff.
- The machining details for the orifice plate.
- A selection of photographs taken during the construction.
- A description and photographs of the flow test conducted on the modified LLO on April 11, 2003.

[1] Klohn Crippen 2003 Anvil Range Mine, Water Supply Dam, Low-Level Outlet Assessment. Report dated February 2003.

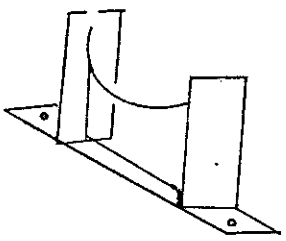


1. Remove the existing Three (3), Concrete Floor Supports.

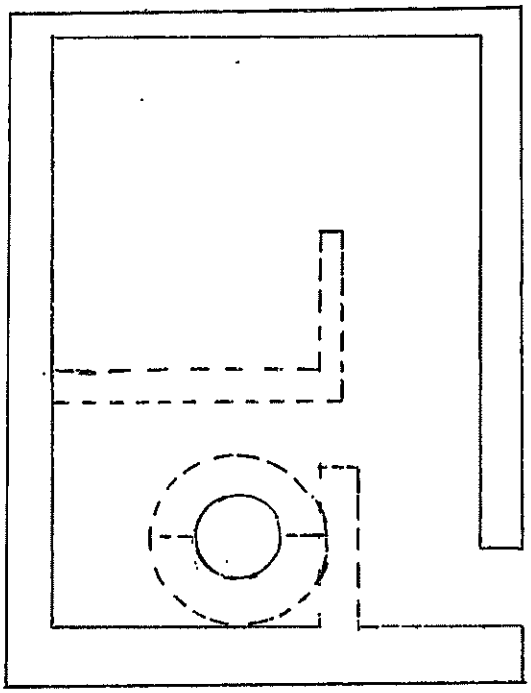
2. Replace the Three (3), Supports with "I"- Beams Supports welded to the underside of the Plug Valve and the Gate Valve Flanges; to be placed on ½" Thick x 4" Wide x 24" Long Floor Plate and Anchored to the floor with 1" Diameter Anchors.

3. An additional Two (2), "I" - Beam Supports will also be placed on the 42" Diameter End Flange of the 42" to 24" Eccentric Reducer and between the Wall and the 24" Smith - Blair Coupling in the same manner.

4. The upstream side of the 24" pipe located in the Diffuser Chamber will have One (1), Foot cut off the length prior to placement of the Flange End and Orifice. This will leave a One (1), Foot length of Pipe in the Diffuser Chamber.



"I" – Beam Anchors



1. A Split Ring Donut, 1" Thick x 6" Wide x 24" I.D. will be placed against the Wall, upstream of the Smith - Blair Coupling and welded to the 24" Diameter Pipe to prevent Expansion Surges. Location on Wall is adjacent to the existing Stairway.

2. The Orifice will be bolted to the end face of a Weld - On Flange, inside the Diffuser Chamber once a decision is made on the Type of Flange and Actual Orifice Plate.



Photo 1: 24 inch diameter pipe in dissipater chamber prior to modifications



Photo 2: Welding within the dissipater chamber



Photo 3: Tightening bolts on the orifice plate



Photo 4: Installed supports on the pipe within the valve chamber

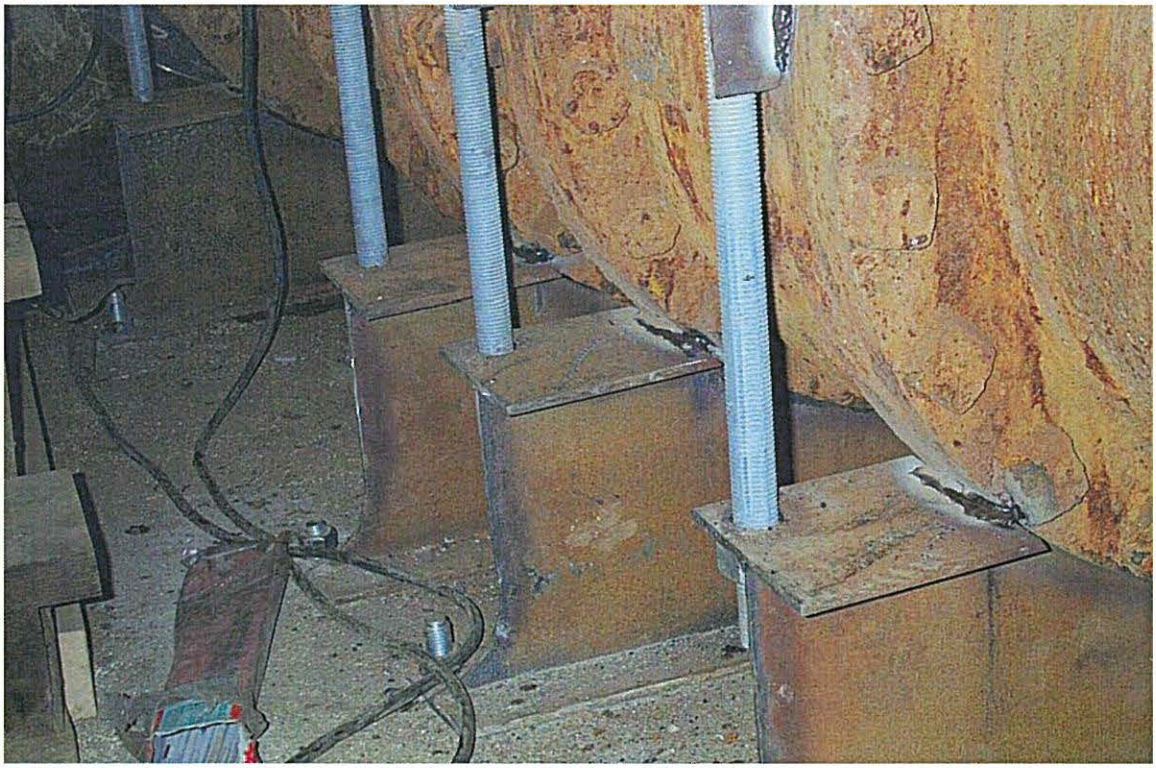
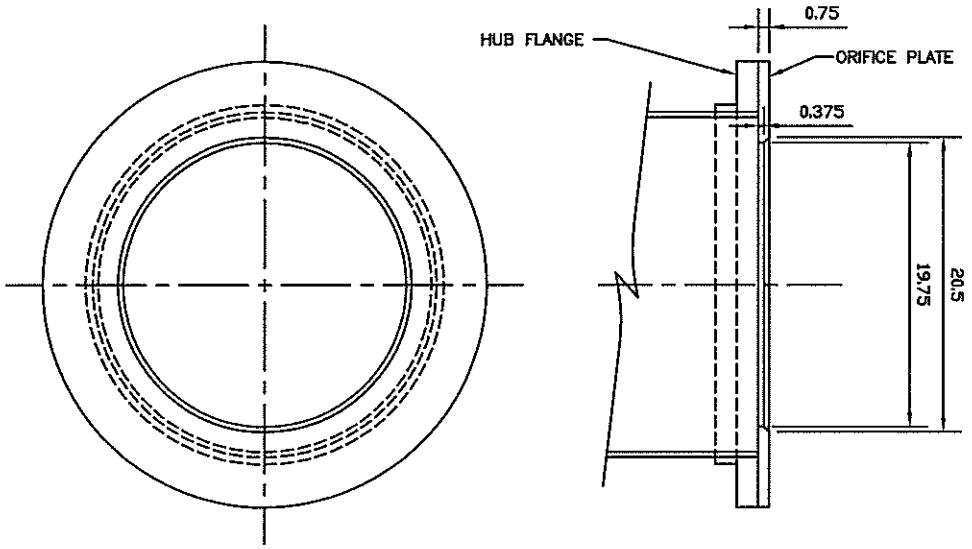


Photo 5: Supports for the pipe within the valve chamber



FRONT ELEVATION SECTION

NOTES:
1. Dimensions of hub flange not to scale.
2. Outside diameter of orifice plate to match hub flange.
3. Pipe is given as 24" Standard on as built drawings.
4. According to pipe catalogues, 24" Standard is Schedule 20 with a wall thickness of 0.375" and an internal diameter of 23.25".
5. Orifice plate bolt hole details to match hub flange.

April 13, 2003

To: Cam Scott

From: Dana Haggar

Re: Full flow test of the low level outlet pipe at the FWSD

A full flow discharge test of the low level outlet pipe at the FWSD was performed on Friday April 11th, 2003. The water elevation at the time of the test was measured at 1090.011 m amsl (about 6 m below the spillway).

The weather was mild with clear skies and temperature at -2°C. The channel down stream of the valve house was relatively free of ice and any noticeable obstructions.

The gate valve and globe valve were both closed off at 8am. The knife gate valve was then opened to full and then the globe valve was slowly opened.

At half open, the flow was allowed to stabilize and lab personnel preformed a flow reading just down stream of the valve house where the weir plate had been removed. Measurements were recorded every 5 cm (2 inches) across the width of the channel and averaged. The total flow calculated was 0.7 m^3/s or 9,239 Imperial gallons per minute (Igpm), which is 11,095 USgpm. It was noted that the channel downstream was less than half full.

The valve was opened to three quarters and slight vibrations were felt throughout the valve house for less than a minute. The valve was then opened to full and the flow was allowed to stabilize for 45 minutes. Another flow reading was preformed as above and was recorded at 2.1 m^3/s or 27,716 Igpm (33,286 USgpm). This is very close to the rating curve prediction (27,600± Igpm) by Klohn Crippen earlier this year. Furthermore, it was noted that the channel downstream was slightly above half flow at this rate.

Once the flow was calculated, the globe valve was reduced down to less than a third open and the flow has been reduced to 5.3 m^3/min or 1,165 Igpm (1,400 US gpm).

Mr. Bud McAlpine of DIAND (Water Resources) was present during the test period and was able to observe the entire test procedure.

Pictures of the channel taken during the test period are attached.

An excavator was on standby along the Rose Creek diversion, to clear any ice dams that might form, but no such developments occurred.



Photo 1: Water level in fresh water channel at start of test, April 11, 2003



Photo 2: Water level in fresh water channel when valve is fully open, April 11, 2003

APPENDIX C

APPENDIX C1
Updated and Revised Inflows to the FWSD

SRK Consulting
Engineers and Scientists

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MEMORANDUM

DATE: February 24, 2003

TO: File 1CD003.22

FROM: Patrick Bryan / Gerry Ferris

RE: Revised Inflows to FWR – FWSD Breach

As part of planning for the breach of the fresh water supply dam (FWSD), it will be necessary to develop a good understanding of the hydrology of the South Fork of Rose Creek, particularly for the periods of the year slated for the reservoir drawdown and the related construction activities. A valuable source of information for developing this understanding is a streamflow gauging station operated by the Interim Receiver on the North Fork of Rose Creek (Station R7), located just upstream of the outlet of the Faro Creek Diversion. This streamflow gauging station commands a similar catchment area to that controlled by the FWSD (i.e., R7 has a catchment of 95 km^2 vs. 67 km^2 for the FWSD). This memorandum briefly summarizes the work undertaken to process the raw stage data collected at the R7 gauge. Particular emphasis is placed on accounting for the effect of ice on the measured stage data. Most of the work was carried out in early 2002 during the preparation of a site-wide water balance for the Anvil Range Mine Complex (see Appendix A of Gartner Lee Ltd., 2002).

The R7 streamflow record presented in this memorandum supersedes a provisional record that was published in earlier documents describing the option of lowering the crest of the FWSD (Northwest Hydraulic Consultants, 2001).

The processing of the R7 record involved the following three steps:

- develop an empirical relationship between discharge and stage (i.e., the rating curve);
- screen the data to identify periods when stage was influenced by ice effects (e.g., ice jams downstream of gauge and/or formation of ice on the pressure transducer); and,
- make estimates for missing data and for portions of flow record influenced by ice (a process known as "patching").

These steps are discussed under separate headings.

Rating Curve for Station R7

An automated streamflow gauging station was first established at R7 in 1990. The datalogger and pressure transducer at this original station were prone to many failures and, as a result, only minimal stage data were collected. However, a substantial number of direct discharge measurements (using a current meter) were measured. The pre-1996 data was not used as part of this assessment.

The R7 station was rehabilitated in late 1996. Since then, the station has operated almost uninterrupted and has provided reliable measurements of stage. From 1996 to 2000, a total of eight direct discharge measurements were made, covering a range of flows from 0.11 m^3/s (1,450 igpm) to 3.2 m^3/s (42,200 igpm).

These direct discharge measurements, together with their coincidental measurements of stage, were used to establish a rating curve for the R7 station. Figure 1 shows a plot of the pairs of assembled discharge and stage data. A power regression was fitted to these data to facilitate conversion of the R7 stage record into an equivalent flow record. The power regression is expressed in equation form as follows:

$$\mathbf{Q = 5.76\ (S - 0.3)^{1.95}}$$

where:
Q = estimated discharge rate (m^3/s); and,
S = stage measured by pressure transducer (m).

The above equation was used to extrapolate the rating curve well above the maximum available direct discharge measurement (3.2 m^3/s). Accordingly, care had to be exercised in defining the exponent of the equation. Guidance on selecting an appropriate exponent was obtained from the hydraulics of common weirs, which suggested that the true exponent likely falls in the range of 1.5 (rectangular weir) to 2.5 (triangular weir). The exponent of the equation was forced to fall within this range by adjusting each stage measurement by a constant. Through a trial and error process, a constant value of -0.3 m was selected. This resulted in a physically reasonable value for the exponent of 1.95.

Screening R7 Flow Record for Erroneous Data

Measurements of stage in northern streams are prone to the effects of ice, such as ice jamming and the formation of anchor ice. These effects tend to cause high water levels that can be misinterpreted as representing high flow rates. This section describes an analysis that was undertaken to identify portions of the R7 stage record that were influenced by ice.

The screening process involved three steps. Firstly, the rating curve developed above was used to convert all available stage readings (collected at 45 minute or hourly intervals) into equivalent flow rates (without regard to the potential that some of the stage readings may have been influenced by ice). Secondly, the resulting flow rates were aggregated into a provisional daily average record. Finally, this provisional record was compared against the streamflow records of Station X14 and Station 09BA001. The former station is part of the flow monitoring network operated by the Interim Receiver and is located on Rose Creek downstream of R7. The latter station is operated by the Water Survey of Canada (WSC) on the Ross River. The WSC apply special processing techniques to their flow records to account for the effects of ice on the measured stream stage.

Figures 2 and 3 were prepared to facilitate the screening process. Examination of these plots identified the following suspect data within the provisional R7 flow record:

- in all years, the provisional flow record shows an anomalously high flow rate at the beginning of the winter that is not observed in the records of either X14 or Ross River;
- in the summer of 1999, the R7 flows are likely erroneous because they do not reflect the large rainfall-derived flows that were experienced in the neighbouring catchment of Ross River; and,
- an anomalously high spike occurs in the R7 record at the beginning of the 1999 freshet that is not observed in the regional streamflow record and that also is not followed by a typical stream recession.

The above periods of suspect data were removed from the provisional R7 flow record.

Patching R7 Flow Record

The planning of the FWSD removal required the estimation of inflow rates to the fresh water reservoir (FWR) for long durations, ranging from one week to several months. The basic

data for making the inflow estimates were long, continuous records of streamflow collected in the region. For the R7 gauge to qualify as a suitable source of data for this analysis, breaks in the R7 flow record had to be patched. This section describes the patching process and presents the resulting corrected flow record for Station R7.

Most of the breaks in the R7 record are due to the removal of suspect data, as outlined in the section above. However, a gap also exists in the summer of 1997 when the operation of the datalogger and pressure transducer was temporarily interrupted (possibly due to battery failure).

The adopted method for patching the R7 record was by correlation with a regional streamflow gauging station. This regional station had to meet four criteria, namely it had to: be operated year-round; have accurate flows in open water and ice conditions; possess similar elevational characteristics as the R7 catchment; and, have a period of record that fully overlapped the R7 record. The station used previously for screening the R7 record (viz., Ross River) was identified as a suitable candidate for this purpose. Figure 4 shows a plot of the reliable R7 flow data against the coincidental flows measured at the Ross River station. These two data sets exhibit good correlation ($r^2 = 0.78$). Breaks in the R7 record were patched using a linear regression fitted to the two sets of data.

Figure 5 shows the patched daily record for Station R7. The monthly flow records for years 1996 to 2001 (or the months of the year available) are presented in Table 1.

The inflows to the FWR can be estimated by scaling the flows in Table 1 by the ratio of the catchment areas of the FWR and Station R7 (i.e., 67 km^2/95 km^2 = 0.71). This suggests that the long-term average inflow to the FWR is approximately 0.66 m^3/s (8,700 igpm).

The data for Station R7 presented in the Preliminary Design Report (Figure 2.7 of that report) is the same as the corrected data presented in this memorandum. The information contained in Table 1 of this memorandum provides an update of the data presented in Table 2.5 and Figure 2.8 of the preliminary design report. The data presented in this memorandum should supersede the information contained in the preliminary design report.

References

Northwest Hydraulic Consultants. 2001. Hydrotechnical Assessment for Faro Mine Site. Report prepared for BGC Engineering Inc.

Gartner Lee Limited. 2002. Anvil Range Mine Complex 2002 Baseline Environmental Information. Volume 2 of 2. Report prepared for Deloitte and Touche Inc.

SRK Consulting Ltd. 2003. Preliminary Breach Design, Fresh Water Supply Dam, Faro Mine. Report prepared for Deloitte & Touche Inc., February.

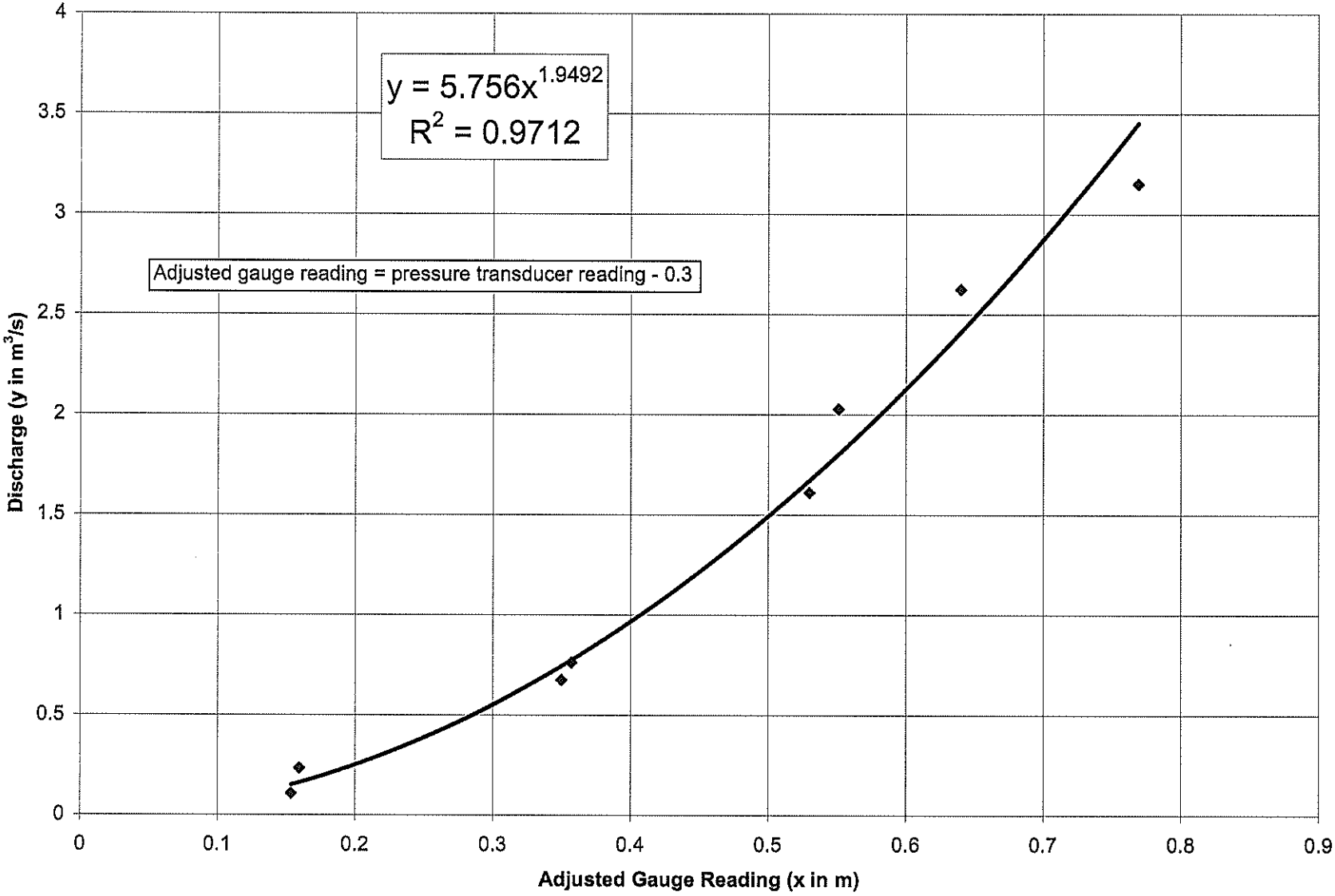
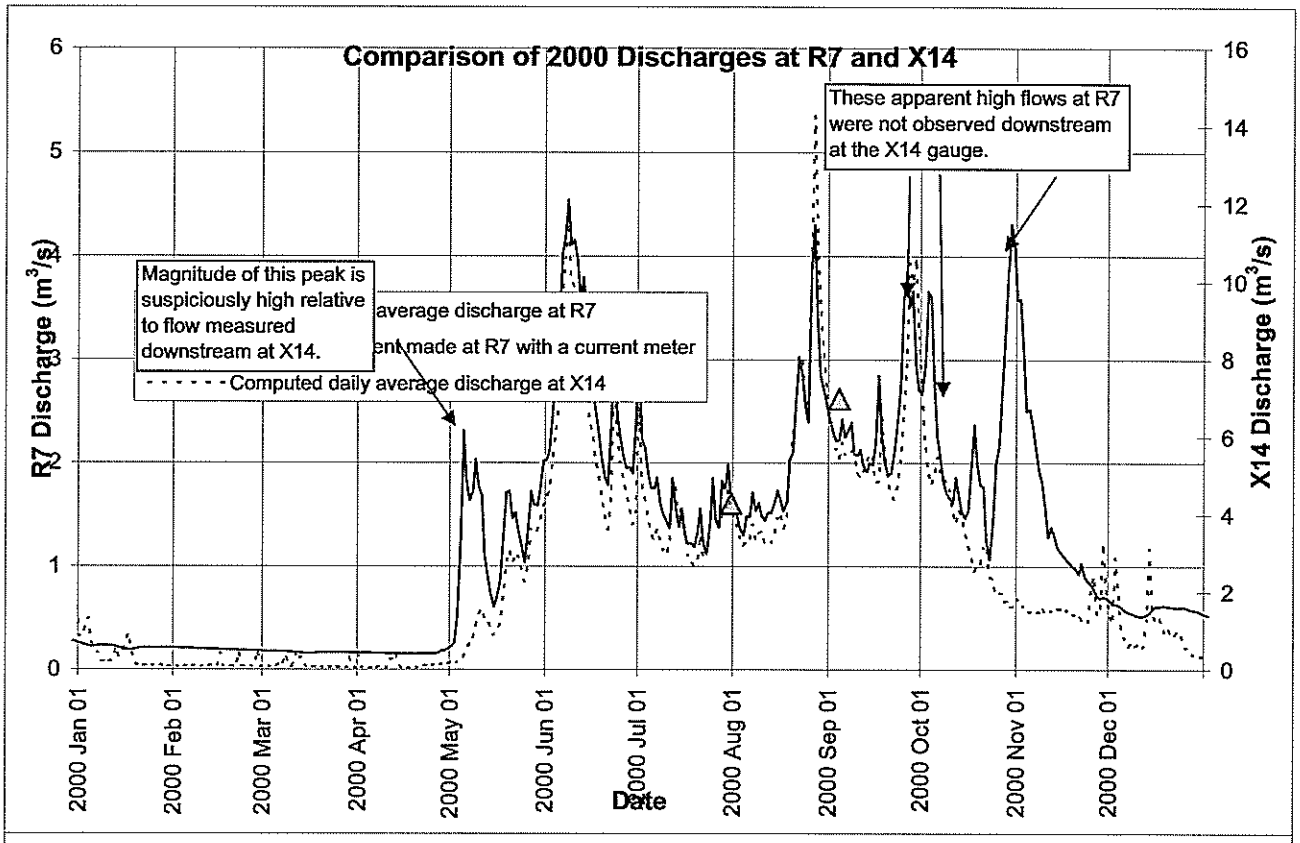


Figure 1: Rating Curve for North Fork of Rose Creek at Station R7



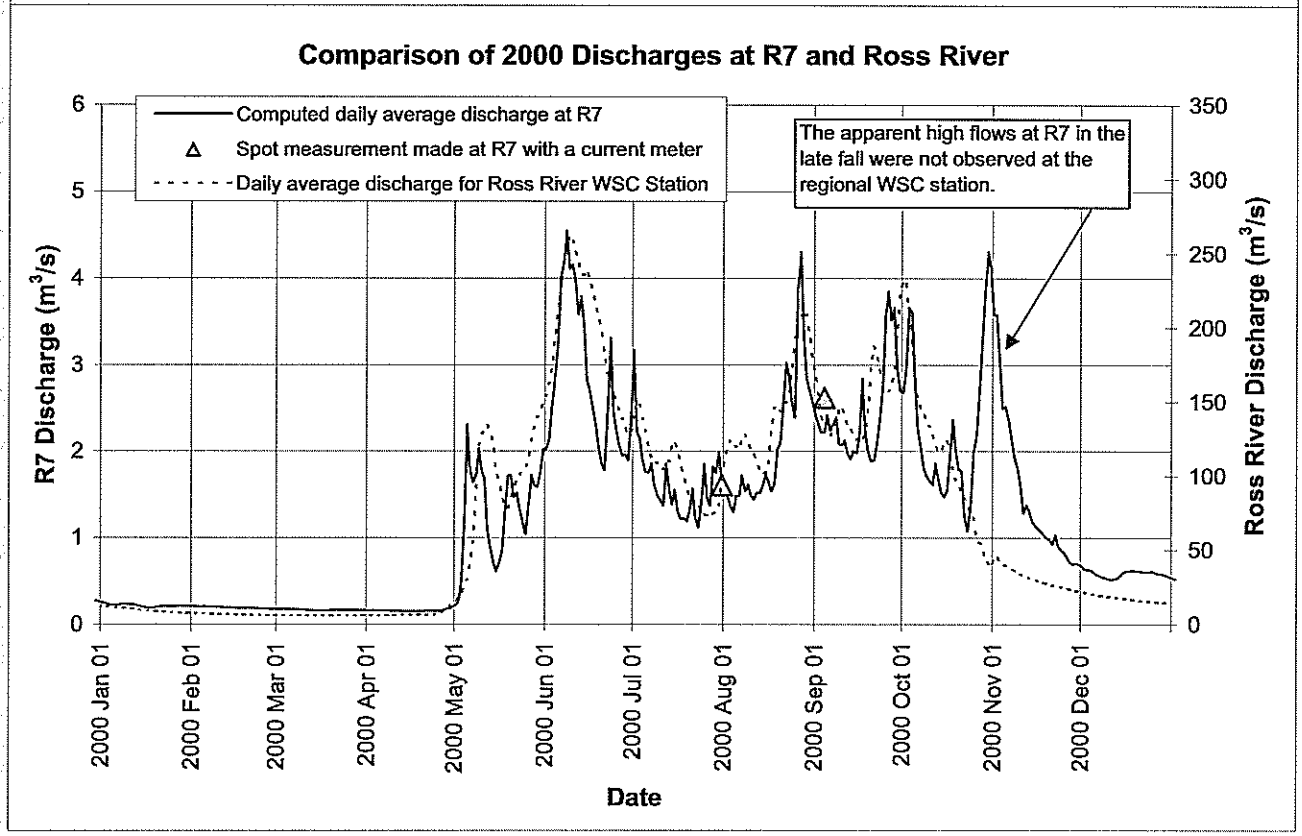


Figure 2: Evidence of Spurious Data Within Raw R7 Discharge Record

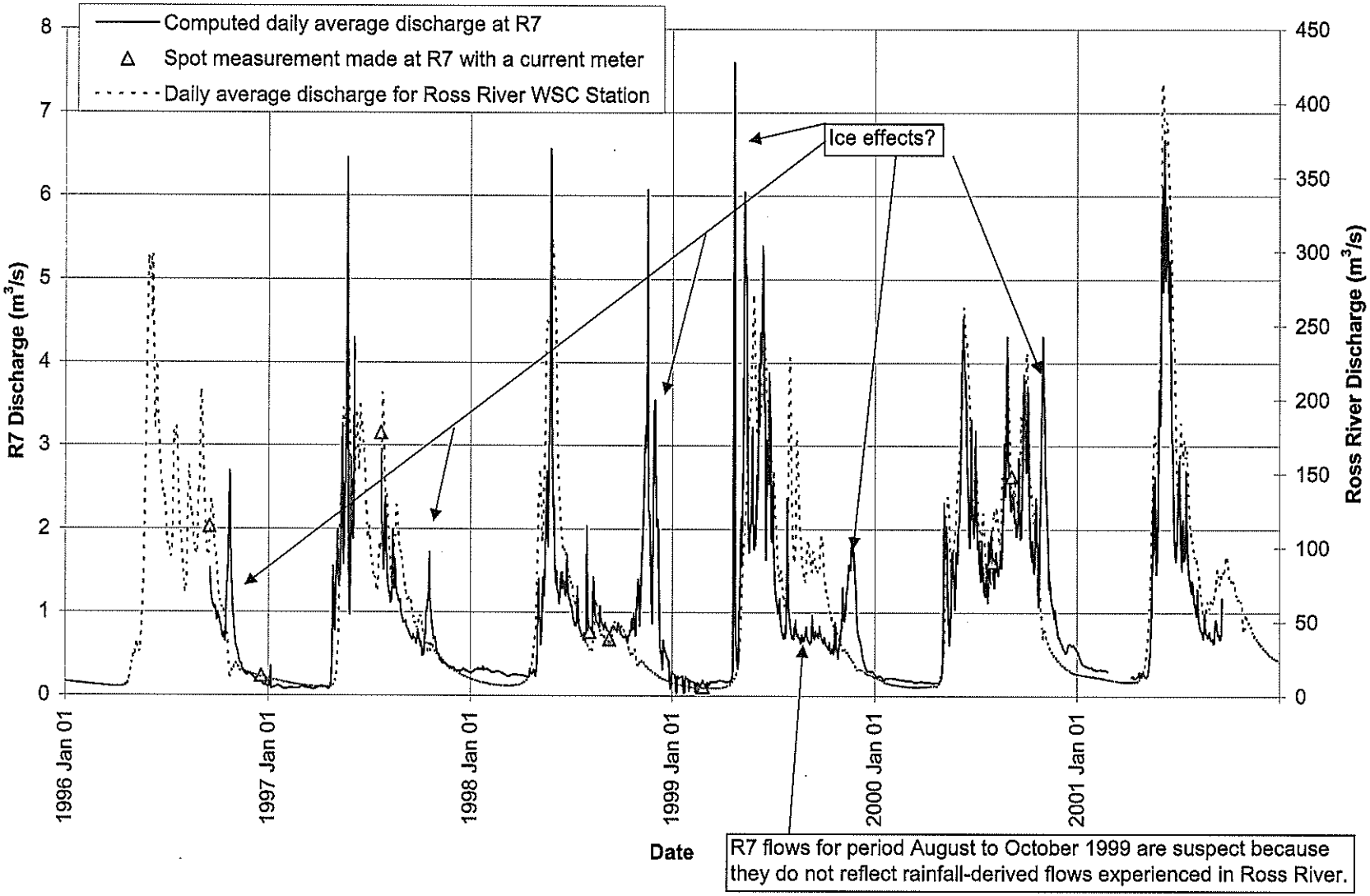


Figure 3: Screening of Raw R7 Discharge Record for Erroneous Data

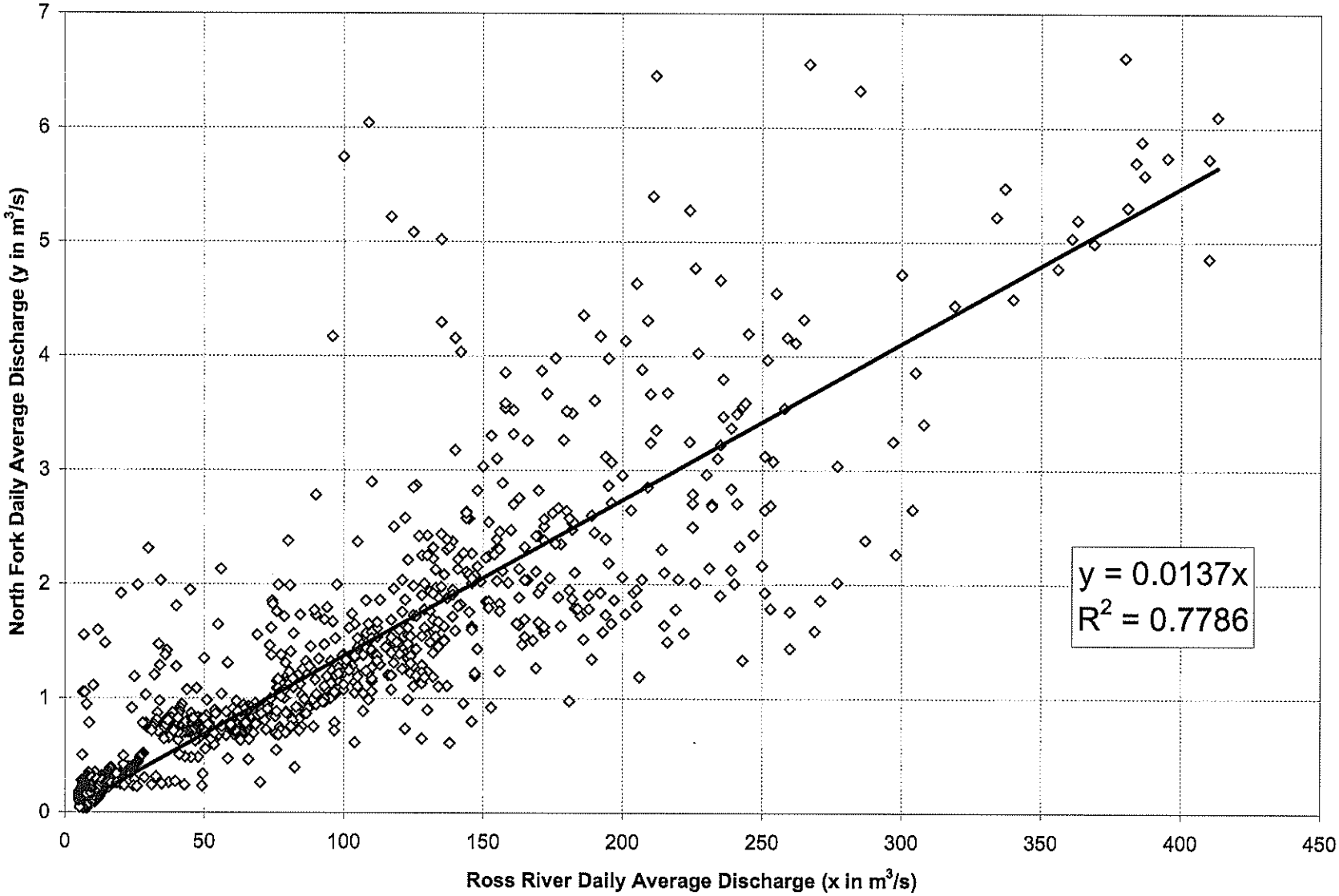


Figure 4: Correlation between Coincidental Flows on the North Fork and Ross River

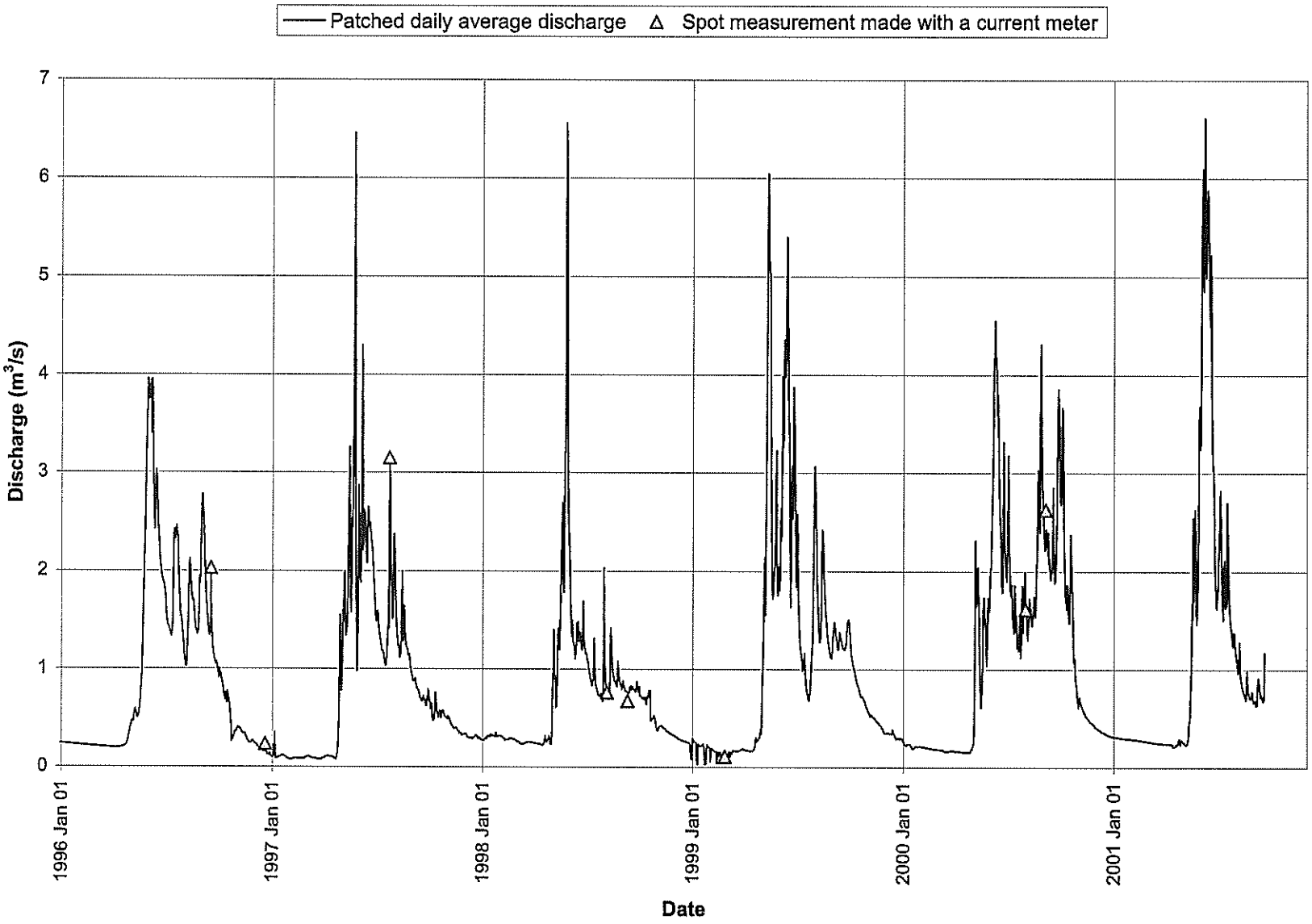


Figure 5: Patched Daily Streamflow Record for North Fork of Rose Creek at R7

Table 1 Monthly Discharge Record for North Fork of Rose Creek at Station R7

Month	Monthly discharge in m^3/s for:						Average
	1996	1997	1998	1999	2000	2001	(m^3/s)
Jan		0.11	0.31	0.18	0.22	0.30	0.22
Feb		0.09	0.29	0.14	0.20	0.27	0.20
Mar		0.09	0.25	0.16	0.17	0.25	0.18
Apr		0.26	0.25	0.23	0.16	0.24	0.23
May		2.20	2.12	2.71	1.34	1.39	1.95
Jun		2.34	1.34	3.23	2.85	4.13	2.78
Jul		1.54	0.91	1.27	1.63	1.77	1.43
Aug		1.34	0.91	1.63	2.10	0.83	1.36
Sep	1.52	0.76	0.80	1.33	2.45		1.37
Oct	0.61	0.56	0.61	0.83	1.74		0.87
Nov	0.31	0.39	0.37	0.46	0.53		0.41
Dec	0.17	0.30	0.26	0.32	0.35		0.28
Annual		**0.83**	**0.70**	**1.04**	**1.14**		**0.94**

Note: An analysis was undertaken to account for significant influences of ice on the measured stage record. However, some undetected influences may remain. Accordingly, caution must be excercised when using the winter flows (November to April) of this record to characterize the low flow regime of the North Fork of Rose Creek. Only two direct measurements of flow were made during the winter months in the period 1996 to 2000.

APPENDIX C2
Preliminary Hydrology and Hydraulic Design

SRK Consulting
Engineers and Scientists

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MEMORANDUM

DATE: April 3, 2003

TO: File 1CD003.22

FROM: Patrick Bryan

RE: Hydraulics and Hydrology – FWSD Breach Design

This memorandum documents the hydraulic and hydrologic analyses that were undertaken in support of the design of the FWSD breach. These analyses included:

- estimation of average channel size and planform geometry for a restored channel that will be stable through the excavated notch and downstream of the dam;
- estimation of minimum rock size required for construction of riffles within the restored channel of the South Fork of Rose Creek;
- characterization of the reservoir inflows during the proposed drawdown period (August to November) and the construction period (December to March); and,
- characterization of the summer low flow regime of the South Fork of Rose Creek.

The various hydraulic and hydrologic analyses performed in support of the final design elements completed by nhc (Appendix D3) are described below under separate headings.

Bankfull Discharge

An estimate of bankfull discharge was required to perform the interrelated tasks of: i) applying hydraulic geometry formulas; ii) estimating the hydraulics of the main channel of the restored South Fork of Rose Creek; and iii) estimating the size of rock required to form riffles.

The bankfull discharge was assumed to be the 2-year peak instantaneous flood. A hydrology study prepared by Northwest Hydraulic Consultants (nhc, 2001) estimated the magnitude of this flood at the FWSD to be 5.6 m^3/s.

Some evidence exists to suggest that the true bankfull discharge may be greater than 5.6 m^3/s. A soils investigation report prepared for the FWSD construction (Ripley, Klohn & Leonoff, 1968) describes the original stream at the dam site as being "incised in a shallow meandering channel that is about 20 ft wide and about 5 ft deep". Given the valley slope of 1%, assumed channel sideslopes of 1.5H:1V and a Manning's n of 0.05, these channel dimensions suggest a bankfull

discharge of about 10 m^3/s. A discharge of 10 m^3/s has an estimated return period between 4 and 5 years (based on nhc, 2001).

Stream Morphology

Values of channel size and planform geometry for the channel design were obtained from empirical relationships developed largely in western Canada. The empirical relationships provided the following guidelines for the design of the channel:

1) the slope of the channel (approx. 1%) is consistent with a riffle-pool morphology (Anon., 1996);
2) the pool-riffle-bar unit has a characteristic spacing of five to seven channel widths (Church, 1992);
3) for a stable channel, pools comprise about 50% to 75% of the channel length and have a wide range of depths (Anon., 1996);
4) the average width of a stable channel with a bankfull discharge of 5.6 m^3/s should fall in the range of 8 to 12 m, based on hydraulic geometry relationships for gravel rivers in Canada (Carson and Griffiths, 1987); and,
5) the soils investigation report referred to in the previous section suggests the actual channel width was about 6 m.

Based on the above information, an average width of 8 m was adopted for the main channel. This width set the average length of the pool-riffle units at approximately 48 m (or six times the width).

Minimum Rock Size for Riffles

The rock for the riffles was sized to just be stable during passage of the bankfull discharge. This was judged to be a critical condition in which the rock would probably be subjected to its greatest shear stress. The hydraulic gradient (and hence shear stress) in the vicinity of the riffles should decrease as the flows spill onto the floodplain.

The estimation of the rock size for the riffles entailed two sets of computations. Firstly, the depth and velocity of flow on the riffle were estimated. Secondly, the size of rock required to resist the imposed fluid and gravity forces was assessed. This was an iterative process because the flow hydraulics and the rock size depend on each other.

The hydraulics were simulated using the Manning's equation. The resistance caused by the rock (Manning's n) was estimated by an empirical equation that is a function of the rock's median

diameter (Strickler equation). The rock size required to resist the imposed forces was estimated by two different techniques, one developed by the US Department of Agriculture (Robinson, Rice and Kadavy, 1998) and the other by the civil engineering department at the University of Saskatchewan (Smith and Kells, 1995). The two methods were selected because they: i) examine rock on steep slopes subject to downslope flow; and, ii) provide estimates of rock sizes that are just stable under the imposed forces (i.e., F.O.S. = 1).

Table 1 presents a printout of the spreadsheet calculations. For an assumed riffle slope of 10% and a design discharge of 5.6 m^3/s (bankfull), the required D_{50} for the riffle rock is about 240 mm (about 10 inches) for a factor of safety of one. Assuming a shape halfway between a cube and sphere, this size of rock weighs 58 lb. The USDA and University of Saskatchewan methods provided similar estimates of rock size.

The USDA method computes the stable median diameter for angular rock. A larger diameter is required for rounded rock (details are provided in Robinson et al, 1998).

High Inflow Rates to FWS Reservoir during Draining Period

The drawdown of the fresh water supply (FSW) reservoir is tentatively scheduled to begin in July. Allowance has been made for up to four months to complete the drain down. The actual time required for the drawdown will depend on the inflows to the reservoir and the controlled release rate from the low-level outlet. This section is aimed at estimating the potential inflow rates that could occur during the period August 1 to November 30 under wet climatic conditions.

The inflows were estimated by a technique known as Regional Analysis. This involved transposing hydrological information from regional streamflow gauging stations to the ungauged site of the FWSD. Four broad steps were required to develop the Regional Analysis.

The first step involved identifying streamflow gauging stations in the region that have reasonably long records (>10 years), command relatively small drainage areas and experience comparable climatic conditions as the mine site. A search of the networks of stations operated by the Water Survey of Canada (WSC) and Indian and Northern Affairs (IANA) revealed a total of five candidate stations for the Regional Analysis (see Table 2).

The second step entailed assembling raw flood data from the daily streamflow records of the five selected stations. From each of these records, a total of ten annual series of flood values were extracted. All of these annual series had one common characteristic, they contained a chronological list of the largest flow that occurred each year during the period August 1 to November 30. The differences in the ten annual series related to the period over which the

largest flow was defined. The defined periods were 1, 2, 3, 4, 7, 10, 30, 60, 90 and 122 consecutive days. The last duration equals the length of the period from August 1 to November 30.

The third step involved fitting a theoretical frequency distribution (Log-Pearson Type III) to each annual series assembled in the second step. This meant a total of 50 fittings were undertaken (i.e., 5 stations with 10 annual series per station). The fitted frequency distributions were then used to predict the magnitude of the August to November flows at the regional stations for return periods ranging from 2 to 100 years and durations ranging from 1 day to 122 days. The second and third steps were performed using a suite of computer programs developed by the U.S. Geological Survey (USGS) for processing hydrological data (viz., IOWDM4.1, SWSTAT4.1 and ANNIE4.1). Table 2 summarizes the results of the third step. To facilitate comparison of the floods generated on the differently sized catchments, the flood values in Table 2 have been expressed as unit discharges in units of L/s/km^2 (i.e., the absolute flood discharge has been divided by the contributing catchment area).

The final step entailed selecting flood values from Table 2 to represent the inflows of the FWS reservoir. Details for this final step are provided in the footnotes of the table.

For a typical year (return period of 2 years), the average inflow to the FWS reservoir during the period August to November is estimated to be 500 L/s (i.e., 7.5 L/s/km^2 x 67 km^2). For an extremely wet year with a return period of 100 years, the average inflow over this same period is estimated to be 160% greater, or 1,270 L/s.

High Inflow Rates to FWS Reservoir during Construction Period

The excavation of the dam notch and restoration of the stream channel are slated for the period December 1 to March 31. This section presents estimates of potential high inflows to the reservoir during this period for a range of return periods.

The general procedure outlined above for the August to November period was adhered to in estimating the magnitude of potential high inflows during the construction period. Differences in the specific application of Regional Analysis to the construction period are outlined below:

1) The streamflow gauging station on Vangorda Creek could not be used because it was only operated seasonally during the open water season.
2) The streamflow record for a long-term station in the eastern interior of Alaska (Salcha River) was added to the analysis to include a data set that extends over a significantly longer period of record than available at the other selected stations.

3) The annual series were extracted for the period December 1 to March 31.
4) The longest duration examined was changed from 122 to 121 days (i.e., except for leap years, the period December 1 to March 31 is one day shorter than the period August 1 to November 30).

The results of the analysis are presented in Table 3. The unit flows predicted for all return periods and all stations are extremely low and are consistent with baseflow conditions (i.e., the streamflow is derived from groundwater discharge). This suggests that no significant rainstorm or early snowmelt was ever recorded in the winter months (December 1 to March 31) at the five regional stations. This includes Salcha River, which has operated for 53 years.

Based on the above discussion, the system for diverting water around the construction site will only require a capacity equal to a high baseflow rate. The baseflow can be expected to be highest at the beginning of the construction period and then follow a recession curve through the remainder of the winter.

In a typical year (return period of 2 years), the peak daily inflow to the FWS reservoir during the December 1 to March 31 period is estimated to be 200 L/s. The average over the full four-month construction period would be approximately 115 L/s. The corresponding flows for a 100-year wet condition are 560 L/s and 280 L/s, respectively.

Summer Low Flows

The restored channel of the South Fork of Rose Creek will be required to provide fish passage during low flow periods in the summer to satisfy requirement of fish passage under most flow conditions. This section describes the steps undertaken to estimate the magnitude of low flows in this stream during the period June 1 to September 30 for a range of return periods.

The general procedure for estimating the low flows was similar to that used for estimating the August to November flood flows, with the following differences:

1) The streamflow record for the South MacMillan River station was rejected for the low flow analysis. The mean annual runoff for this station is roughly double that of the South Fork of Rose Creek (624 mm vs. 311 mm). As a result, the South MacMillan River sustains a considerably greater flow in summer dry periods than does the South Fork (when expressed as a unit discharge).
2) The streamflow record for the North Fork of Rose Creek (Station R7) was included in the low flow analysis. This record covers a period of six years, which is adequate for estimating events of frequent occurrence (say, up to a 20-year return period).

3) Preparation of the annual series involved extracting the lowest flow in each year of record for the period June 1 to September 30.
4) The fitted frequency distributions were used to estimate low flows for a smaller range of return periods than specified for the flood analyses (viz., 2, 5, 10 and 20 years).

The results of the low flow analysis are presented in Table 4. During a typical year, the 7-day low flow for the period June 1 to September 30 is estimated to be 470 L/s at the site of the FWSD. The 7-day, 10-year low flow event for this same location and period is computed to be 290 L/s. For comparison, the long-term average annual flow at the FWS reservoir is estimated to be 660 L/s.

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Table 1 Estimation of stable rock size for riffles (assuming 10% slopes)

Channel slope =	0.1	m/m		
Bottom width =	6	m		
Side slope =	2	H:1V		
Depth of flow (guess) =	0.272427	m		
Wetted perimeter =	7.218329	m		
Flow area =	1.782993	m^2		
Hydraulic radius =	0.247009	m		
Manning's n =	0.039633			
Discharge =	5.600615	m^3/s		
Average velocity =	3.141132	m/s		
Riprap d_{50} (guess) =	0.28	m		
Riprap d_{50} (computed) =	0.278815	m	278.8153 mm (FOS = 1.2)	96.38894 lb (assuming midway between sphere and cul
conservative unit discharge =	0.933436	m3/s/m	232.3461 mm (FOS = 1)	55.78063 lb (assuming midway between sphere and cul
Top width of free surface =	7.089707			
Froude number =	1.999821			
average flow width =	6.544853	m		
approximate unit discharge =	0.855728	m3/s/m		
USDA D50 (S < 0.1) =	224.2505	mm (FOS=1)	50.15075 lb (assuming midway between sphere and cube)	
conservative unit discharge =	0.933436	m3/s/m		
USDA D50 (S < 0.1) =	234.8044	mm (FOS=1)	57.56996 lb (assuming midway between sphere and cube)	

Table 2 Estimation of High Inflow Rates to FWR during Reservoir Draining Period (August 1 to November 30)

Streamflow Gauging Station		Length of Record	Catchment Area	Mean Annual Runoff	Authority [b]	Return Period	Average high discharge in L/s/km^2 for the following number of consecutive days:									
ID No.	Name	(years)	(km^2)	(mm)		(years)	1	2	3	4	7	10	30	60	90	122
09BA001	Ross River at Ross River	36	7250	293	WSC	2	18	18	17	17	16	15	13	11	9.4	7.7
						10	28	27	27	26	24	22	19	16	14	11
						25	32	31	30	29	27	25	21	18	16	12
						50	35	34	33	31	28	27	22	20	17	14
						100	37	36	35	33	30	28	23	21	18	15
09AD002	Sidney Creek at km 46 South Canol Road	12	372	350	WSC	2	18	17	16	16	14	14	11	10	9.2	8.1
						10	36	33	31	30	27	25	19	16	15	13
						25	48	44	41	39	35	33	23	19	18	15
						50	58	52	49	46	42	39	27	22	20	17
						100	70	62	58	54	50	45	31	24	22	19
09AG003	South Big Salmon River below Livingstone Creek	15	515	246	WSC	2	19	18	17	17	15	15	13	11	9.4	7.8
						10	37	34	32	30	28	26	20	17	15	12
						25	49	43	40	38	34	31	24	20	17	15
						50	59	50	46	43	39	36	27	22	19	16
						100	69	58	52	49	44	40	30	24	21	18
09BB001	South MacMillan River at km 407 Canol Road	22	997	624	WSC	2	58	55	52	50	44	41	30	25	21	17
						10	82	75	70	66	59	55	44	36	29	23
						25	90	82	76	71	64	61	51	42	33	26
						50	95	86	79	74	68	64	56	47	36	28
						100	99	89	82	77	71	68	61	52	39	30
29BC003	Vangorda Creek at Faro Townsite Road [a]	16	91.2	235	IANA	2	14	13	13	13	12	11	9.4	8.2	7.5	6.4
						10	26	24	23	22	21	20	16	13	11	9.3
						25	34	30	29	28	26	25	20	16	13	11
						50	40	36	34	33	31	29	23	19	15	12
						100	47	41	39	38	35	34	26	21	16	13
Estimated Inflow Rates for the Fresh Water Reservoir (FWR) [c, d]		n/a	67	311	n/a	2	**17**	**16**	**16**	**15**	**14**	**14**	**11**	**10**	**8.9**	**7.5**
						10	**37**	**34**	**32**	**30**	**28**	**26**	**20**	**17**	**15**	**13**
						25	**49**	**44**	**41**	**39**	**35**	**33**	**24**	**20**	**18**	**15**
						50	**59**	**52**	**49**	**46**	**42**	**39**	**27**	**22**	**20**	**17**
						100	**70**	**62**	**58**	**54**	**50**	**45**	**31**	**24**	**22**	**19**

Notes: a) The gauging station on Vangorda Creek is operated on a seasonal basis. Missing data within the daily record of this station were patched using a correlation with WSC Station 09BC001 (Pelly River at Pelly Crossing). The data for most of October and all of November were usually missing.

b) WSC = Water Survey of Canada and IANA = Indian and Northern Affairs

c) Two observations were made about the regional flood data contained in this table. Firstly, the unit flood values appear to be independent of drainage area for the longer durations (>30 days) and only weakly correlated for the shorter durations. Secondly, the unit mean annual runoff (MAR) appears to explain a significant amount of variation in flood magnitude between the stations (i.e., the unit flood increases with increasing MAR). Because of this latter observation, the flood data for the South MacMillan River were not used to characterize the flood regime of the FWR. The MAR of the South MacMillan River is about double that of the FWR.

d) Two approaches were used to estimate the inflows to the FWR during the reservoir draining period. For a return period of 2 years, the inflow rate was taken as the average of the predicted flows at the regional stations. For each of the other return periods, the inflow to the FWR was assumed equal to the maximum of the flows estimated at the regional stations. In most cases, Sidney Creek provided the largest unit flow value.

Table 3 Estimation of High Inflow Rates to FWR during Construction Period (December 1 to March 31)

Streamflow Gauging Station		Length of Record	Catchment Area	Mean Annual Runoff	Authority[a]	Return Period	Average high discharge in L/s/km^2 for the following number of consecutive days:									
ID No.	Name	(years)	(km^2)	(mm)		(years)	1	2	3	4	7	10	30	60	90	121
09BA001	Ross River at Ross River	35	7250	293	WSC	2	2.3	2.2	2.2	2.2	2.1	2.0	1.8	1.5	1.3	1.2
						10	3.1	3.1	3.1	3.0	3.0	2.9	2.5	2.1	1.8	1.6
						25	3.5	3.5	3.4	3.4	3.4	3.3	2.9	2.3	2.0	1.7
						50	3.8	3.8	3.7	3.7	3.6	3.6	3.2	2.6	2.1	1.8
						100	4.0	4.0	4.0	4.0	3.9	3.8	3.4	2.7	2.3	1.9
15484000	Salcha River near Salchaket	53	5618	261	USGS	2	2.0	2.0	1.9	1.9	1.9	1.9	1.7	1.5	1.3	1.2
						10	3.0	3.0	3.0	3.0	2.9	2.9	2.6	2.3	2.0	1.9
						25	3.5	3.5	3.4	3.4	3.4	3.3	3.0	2.7	2.4	2.2
						50	3.8	3.8	3.8	3.8	3.7	3.7	3.3	2.9	2.7	2.5
						100	4.2	4.1	4.1	4.1	4.0	4.0	3.6	3.2	3.0	2.7
09AD002	Sidney Creek at km 46 South Canol Road	11	372	350	WSC	2	3.9	3.9	3.9	3.8	3.8	3.7	3.5	3.1	2.9	2.7
						10	5.9	5.8	5.8	5.7	5.6	5.4	4.9	4.3	3.8	3.4
						25	6.9	6.8	6.7	6.7	6.5	6.3	5.7	4.9	4.1	3.7
						50	7.6	7.6	7.5	7.4	7.2	6.9	6.3	5.3	4.4	4.0
						100	8.4	8.3	8.2	8.1	7.8	7.6	6.9	5.8	4.7	4.1
09AG003	South Big Salmon River below Livingstone Creek	14	515	246	WSC	2	2.3	2.2	2.2	2.2	2.1	2.1	1.8	1.5	1.2	1.1
						10	4.7	4.7	4.6	4.6	4.5	4.4	4.0	3.3	2.7	2.3
						25	6.1	6.0	5.9	5.9	5.8	5.7	5.3	4.3	3.6	3.1
						50	7.1	7.0	7.0	6.9	6.7	6.7	6.3	5.1	4.3	3.6
						100	8.2	8.0	8.0	7.9	7.7	7.7	7.3	6.0	5.0	4.2
09BB001	South MacMillan River at km 407 Canol Road	21	997	624	WSC	2	4.3	4.2	4.2	4.1	4.0	3.9	3.4	2.8	2.4	2.1
						10	5.9	5.9	5.8	5.8	5.6	5.4	4.7	3.9	3.3	2.9
						25	6.7	6.6	6.6	6.6	6.3	6.1	5.2	4.4	3.7	3.2
						50	7.3	7.2	7.2	7.1	6.8	6.6	5.7	4.8	3.9	3.4
						100	7.9	7.8	7.7	7.7	7.3	7.0	6.1	5.2	4.2	3.6
Estimated Inflow Rates for the Fresh Water Reservoir (FWR) [b]		n/a	67	311	n/a	2	**2.9**	**2.9**	**2.9**	**2.9**	**2.8**	**2.7**	**2.4**	**2.1**	**1.8**	**1.7**
						10	**5.9**	**5.9**	**5.8**	**5.8**	**5.6**	**5.4**	**4.9**	**4.3**	**3.8**	**3.4**
						25	**6.9**	**6.8**	**6.7**	**6.7**	**6.5**	**6.3**	**5.7**	**4.9**	**4.1**	**3.7**
						50	**7.6**	**7.6**	**7.5**	**7.4**	**7.2**	**6.9**	**6.3**	**5.3**	**4.4**	**4.0**
						100	**8.4**	**8.3**	**8.2**	**8.1**	**7.8**	**7.7**	**7.3**	**6.0**	**5.0**	**4.2**

Notes: a) WSC = Water Survey of Canada and USGS = United States Geological Survey

b) Two approaches were used to estimate the inflows to the FWR during the construction period. For a return period of 2 years, the inflow rate was taken as the average of the predicted flows at the five regional stations. For each of the other return periods, the inflow to the FWR was assumed equal to the maximum of the flows estimated at the regional stations. In most cases, Sidney Creek or South Big Salmon River provided the largest unit flow value.

Table 4 Estimated Low Flows in the South Fork of Rose Creek During the Summer (June 1 to September 30)

Streamflow Gauging Station		Length of Record	Catchment Area	Mean Annual Runoff	Authority [c]	Return Period	Average low discharge in L/s/km^2 for the following number of consecutive days:					
ID No.	Name	(years)	(km^2)	(mm)		(years)	1	7	30	60	90	122
09BA001	Ross River at Ross River	36	7250	293	WSC	2	6.7	7.1	8.7	10	13	18
						5	4.9	5.2	6.2	7.6	9.5	14
						10	4.1	4.4	5.1	6.2	8.0	12
						20	3.4	3.7	4.3	5.3	6.8	11
09AD002	Sidney Creek at km 46 South Canol Road	12	372	350	WSC	2	6.7	7.0	8.3	9.4	13	22
						5	5.3	5.6	6.5	7.3	9.4	17
						10	4.7	4.9	5.8	6.5	8.0	14
						20	4.3	4.5	5.3	5.9	6.9	12
09AG003	South Big Salmon River below Livingstone Creek	14	515	246	WSC	2	6.6	7.2	8.5	10	12	16
						5	5.5	5.8	6.6	7.7	9.2	12
						10	5.1	5.2	5.9	6.8	7.9	10
						20	4.8	4.9	5.5	6.1	7.0	9.4
29BC003	Vangorda Creek at Faro Townsite Road [a]	15	91.2	235	IANA	2	4.8	5.2	6.4	7.6	9.2	13
						5	3.7	4.0	4.8	5.7	7.2	9.9
						10	3.2	3.5	4.2	5.0	6.4	8.6
						20	2.9	3.2	3.7	4.6	5.7	7.6
R7	North Fork of Rose Creek above Faro Creek Diversion Channel [b]	6	95	332	ARMC	2	7.6	8.2	11	13	14	19
						5	6.5	6.9	8.1	9.7	11.0	14
						10	6.1	6.4	7.1	8.5	9.7	12
						20	5.9	6.2	6.3	7.6	8.6	10
Estimated Summer Low Flows for South Fork of Rose Creek at Fresh Water Reservoir [d]		n/a	67	311	n/a	2	6.6	7.0	8.3	9.4	12	16
						5	4.9	5.2	6.2	7.3	9.2	12
						10	4.1	4.4	5.1	6.2	7.9	10
						20	3.4	3.7	4.3	5.3	6.8	9.4

Notes:

a) The gauging station on Vangorda Creek is operated on a seasonal basis. Missing data within the daily record of this station were patched using a correlation with WSC Station 09BC001 (Pelly River at Pelly Crossing).

b) The flow record for the North Fork of Rose Creek (NFRC) gauging station is probably less accurate than the records of the other stations in this table, largely because fewer direct discharge measurements are made at the NFRC station than at the government stations. Missing and suspect data within the NFRC daily record were patched using a correlation with WSC Station 09BA001 (Ross River at Ross River).

c) WSC = Water Survey of Canada, IANA = Indian and Northern Affairs, and ARMC = Anvil Range Mining Corporation (Interim Receivership)

d) The low flows for the South Fork of Rose Creek were estimated to equal the minimum of the flows predicted for the three WSC Stations. The adopted flows are bounded by the predicted flows for Vangorda Creek and NFRC.

APPENDIX D

APPENDIX D1
Reservoir Drawdown Assessment

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PROJECT MEMORANDUM

To:	**File**	**Fax No.:**	
Attention:	**01CD001.22**	**CC:**	
From:	**Gerry Ferris**	**Date:**	**April 11, 2003**
Subject:	**Reservoir Drawdown – FWSD Breach Project**		
No. of Pages (including this page): 15		**Project No:**	**0257-012-06**

As indicated in Chapter 2.2.3, the Interim Receiver modified the downstream end of the low level outlet (LLO) in March 2003. The modifications, which were based on recommendations from Klohn (2003), will increase the rate at which water can be safely discharged from the LLO. The Interim Receiver plans to maintain the reservoir at a nominal elevation of 1090 m amsl throughout the spring and early summer of 2003, although reservoir levels higher than 1090 m amsl are likely on a during this timeframe.

This memorandum evaluates the reservoir drawdown schedule, based on the technical and permitting factors that are expected to influence the methodology, net drawdown rate and completion date for reservoir drawdown.

Factors that Influence Drawdown

There are five main factors that affect the reservoir drawdown schedule:

- Permits.
- Completion of the fish salvage.
- Capacity of the LLO in relation to reservoir inflows.
- Rapid drawdown failures of the dam.
- Potential flooding events during construction period.

Permitting

Permits must be obtained from the following agencies prior to commencement of the breach project:

- Fisheries and Oceans Canada (DFO).
- Indian and Northern Affairs Canada (DIAND).
- Fisheries and Oceans Canada (Coast Guard).

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- Yukon Water Board.
- Yukon Government (Department of Environment).

Although permits are required from all the noted agencies for the breach project, it is expected that only the DFO and YG permits are required as part of the reservoir drawdown. These permits are required since complete reservoir lowering has the potential to adversely alter fish habitat, at least temporarily. It should be noted that lowering of the reservoir over the winter does not permanently alter the structure or the reservoir, since the reservoir will re-fill in the spring (reservoir lowering in the winter was a routine occurrence during mining operations).

It is understood, based on a meeting held in Calgary on February 18, 2003, that the CEAA screening level review will be complete on about May 23, 2003. DFO indicated in that meeting that, subject to a positive result from the CEAA screening review, the necessary permits could be issued by about June 9, 2003. The YG permit is expected on approximately the same schedule.

The DFO/YG permits are expected to consist of a two stage approval process, the first being approval of the project in general and the second being approval of the specific details of the fish salvage plan. The outline of the fish salvage plan is contained in the breach design report (Chapter 7), but the specific details cannot be developed until this summer, given the need to perform fish counts in candidate receiving areas. The second stage of the permit may place a limit on the reservoir drawdown as outlined in the next section of the memorandum.

Fish Salvage

As noted above, the fish salvage from the reservoir can not be performed prior to receipt of DFO / YG approval. The fish salvage must be completed prior to completing the reservoir lowering, to prevent fish kill within the former reservoir area and prior to ice formation on the reservoir. Preliminary fish salvage plans envisioned using nets and performing the salvage prior to lowering the reservoir below 1086 m amsl. Based on the type of nets envisioned for use, the reservoir should not be lowered below 1086 m amsl to ensure an efficient transfer operation (based on the reservoir bathymetry, shrubs and stumps on the base of the reservoir and net size).

Based on the schedule for the fish surveys, development of the transfer plan, receipt of final approvals from DFO and YG, and implementation of the transfer, it is currently expected that the fish salvage will not be completed until about July 22, 2003.

Capacity of the LLO and Reservoir Inflows

The recent modifications to the LLO (Appendix B) followed the recommendations by Klohn (2003). The Klohn report included a recommended discharge rating curve to describe the LLO discharge capacity as a function of the reservoir elevation (Figure 2.3 of the breach report).

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The recommended curve for drawdown evaluation indicates that if the reservoir was full (3705 ft mine data or 1096.3 m amsl), the discharge would be 34,900 Igpm (2.64 m^3/s) and with the water level in the reservoir 0.3m (1 foot) above the inlet of the LLO, the discharge would be 15,000 Igpm (1.14 m^3/s).

The inflows to the FWSD reservoir had been previously estimated based on the measurements from station R7 (Northwest Hydraulic Consultants, 2001). Station R7 is located on the North Fork of Rose Creek upstream of the confluence with the Faro Creek Diversion. This streamflow gauging station commands a similar catchment area to that controlled by the FWSD (i.e., R7 has a catchment of 95 km^2 vs. 67 km^2 for the FWSD). A review of the data from station R7 was recently completed (Appendix C1) to assess the effects of ice on the data set and include data from more recent monitoring.

The 2002 review included processing of the available data in the R7 record according to the following three steps:

- develop an empirical relationship between discharge and stage (i.e., the rating curve);
- screen the data to identify periods when stage was influenced by ice effects (e.g., ice jams downstream of gauge and/or formation of ice on the pressure transducer); and,
- make estimates for missing data and for portions of flow record influenced by ice (a process known as "patching").

A revised and expanded dataset was created for station R7 through this process. The daily flow data of the revised data set was converted to a monthly flow record for the station, and then the ratio of the catchment areas (i.e., 67 km^2/95 km^2 = 0.71) was used to estimate the monthly inflows to the FWS reservoir (Table 1).

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Table 1 Inflows to the Fresh Water Reservoir

Month	Monthly discharge in m^3/s for:						Average	Maximum	Minimum
	1996	1997	1998	1999	2000	2001	(m^3/s)	(m^3/s)	(m^3/s)
Jan		0.08	0.22	0.13	0.15	0.21	0.16	0.22	0.08
Feb		0.06	0.20	0.10	0.14	0.19	0.14	0.20	0.06
Mar		0.06	0.17	0.11	0.12	0.17	0.13	0.17	0.06
Apr		0.18	0.18	0.16	0.11	0.17	0.16	0.18	0.11
May		1.54	1.48	1.90	0.94	0.98	1.37	1.90	0.94
Jun		1.64	0.94	2.27	2.00	2.90	1.95	2.90	0.94
Jul		1.08	0.64	0.89	1.14	1.24	1.00	1.24	0.64
Aug		0.94	0.63	1.15	1.47	0.59	0.95	1.47	0.59
Sep	1.07	0.53	0.56	0.93	1.71		0.96	1.71	0.53
Oct	0.43	0.39	0.43	0.58	1.22		0.61	1.22	0.39
Nov	0.22	0.28	0.26	0.32	0.37		0.29	0.37	0.22
Dec	0.12	0.21	0.18	0.23	0.25		0.20	0.25	0.12
Annual		**0.58**	**0.49**	**0.73**	**0.80**		**0.66**	**0.99**	**0.39**

Given the inflows to the reservoir outlined in Table 1 and the discharge rating curve for the modified LLO, reservoir drawdown predictions can be made. It should be noted that the actual reservoir drawdown will be dependent on the inflows to the reservoir experienced during 2003. However, the analysis prepared on the basis of the average and maximum inflows should bound the actual reservoir drawdown that can be achieved.

Reservoir drawdown analyses were performed to determine the length of time required to drain the reservoir using the modified LLO. Two different start elevations (start date of July 22, 2003) were used in the analysis, 1086 m and 1092 m amsl. These two reservoir elevations represent, respectively, the lowest reservoir elevation possible on this start date (the reservoir will not be lowered beyond this level until the fish transfer has been completed) and the highest reservoir elevation assuming that conditions are significantly wetter than normal prior to this date.

Figure 1 presents the results of the reservoir drawdown analysis for a variety of inflow conditions (average inflows used the average rate from Table 1 and the reference to a wet month used inflows from the maximum column), based on a reservoir elevation of 1092 m amsl on July 22, 2003. This analysis indicates that the timing of the complete reservoir dewatering is dependent upon the inflows during the drawdown period, with the completion of the dewatering occurring as early as September 1, 2003 if average conditions prevail and November 4, 2003 if maximum inflows (Table 1) prevail. Note that the calculations continue to show that the reservoir is lowered below 1082 m amsl, however, this is not possible since the inlet of the LLO is at 1082. Actual reservoir elevations would be maintained at approximately the inlet elevation, until the inflows were such that the reservoir began to refill or pumping began to completely lower the reservoir. This analysis was performed to illustrate that wet months later in the drawdown can cause the reservoir to refill (i.e. average inflows and wet October).

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Figure 2 presents the results of the same reservoir drawdown analysis assuming the reservoir is at elevation 1086 m amsl on July 22, 2003. This analysis indicates that completion of the dewatering occurs on August 15, 2003 if average conditions prevail and on November 3, 2003 if maximum inflows prevail. Similar to the analysis shown in Figure 1, the effects of wet months (September and October) is that the reservoir could refill, even if the reservoir had been lowered to the inlet elevation of the LLO in August.

Based on this analysis, the reservoir elevation (given a July 22, 2003 start date) at the start of drawdown has minimal effect on when the drawdown is complete (except if average inflows occur). The inflows during drawdown control the timing of the completion of the drawdown and the possibility that the reservoir will refill once lowered to the inlet elevation of the LLO. The analysis indicates that the reservoir would be lowered to the inlet (elevation 1082 mamsl) and not refill by sometime between mid October and mid November.

Rapid Drawdown Analysis

Rapid drawdown failures are initiated on the upstream face of a dam when the reservoir is lowered and the water pressures in the dam remain high. As detailed in the design criteria chapter of the breach design report (Chapter 3), the appropriate factor of safety against failure of the upstream face of the dam during reservoir lowering is 1.3.

The reservoir drawdown scenarios shown in Figures 1 and 2 indicate that a drawdown rate of about 20 to 25 cm/day will occur based on projected inflows to the reservoir (Table 1) and outflows from the reservoir determined from the discharge rating curve (Figure 2.3). In order to assess the performance of the FWSD under the expected drawdown rates, the following were considered:

- Historical performance of the FWSD during mine operations.
- Performance of the FWSD during drawdown in the winters of 2001/02 and 2002/03.
- Stability analysis considering rapid drawdown.

During operations, the mill reportedly required between 6,000 and 7,000 Igpm (0.45 to 0.53 m^3/s). This amount of water was collected at the pump house and pumped to the mill. This intake of water was primarily made up from flow in the South Fork of Rose Creek (i.e. water released through the LLO at the FWSD), although some of this water would have been from the North Fork of Rose Creek and water wells. The net water balance, based on the required water demand from the mill, was negative. Mill personnel knew there was a risk they would run out of water in a dry year (personal communications with site staff) and, as a result, reservoir outflows were kept to a minimum. Despite minimizing the outflow from the reservoir, the reservoir was regularly drawn down by 6 m and, occasionally by as much as 10 m, by the end of the winter.

An analysis of the past reservoir performance, using this operational history as a guide, was made. The inflows from Table 1 were used as the inflows to the reservoir and a constant outflow of 0.4 m^3/s from the LLO was used to meet the mill requirements (the remaining requirement made up from the other sources noted). The results of the analysis are presented in Figure 3. This analysis predicts a reservoir drawdown

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of about 10 m for average winter inflows and about 6 m of drawdown for wet winter inflows. This predicted performance through the winter matches the reported performance of the reservoir. Using the predicted reservoir performance through the winter, the reservoir drawdown rates have been calculated. The estimated drawdown rate that would have occurred during mine operations would have been about 5 to 10 cm/day.

The reservoir drawdown over the winter of 2001/02 was assessed (BGC, 2002) with respect to rapid drawdown failures. This assessment indicated that the rate used (7 to 8 cm/day, with short durations of 15 cm/day) was effectively a "full scale" test which indicated that the dam was safe with respect to potential failures initiated by drawdown at those rates. The drawdown rates during the winter of 2002/03 were similar, but slightly less than those during the winter of 2001/02 (Figure 4), and no structural difficulties were observed. The drawdown rates used in the past two winters are similar to the rates used during mine operations.

The rates proposed for draining the FWS reservoir prior to the breach are at least twice the rates that have been successfully used in the past. Therefore, the past performance of the dam during drawdown does not give an indication of the performance expected during the fall of 2003, given the drawdown rates proposed. A stability analysis assessment of the effects of rapid drawdown was consequently undertaken.

The material properties used in the analyses are summarized in Table 2. The choice of material properties is discussed further in Appendix D2. In the case of the friction angle, the typical range of values that might be appropriate for each of the material types is also provided.

Table 2
Material Properties used in Stability Assessment

Material	Description	Effective Friction Angle (°)		Cohesion (kPa)	Unit Weight (kN/m^3)
		Used in Analyses	Typical range (possible)		
Core (Zone 1)	Glacial till	30° & 33°	30° to 36°	0	20
Shell (Zone 2)	Sand and gravel	38°	32° to 40°	0	20
Foundation Till	Silty, sandy gravel	30°	28° to 36°	0	20

Stability assessments for rapid drawdown are typically performed by assuming that the piezometric conditions within the dam do not change as the reservoir drops (Lane and Griffiths, 2000). This type of analysis considers that the piezometric conditions within the dam are derived from a long-term flow regime and the rate of dissipation of the porewater pressure is less than the rate of change in the reservoir level and, for the purposes of analysis, is assumed to remain constant.

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Figure 5 presents a typical slope stability output for the condition that the reservoir elevation was stable at elevation 1095 m amsl (pressures within the dam had stabilized for this reservoir level) and then the reservoir was completely drained. This analysis (using f = 30°) indicates that the factor of safety would be about 1.0 under full rapid drawdown (completely drained reservoir).

Additional stability analyses were performed to evaluate the likely stability under a variety of piezometric scenarios associated with rapid drawdown. The stability analysis results indicate the rapid drawdown type failures are possible for the dam. They also indicate the importance of the initial water pressures within the dam on the potential upstream failure of the dam. Based on the analysis presented previously in this memorandum, the actual reservoir drawdown could occur over a period of as little as 20 to 30 days, which is a similar timeframe to the time required to record a response in the piezometers within the dam (water pressure changes measured during 2001/02 and 2002/03 lag the start of reservoir drawdown by 20 to 40 days). Given the measured response times in the piezometers and the potential drawdown rate, it is expected that this may be the controlling factor for the rate of reservoir drawdown. Therefore a monitoring program (similar to the monitoring program undertaken during that past two winters) should be implemented to monitor the initial pressures in the dam and the performance of the dam during reservoir drawdown.

The following protocol should be followed during reservoir drawdown. The results of the monitoring should be forwarded immediately to the engineer for assessment. As outlined previously, the actual drawdown rates during the 2003 reservoir lowering will depend on the reservoir inflow, which cannot be predicted with a high degree of certainty given its rainfall dependence. The monitoring protocol may be varied depending on the performance during drawdown.

1. Daily visual inspections.
2. Measuring the water level within the reservoir three times per week.
3. Monitoring the piezometric levels within the dam three times per week.
4. Monitor the standpipe piezometers downstream of the dam, twice per month.

Floods during construction period

Inflow rates to the reservoir were examined as part of the site hydrology assessment. The review (Appendix B) was performed for two separate time periods: August to November and December to March. The analysis of the period from August to November was performed in order to determine the size of floods that could occur during the drawdown period. The analysis of the period from December through March estimated that flows that would have to be dealt with during the construction period.

The results indicated that no significant rainstorm of early snowmelt has ever been recorded in the winter months (December 1 to March 31) at the five stations included in the analysis, which included one station (Salcha River) which has operated for 53 years. The flows are consistent with baseflow conditions (i.e. the stream flow is derived from groundwater discharge).

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Summary

The summary of the main points of the assessment of reservoir drawdown:

- DFO / YG approval of the live fish transfer program will be required prior to the reservoir being lowered below an elevation of 1086 m amsl.
- Based on the required timing of necessary fish measurements in receiving environments and approvals of the finalized fish transfer plan, it is expected that the reservoir lowering could commence on about July 22, 2003.
- Reservoir lowering using the LLO will be completed by between mid-October to mid-November, depending on the inflows to the reservoir.
- Increased flow in the South Fork of Rose Creek would not be expected in the period from December through March. Increased flows have been measured on site in October, however, they have not been measured in November.
- The use of the LLO to lower the reservoir will result in reservoir drawdown rates about twice that previously experienced by the FWSD.
- Depending on the initial piezometric conditions within the dam, reservoir lowering may result in factors of safety lower than target levels with respect to rapid drawdown failures. Therefore, a monitoring program will be implemented to measure the piezometric response of the dam to drawdown. The monitoring program will be used to assess the stability of the dam during drawdown.

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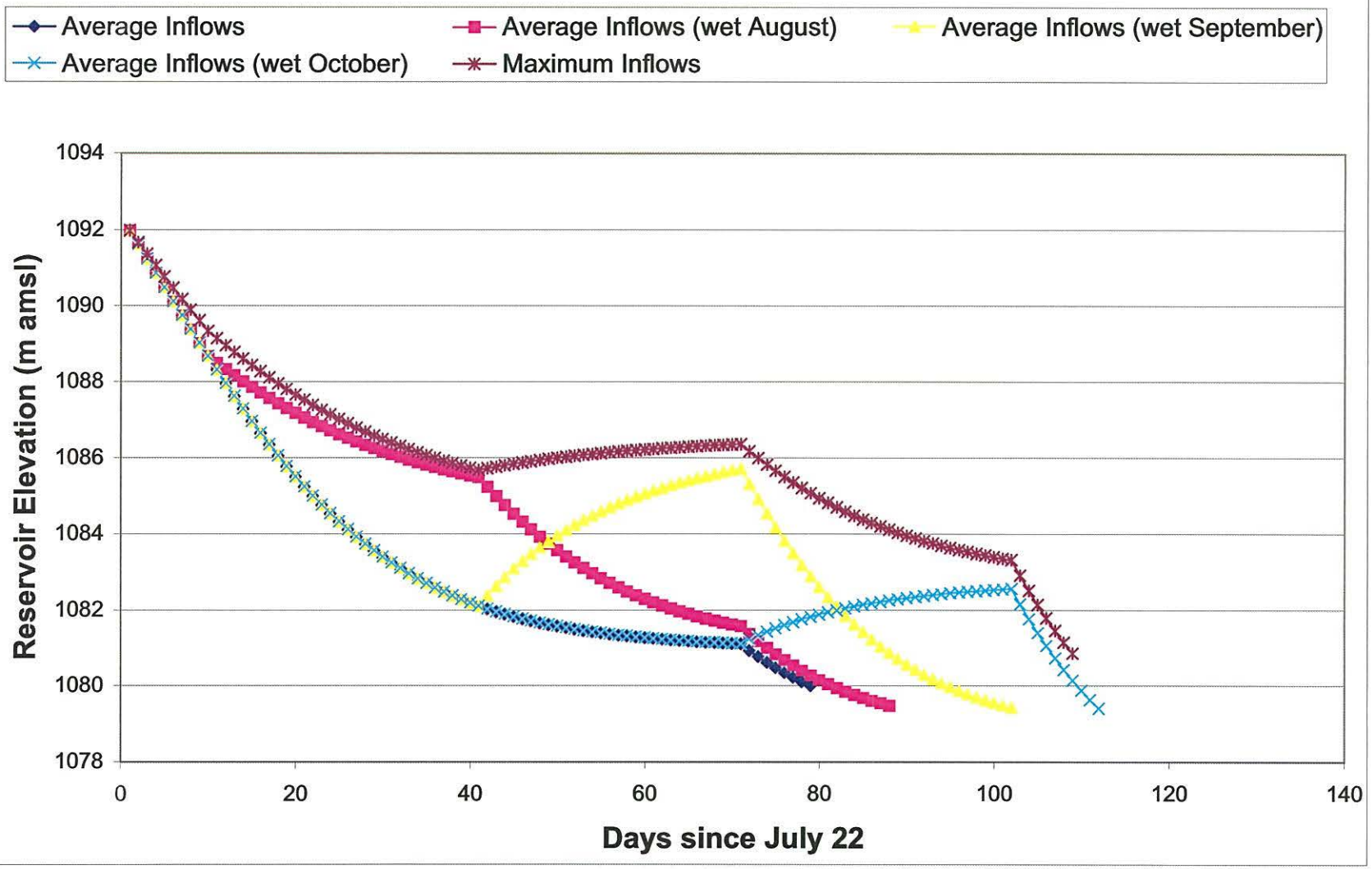
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FIGURES

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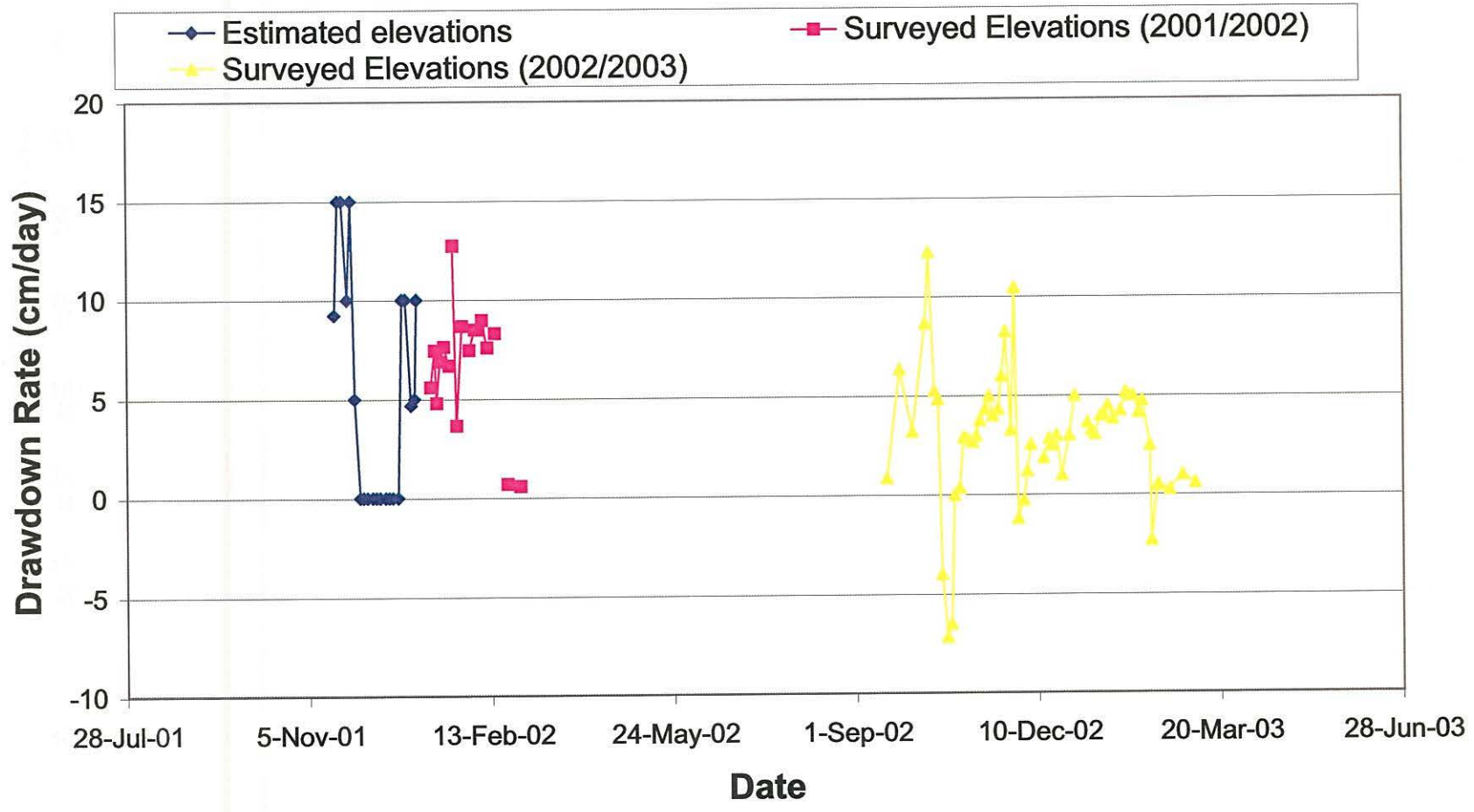
Figure 1- Starting Reservoir Elevation of 1092 m



Reservoir_drawdown.xls/LLO_capacity Chart 5

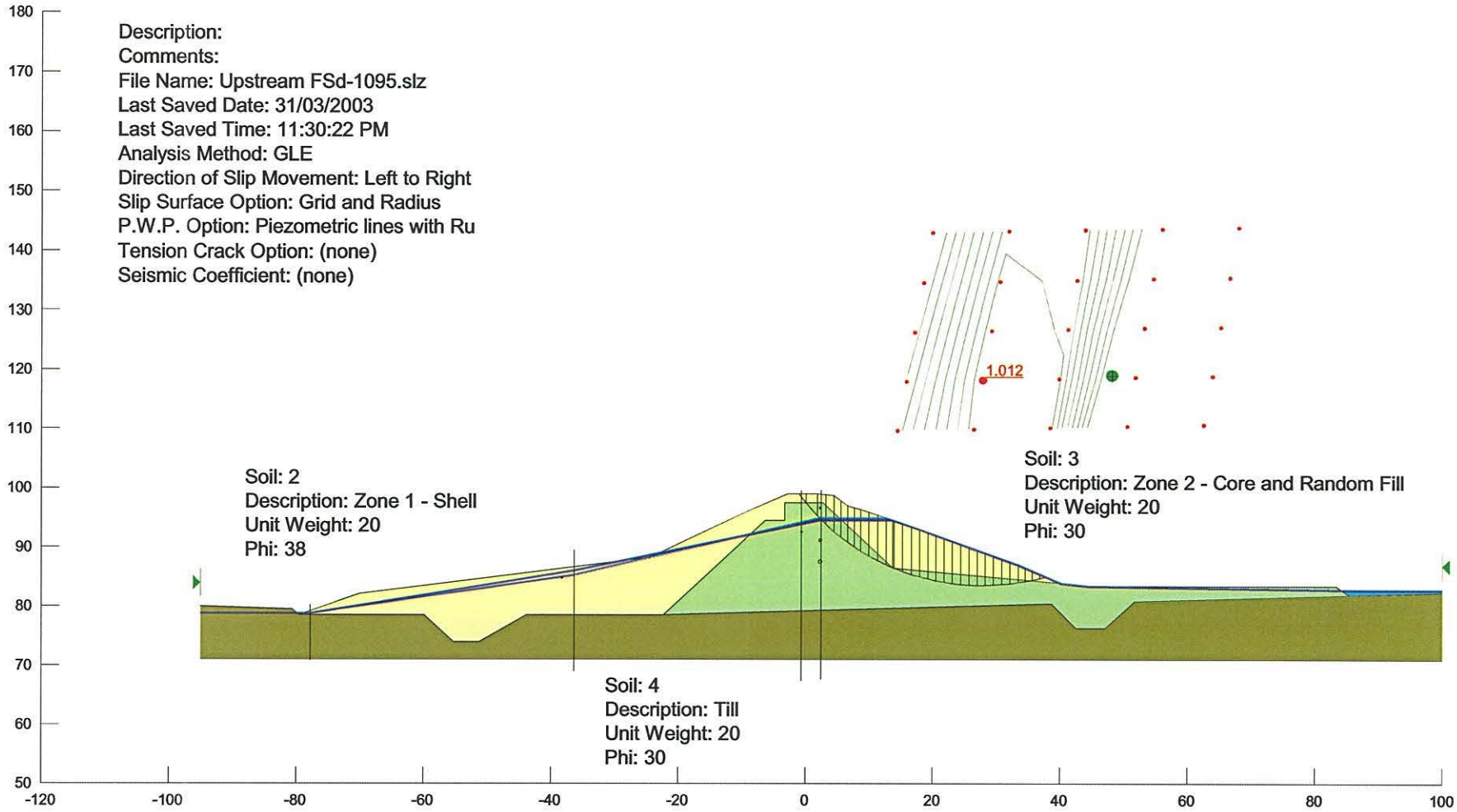
Fig. D1-1

Figure 4 - Drawdown Rates used in Recent Reservoir Lowering



Reservoir_drawdown.xls/rapid_DD Chart 5

Fig. D1-4



Gartner Lee Limited

BGC Engineering Inc. AN APPLIED EARTH SCIENCES COMPANY

SRK Consulting Engineers and Scientists

FWSD Breach
Faro Mine, Yukon Territory

Rapid Drawdown Stability Assessment

Deloitte & Touche Inc.

PROJECT	DATE	APPROVED	FIGURE
1CD003.22	APR.	GWF	5.

Reservoir_drawdown.xls/rapid_DD

Fig D1-5

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PROJECT MEMORANDUM

To:	**File**	**Fax No.:**	
Attention:		**CC:**	
From:	**Gerry Ferris / Cam Scott**	**Date:**	**April 1, 2003**
Subject:	**Stability of FWSD during Breaching and Post-breach**		
No. of Pages (including this page): 23		**Project No:**	**0257-012-06**

Stability analyses have been completed to evaluate the stability of the cut slopes on either side of the breach and the stability of the residual slopes left in place following the dam breach. The analyses were completed using Bishop's method for circular failure surfaces within the slope stability program, Slope/W (GEO-SLOPE, 1998). Bishop's method calculates the factor of safety by satisfying moment equilibrium.

Stability Analysis and Criteria

The design criteria and rationale for the design criteria have been outlined in the main body of the Breach Design report. As indicated, the areas where stability will remain important during and following the breach activities include:

- The upstream stability during reservoir drawdown;
- The upstream and downstream stability of the dam at the end of drawdown and in the long term; and,
- The stability of the sides of the breach, particularly where the existing dam height is significant.

The upstream stability during reservoir drawdown has been addressed within a separate memorandum (Appendix D1), and is not discussed herein.

The appropriate factors of safety against failure of the upstream and downstream face of the dam in the long term are 1.1 at the dam face (shallow failure), 1.3 for a deep seated failure and 1.0 under pseudo-static loading conditions.

The appropriate factors of safety against failure of the breach slide slopes are 1.3 during excavation (due to safety concerns related to men and equipment working within the breach and the potential financial

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implications associated with a slope failure during construction), 1.3 for long-term static conditions and 1.0 under pseudo-static loading conditions.

Cases Considered for Breach Stability

The slope stability analyses performed on the breach sideslope considered the critical section, i.e. through the exposed core of the dam at the location where the dam height is a maximum. The analyses considered two different side slopes within the breach (2.5H:1V and 3H:1V) and the following three basic loading conditions:

- Immediately following excavation of the breach (referred to as "end of construction"),
- Long term, under static loading, and
- Long term, under earthquake loading.

The "end of construction" case is considered to be a transient condition corresponding to relatively high pore pressures that are likely to exist as a result of the long-term seepage through the dam and the slow draining of water following reservoir drawdown. The factor of safety is expected to increase as the phreatic levels within the residual dam structure fall in response to the absence of the reservoir, eventually increasing to the condition illustrated by the long-term analysis.

The long-term conditions are applicable after phreatic levels have dropped and a new set of equilibrium conditions have been established at the structure.

Cases Considered for Long-term Stability of Residual FWSD Structure

Stability analyses for the long term stability of the residual dam were performed on the upstream and downstream sideslopes. The analyses considered the critical sections, i.e. through the highest portion of the residual structure. The analyses considered two different basic loading conditions for both the upstream and downstream slopes:

- Long term, under static loading, and,
- Long term, under pseudo-static loading.

Only the long term analyses were considered for the residual dam structure, since the transient porewater pressures on the upstream side of the dam were considered as part of the rapid drawdown analysis (Appendix D1).

Residual FWSD Structure

The general arrangement of the FWSD is shown in Figure 2.2 (Breach Report). According to a recent (2001/2002) survey of the dam (BGC, 2002), it is approximately 410 m long, 20.5 m high at its highest point (from original ground level) and 6 m to 7 m wide at the crest. The slope of the upstream face of the

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dam is approximately 2.6H:1V and the slope of the downstream face of the dam is 2H:1V. The crest of the dam is at elevation 1099 m amsl and the top of the core at 1097.5 m amsl. Further details concerning the materials used to construct the dam area included in the breach design report and previous stability analyses reports (Golder, 1989 and BGC, 2001).

Side Slopes in the Breach

These stability analyses considered two possible breach configurations, slide slopes of 2.5H:1V and 3H:1V. Benches, having a width of 2 m, are planned at elevations 1087 and 1092 m amsl. The benches were included to limit erosion, by breaking up the continuous slope and limiting the velocity of run-off due to direct rainfall. The design sections are shown in the attached figures, and further details are shown on Drawing 5 of the breach report.

Piezometric Assumptions

Two different piezometric assumptions were analysed, the short term or "end of construction" and the long-term conditions. The "end of construction" piezometric condition was used only for the stability calculations performed on the breach side slopes. The long-term piezometric condition was used in the stability analyses performed on the breach side slopes and the residual dam structure.

The "end of construction" piezometric condition assumed a relatively high surface, with the piezometric surface running from the channel bottom up to the toe of the side slope, then up to a point 5m vertically below the crest. This piezometric level is shown on the plotted outputs from the stability analysis. This piezometric elevation assumption was made based on the response of piezometers within the core of the dam measured during drawdown in the winter of 2001/02 and 2002/03. A copy of the data recorded during these two drawdown periods is included on Figure 1.

For the breach stability assessment, the assumed long-term piezometric line runs upward at a slope of about 8H to 1V from the toe of the slope. For the residual structure stability analysis the piezometric line is based on a typical pattern expected on a valley sideslope with some local raising of the piezometric elevation within the centre of the residual dam structure. The piezometric lines are shown on the attached figures.

Earthquake Loading

The earthquake loading condition was evaluated using the pseudo-static method of analysis. This analysis uses limit equilibrium methods in which the inertial forces due to earthquake shaking are represented by a constant horizontal force (equal to the weight of the potential sliding mass multiplied by a coefficient). The seismic coefficient used in these analyses used the 2003 estimations of the peak ground accelerations (PGA) compiled by the Pacific Geoscience Centre. Specifically, they included the

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PGA from the 1 in 475-year seismic event (0.06g) and, for comparison, the PGA from the 1 in 10,000-year event (0.16g).

Although the PGA was not reduced in these analyses, the seismic coefficient used in pseudo-static analyses is often reduced to roughly 1/3 to 2/3 of the PGA to account for the conservative assumption of a continuously applied force when, in fact, the PGA occurs only briefly.

Material Properties

The material properties used in the analyses are summarized in Table 1. These material properties have been chosen based on laboratory testing results performed on soil collected from the dam (Golder, 1989 and BGC, 2002) and guidance for typical material properties of compacted materials (USBR, 1987 and Mitchell, 1983). In the case of the friction angle, the typical range of values that might be appropriate for each of the material types is also provided.

Table 1
Material Properties

Material	Description	Effective Friction Angle (°)		Cohesion (kPa)	Unit Weight (kN/m^3)
		Used in Analyses	Typical range (possible)		
Core (Zone 1)	Glacial till	30° & 33°	30° to 36°	0	20
Shell (Zone 2)	Sand and gravel	38°	32° to 40°	0	20
Foundation Till	Silty, sandy gravel	30°	28° to 36°	0	20

Based on these values, the friction strengths used in the analysis of the core and foundation till have been chosen to be somewhat conservative. In the case of the shell material, the friction angle used in the analyses is generous. Using zero cohesion for the core and foundation materials is judged to be conservative for the "end of construction" case, but realistic for the long-term cases.

As a comparison, the values used in stability analyses by Golder Associates (1989), BGC (2001) and SRK (2003) are summarized in Table 2, 3 and 4, respectively.

Table 2
Soil Strength Parameters used by Golder (1989)

Material	Effective Friction Angle Values Used	Effective Cohesion (kPa)	Unit Weight (kN/m^3)
Core, Random Fill and Shell Zones	33°	0	20
Foundation	30°	0	20

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Table 3
Material Properties used by BGC (2001)

Material	Range of Effective Friction Angles	Effective Cohesion (kPa)	Unit Weight (kN/m^3)
Core and Random Fill Zones	27° – 36°	0	20
Shell	33° & 38°	0	20
Foundation	30°	0	20

Table 4
Material Properties used in Preliminary Analysis (SRK, 2003)

Material	Description	Effective Friction Angle (°)		Cohesion (kPa)	Unit Weight (kN/m^3)
		Used in Analyses	Typical range (possible)		
Core (Zone 1)	Glacial till	27°	27° to 36°	0	20
Shell (Zone 2)	Sand and gravel	38°	32° to 40°	0	20
Foundation Till	Silty, sandy gravel	30°	28° to 36°	0	20

The friction angle of 27° used in the preliminary analysis (SRK, 2003) and BGC (2001) is considered too conservative based on the comparison of the laboratory testing results and expected material properties. The analysitical results presented in this memorandum, therefore, supersede the results previously presented.

Results

The results of the analysis on the breach sideslope for $\phi = 30°$ are summarized in Table 5, along with the minimum factor of safety specified to govern the stability case (see Breach Design report for discussion on development of the criteria). The outputs from individual results for these analyses ($\phi = 30°$) are attached. The results of the analysis for $\phi = 33°$ are summarized in Table 6, individual analysis runs for this friction angle are not presented.

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Table 5

Results of Stability Analysis ($\phi = 30°$) – Breach Sideslope

Condition Analysed	Calculated Factor of Safety		Minimum Factor of Safety
	Side Slope of Breach		
	2.5H:1V	3H:1V	
Static, immediately post-construction	1.18	1.34	1.3
Static, long term	1.47	1.61	1.3
Pseudo-static (g=0.06), long term	1.23	1.33	1.0
Pseudo-static (g=0.16), long term	0.95	1.00	1.0

Table 6

Results of Stability Analysis ($\phi = 33°$) – Breach Sideslope

Condition Analysed	Calculated Factor of Safety		Minimum Factor of Safety
	Side Slope of Breach		
	2.5H:1V	3H:1V	
Static, immediately post-construction	1.23	1.37	1.3
Static, long term	1.61	1.68	1.3
Pseudo-static (g=0.06), long term	1.28	1.39	1.0
Pseudo-static (g=0.16), long term	0.99	1.04	1.0

The results of the analysis on the residual structure sideslopes for $\phi = 30°$ are summarized in Table 7, along with the minimum factor of safety specified to govern the stability case (see breach design report for discussion on development of the criteria). The outputs from individual results for these analyses ($\phi = 30°$) are attached. Since the analysis results with a friction angle of 30° indicated that the minimum factor of safety was achieved for all cases, the analysis for $\phi = 33°$ was not performed.

Table 7

Results of Stability Analysis ($\Phi = 30°$) – Residual Structure

Condition Analysed	Calculated Factor of Safety		Minimum Factor of Safety
	Sideslope Analyzed		
	Upstream	Downstream	
Static	2.21	2.76	1.3
Pseudo-static (g=0.06)	1.83	2.10	1.0
Pseudo-static (g=0.16)	1.41	1.52	1.0

Based on this analysis, the side slopes of the breach were chosen as 3H:1V. The residual dam structure exceeded the appropriate minimum factor of safety criterion.

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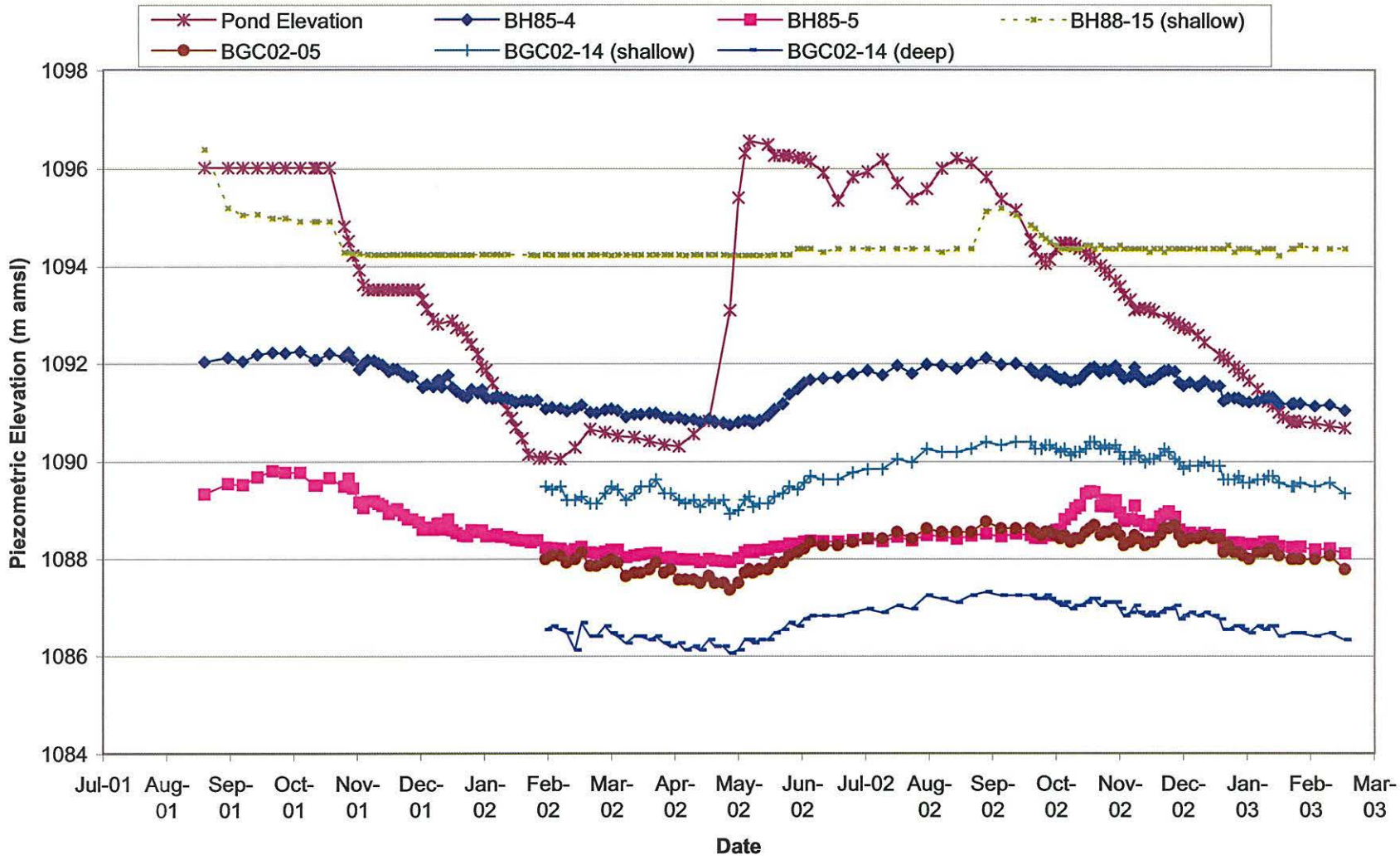
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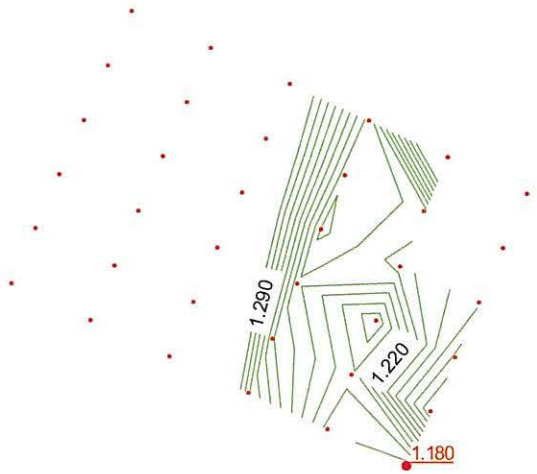
Figure 1
Piezometric Responce in the Core of the FWSD

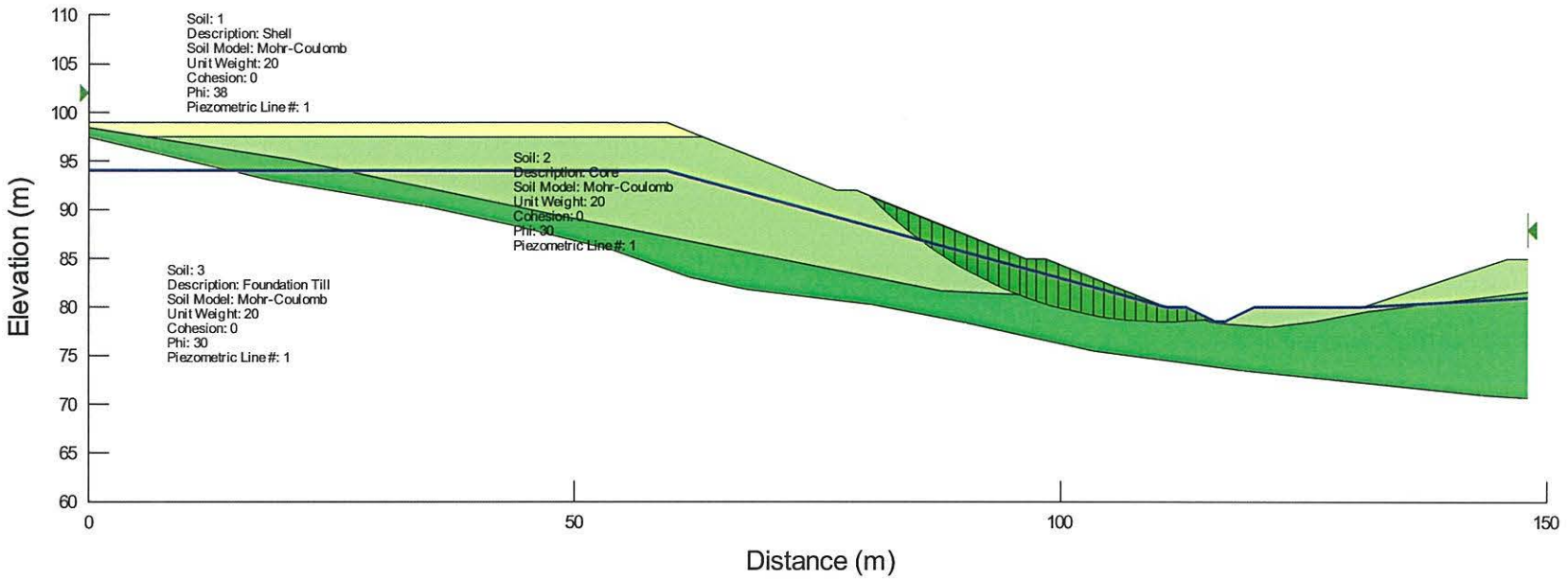


Stability Analysis Results (Breach Sideslopes)

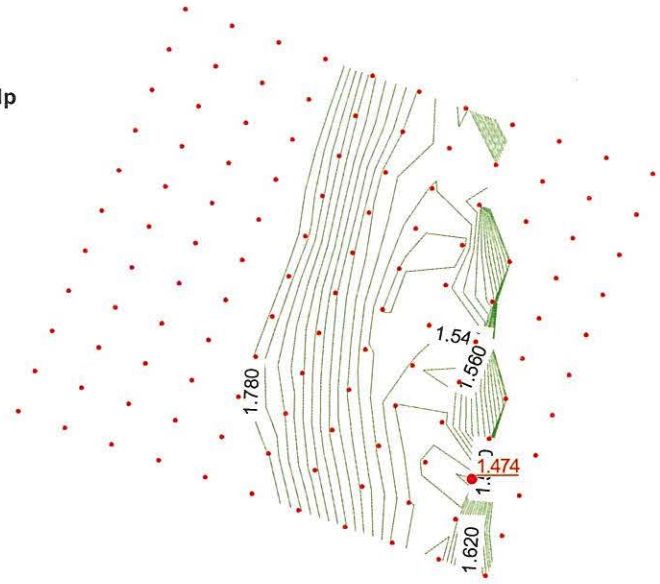
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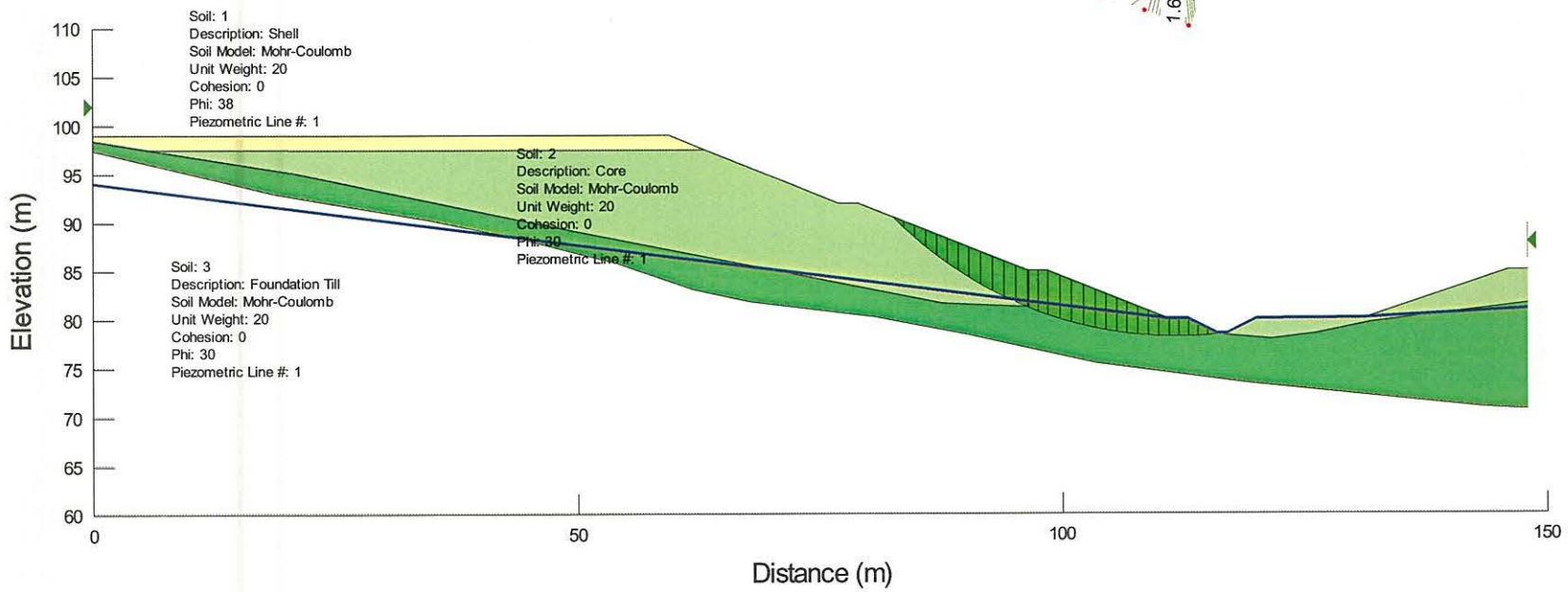
Fresh Water Storage Dam - Actual Section
Breached @ 2.5:1 Slope - Post Construction Water Table
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Analysis Method: Bishop
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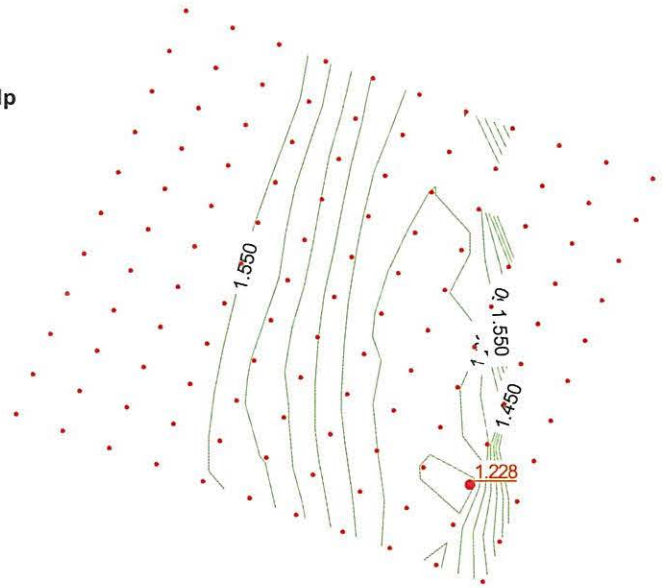


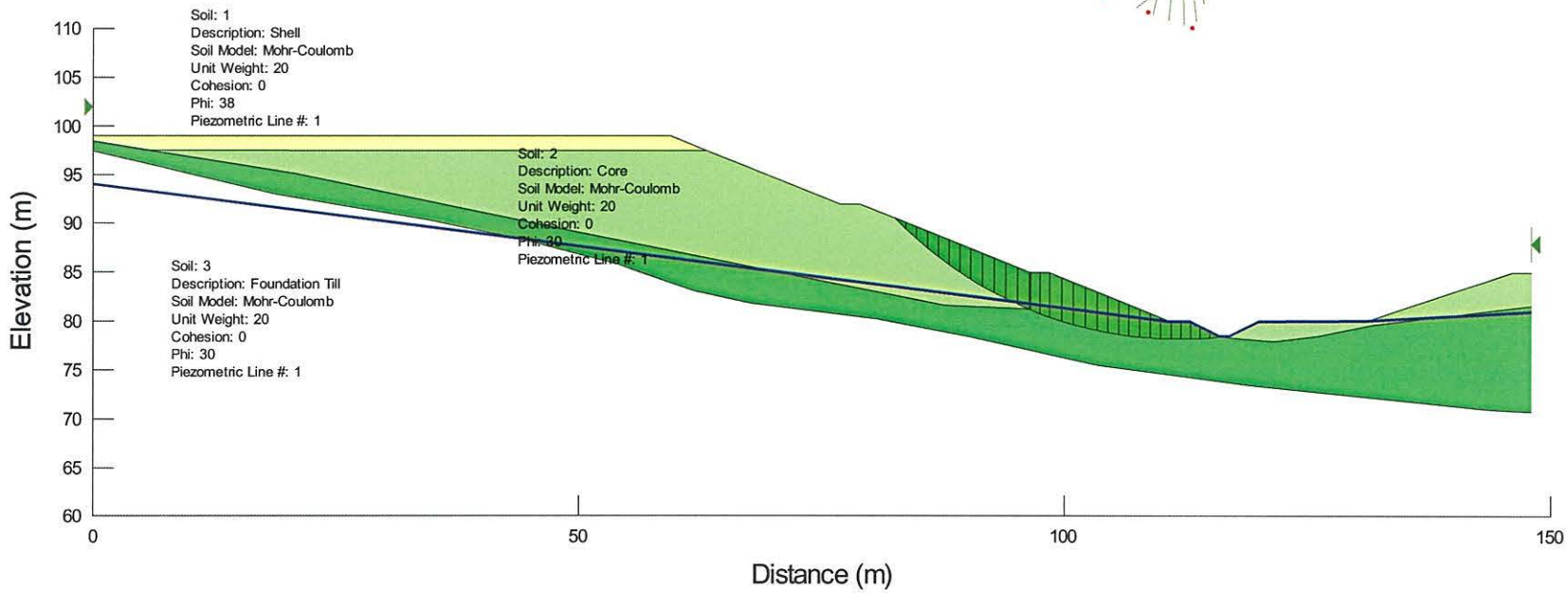
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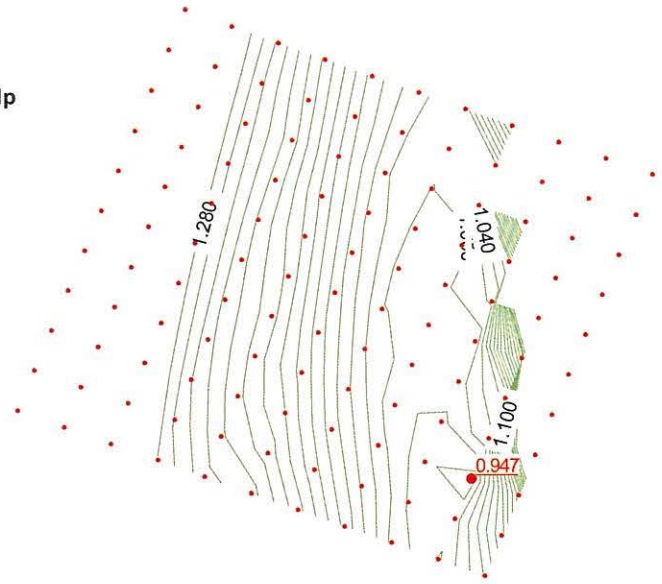


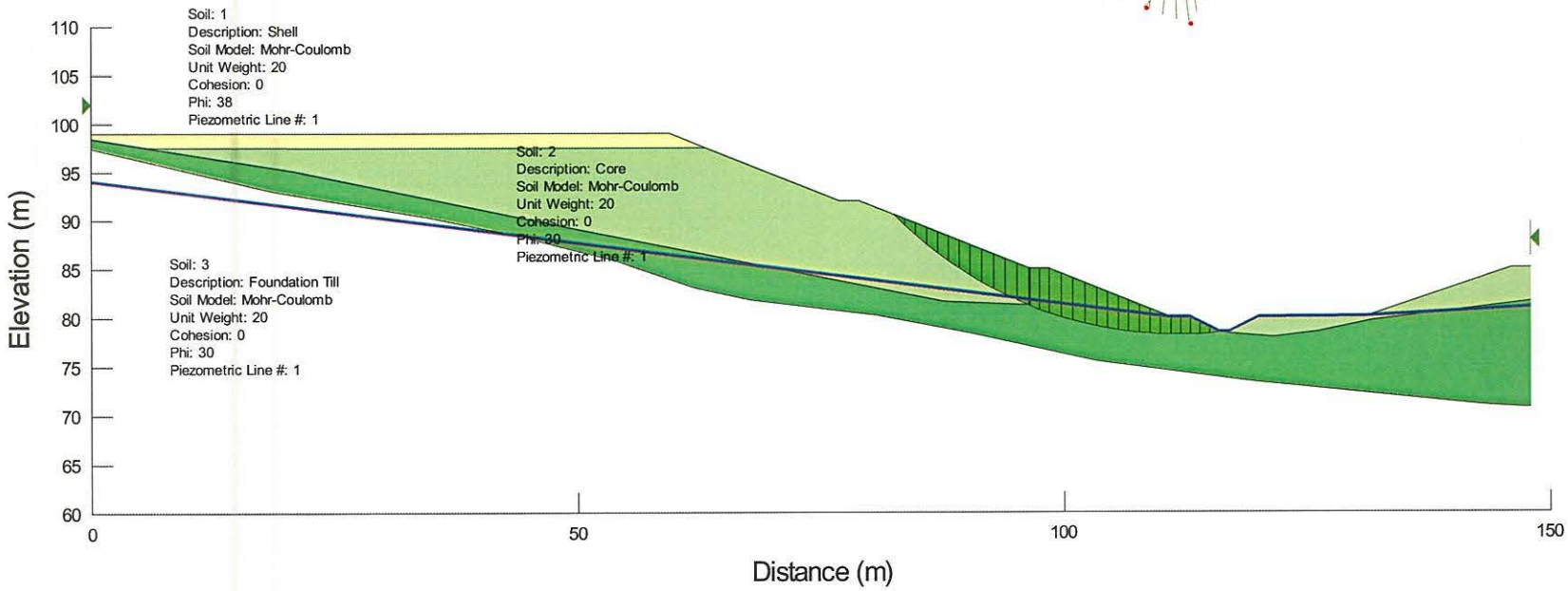
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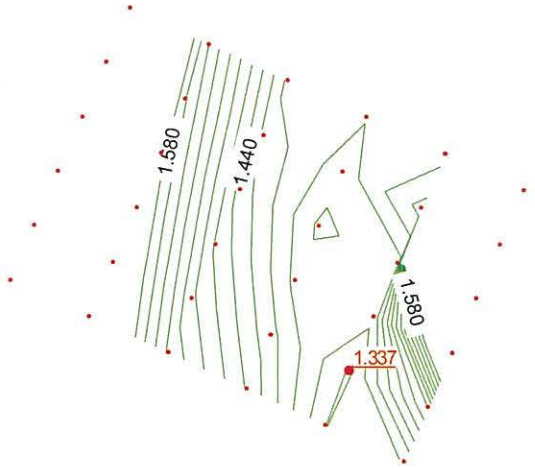


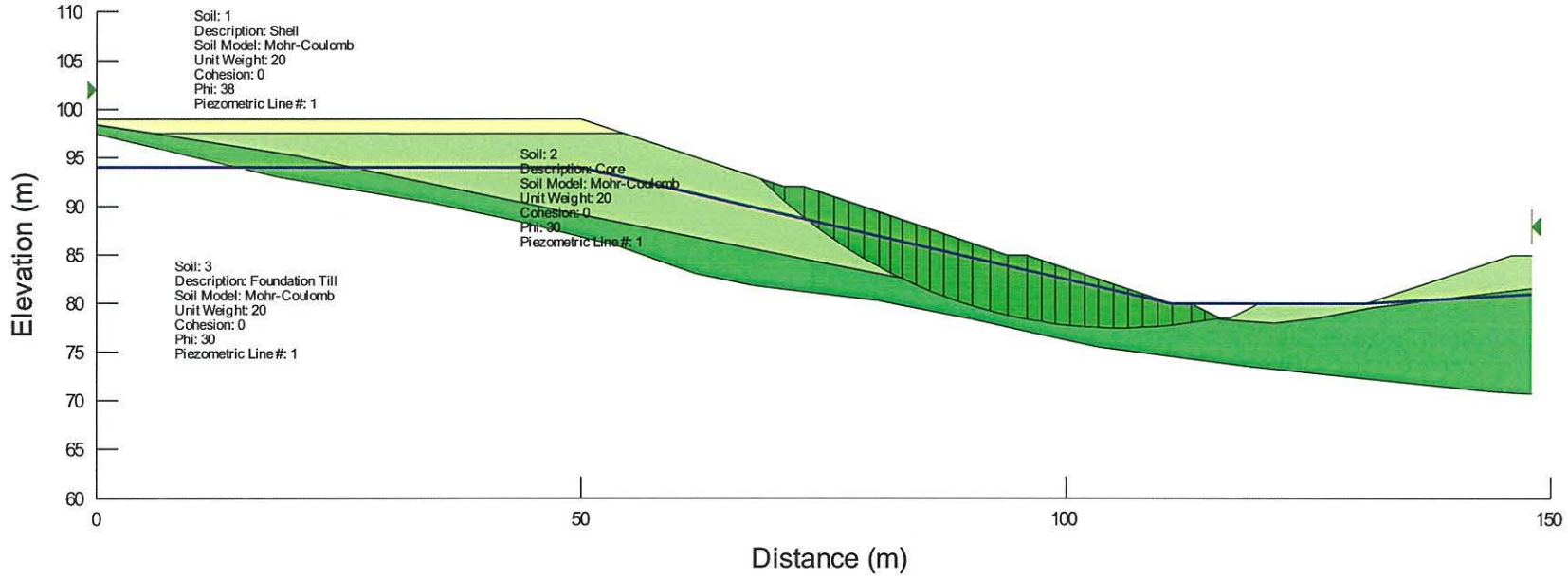
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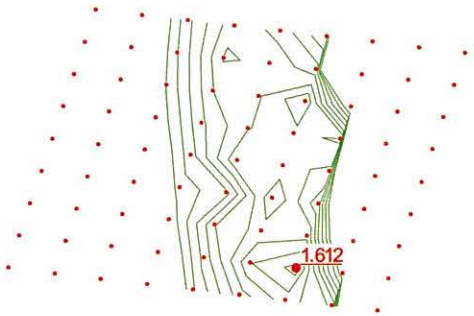


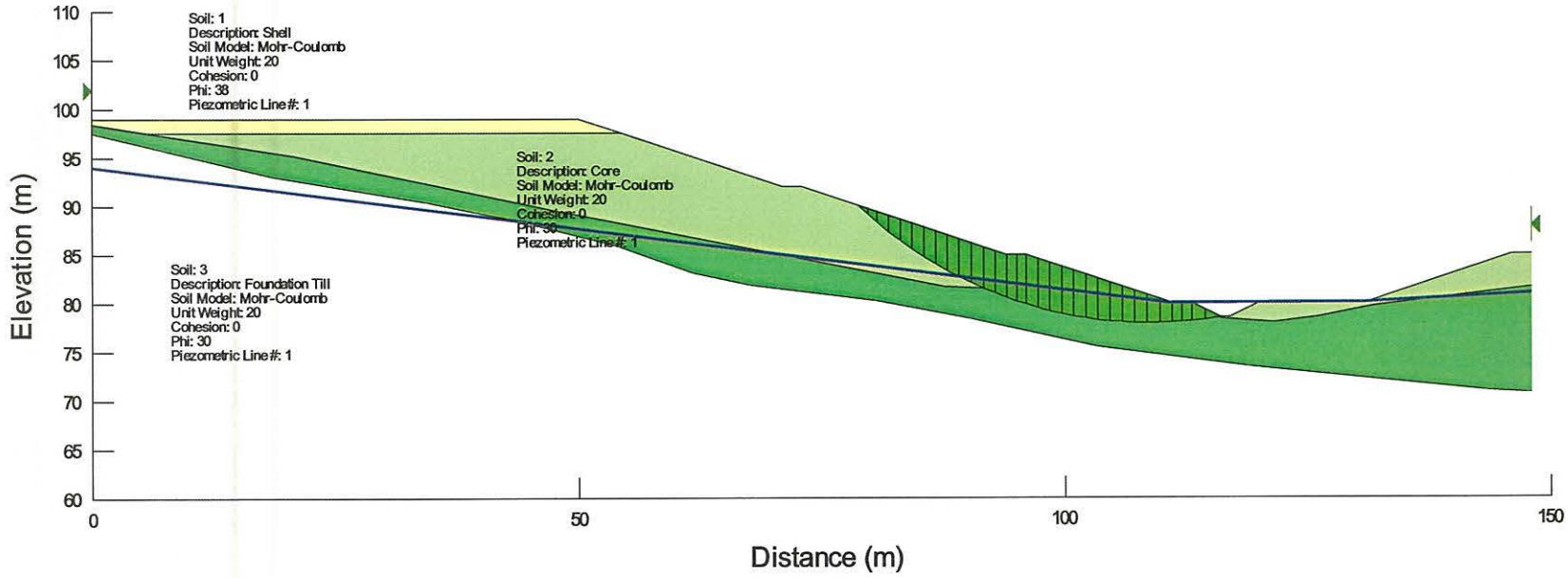
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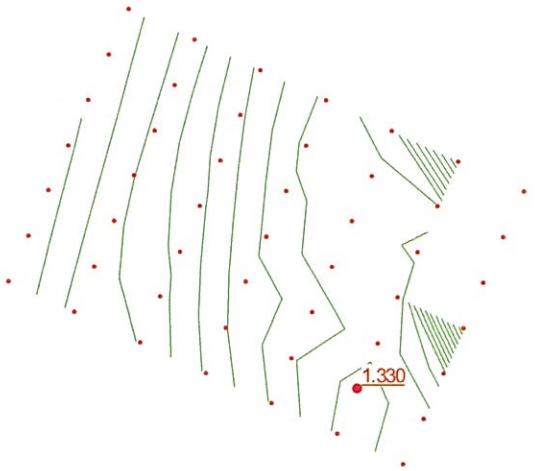


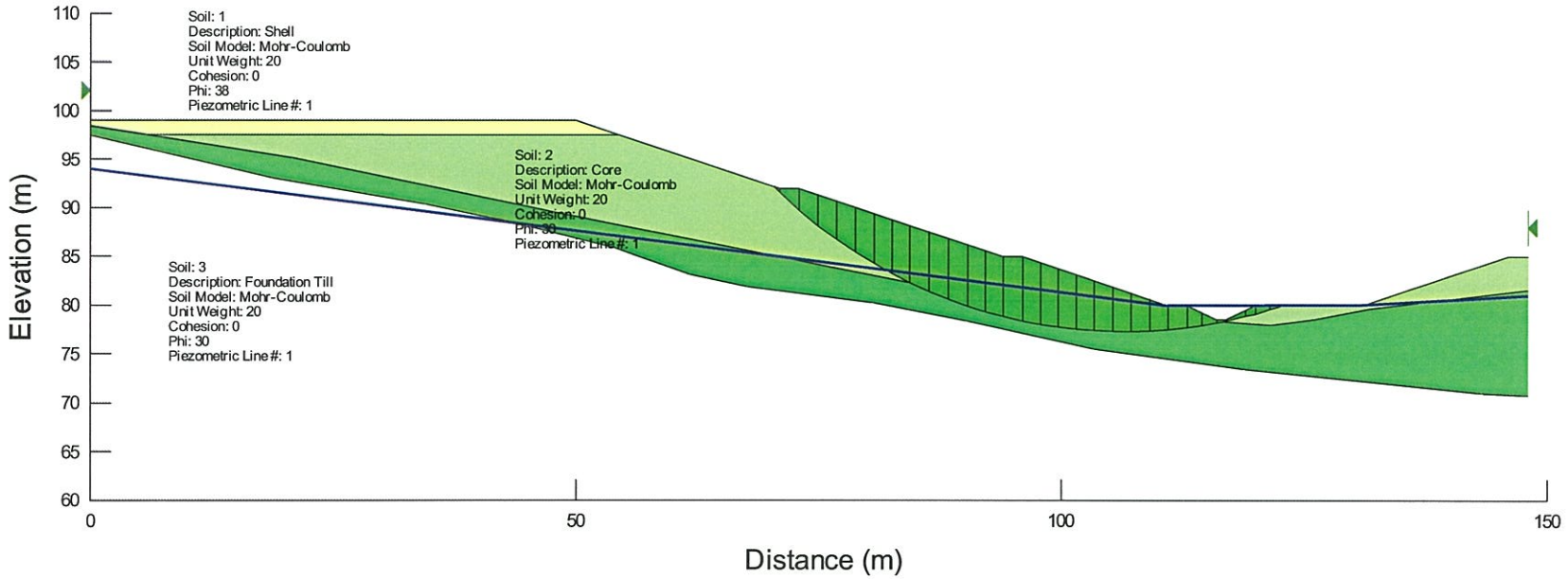
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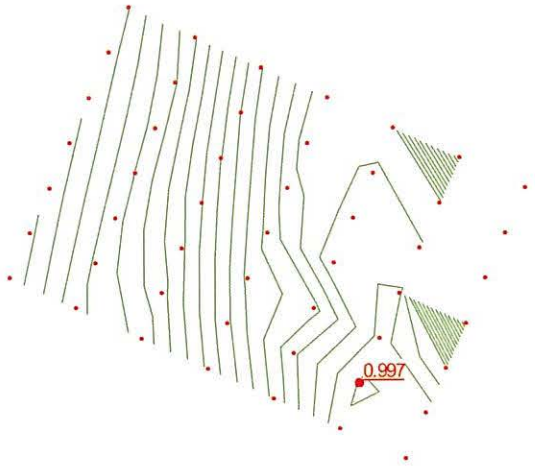


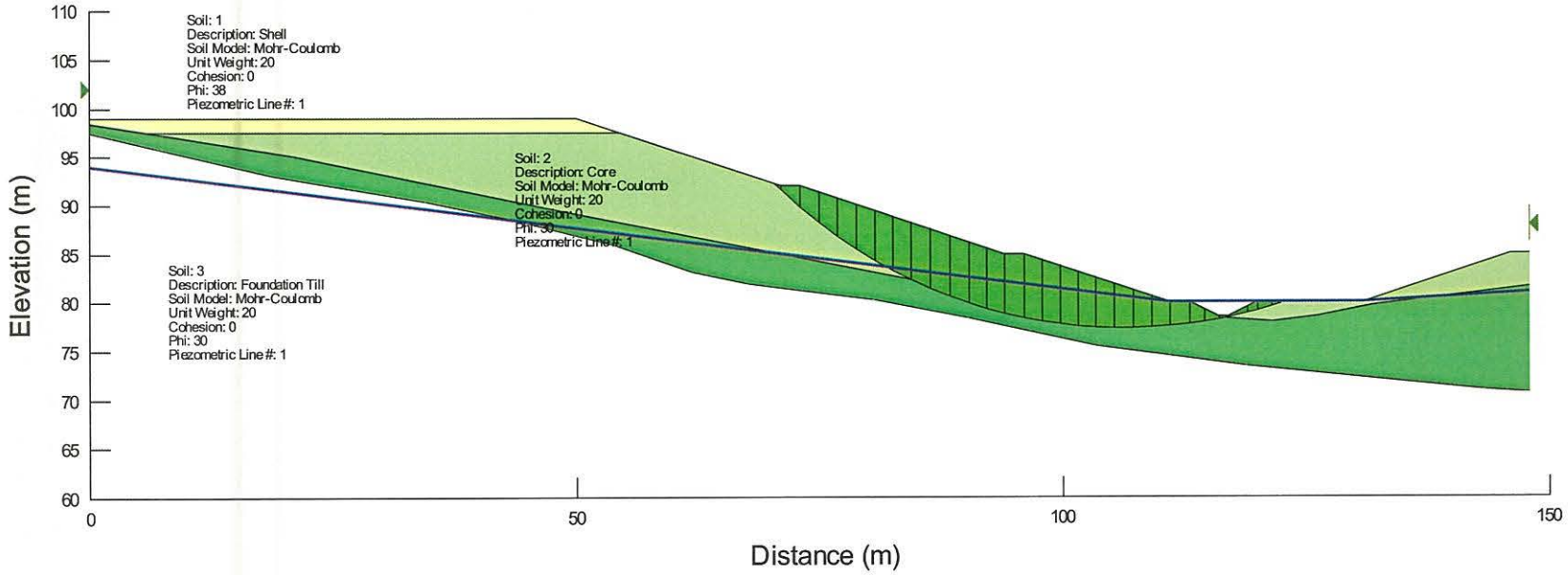
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Fresh Water Storage Dam - Actual X-Section
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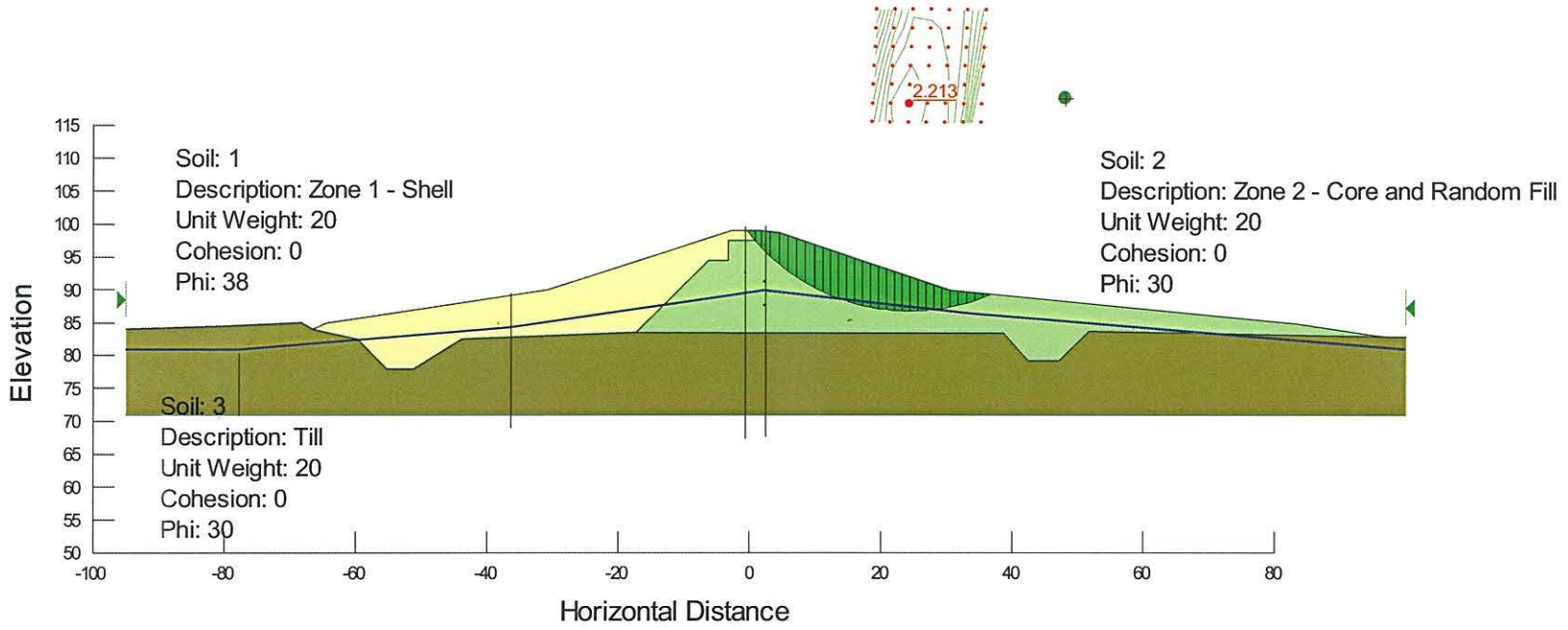




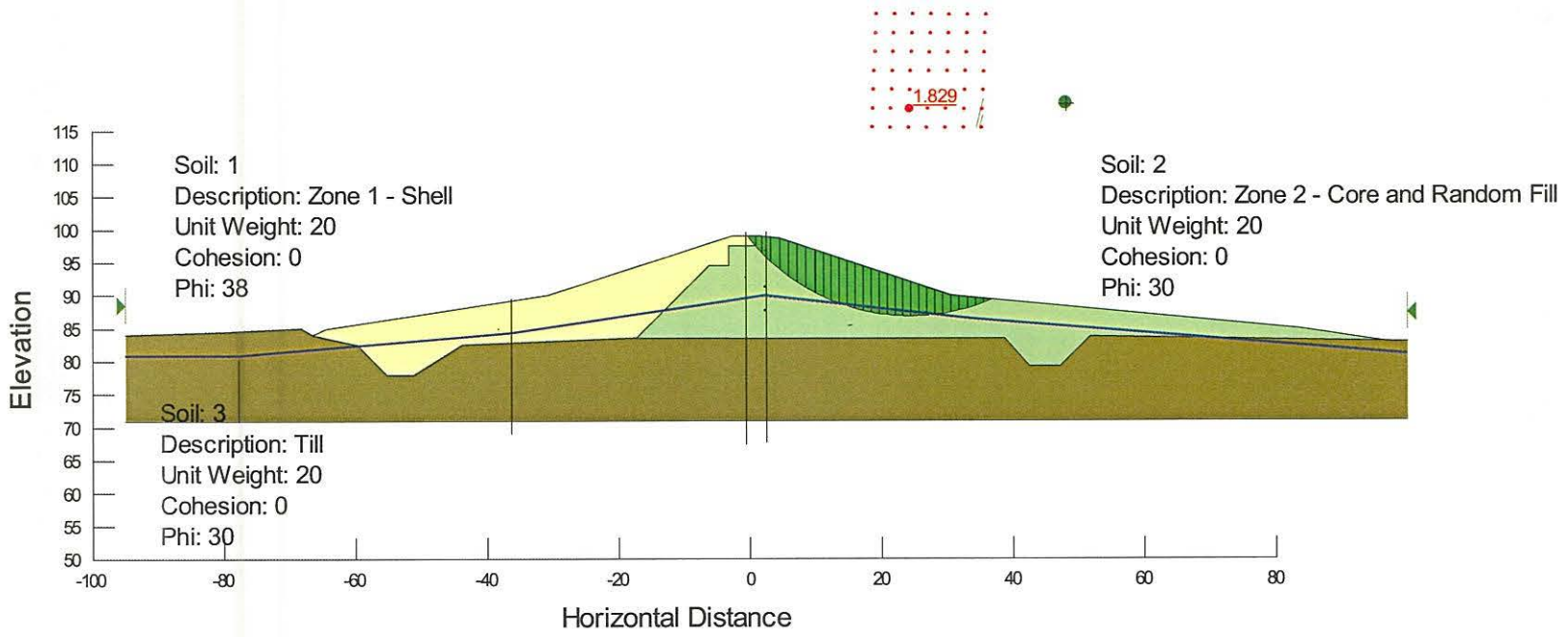
Stability Analysis Results (Residual Dam Structure)

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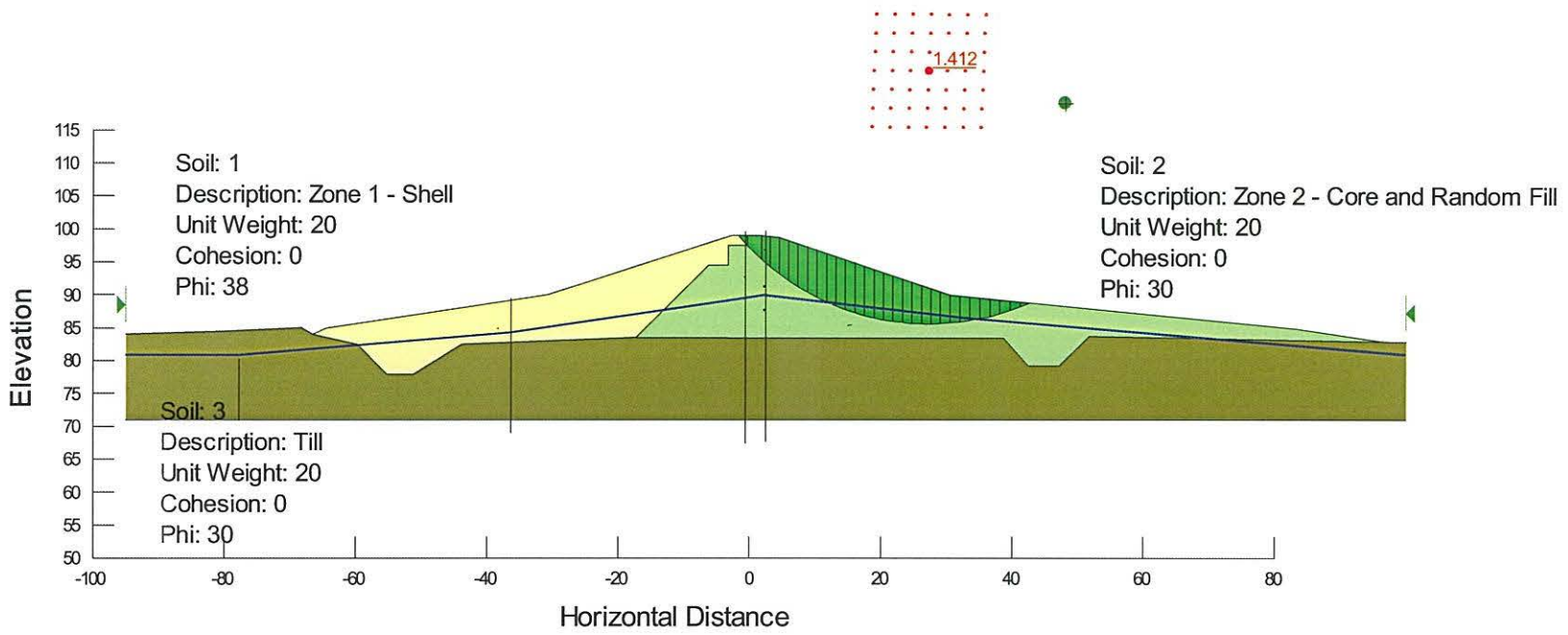
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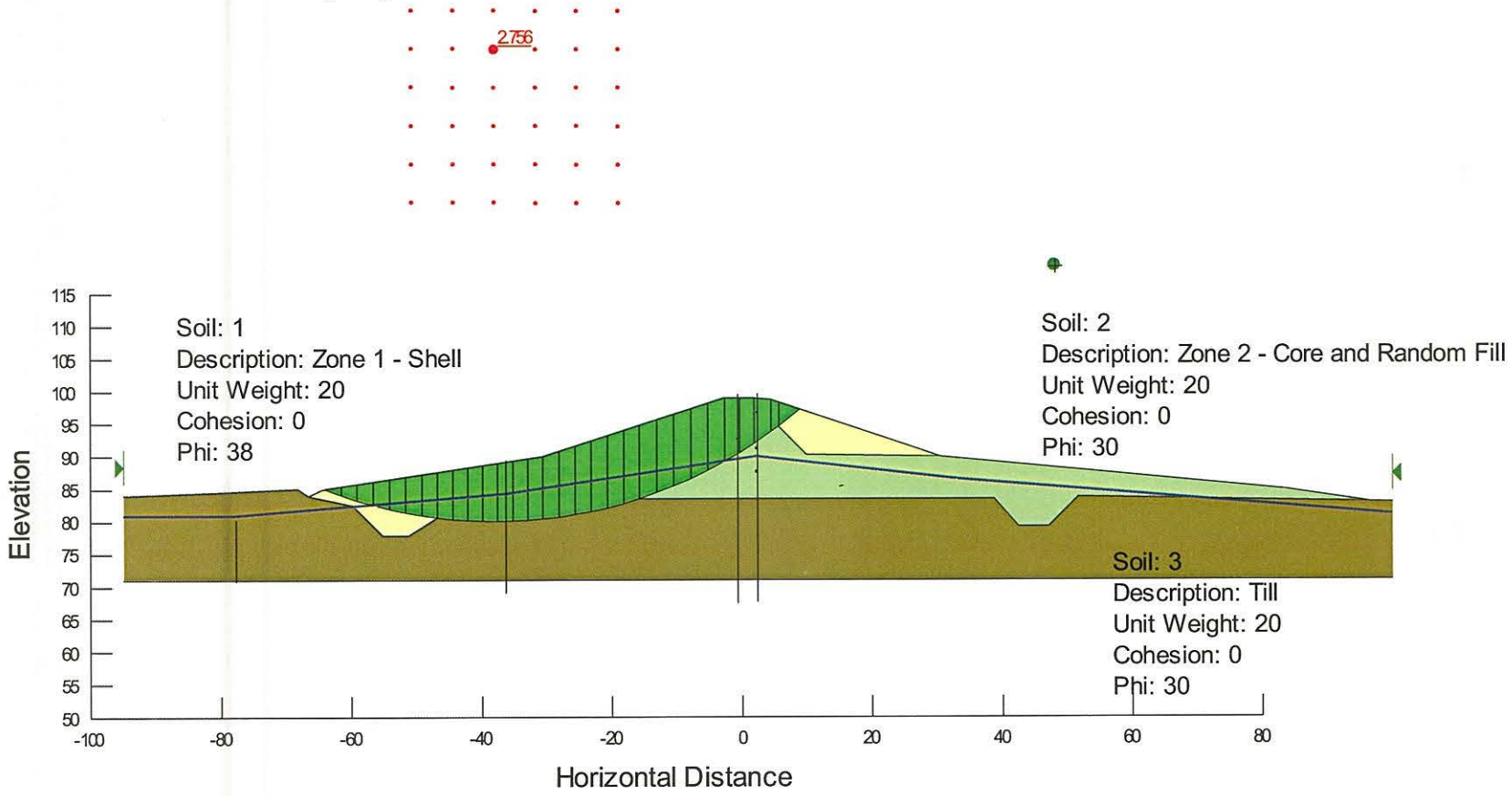
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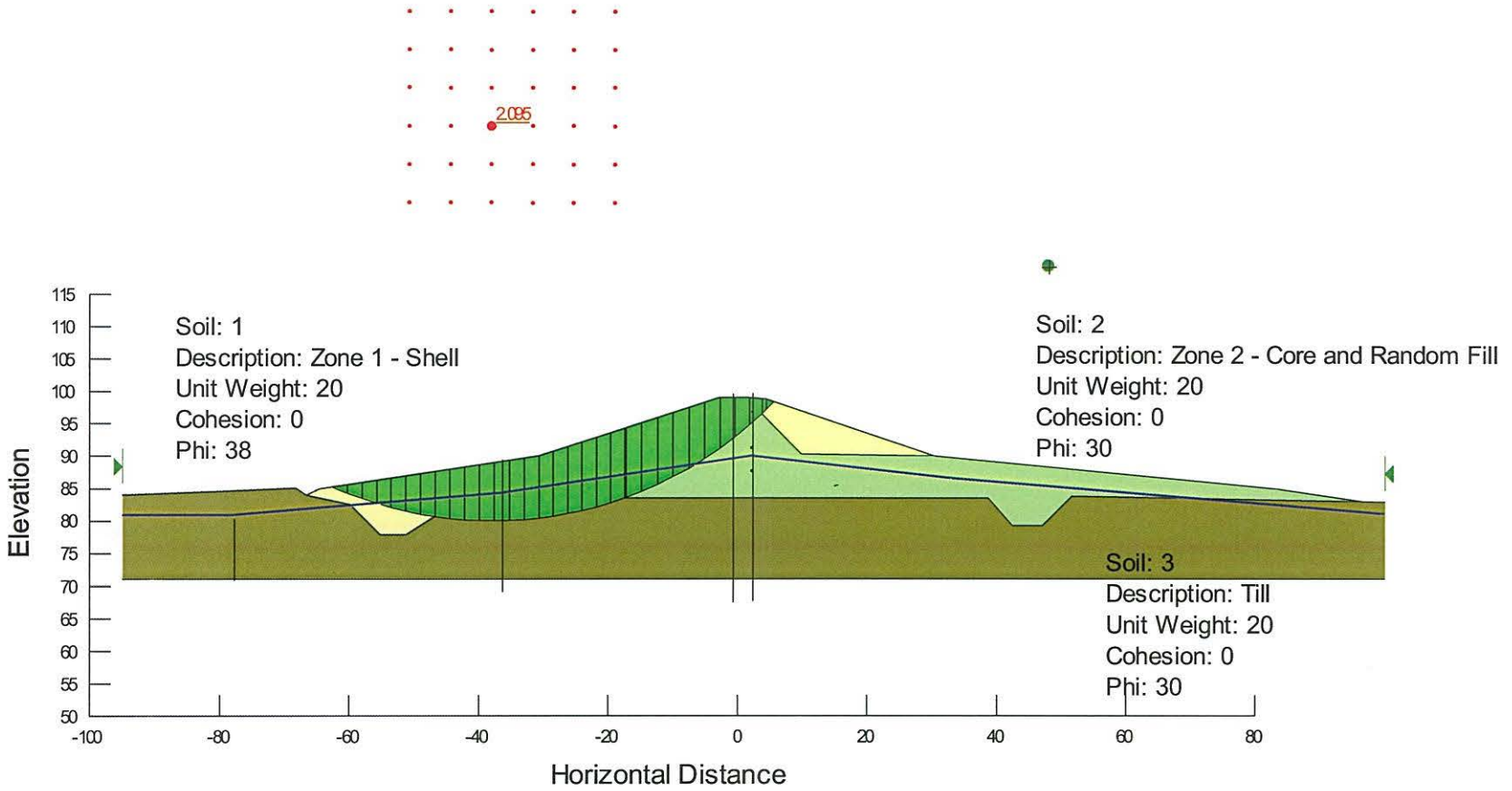
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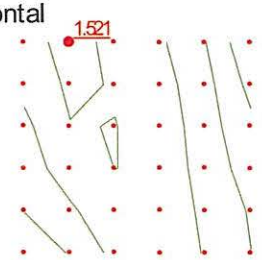
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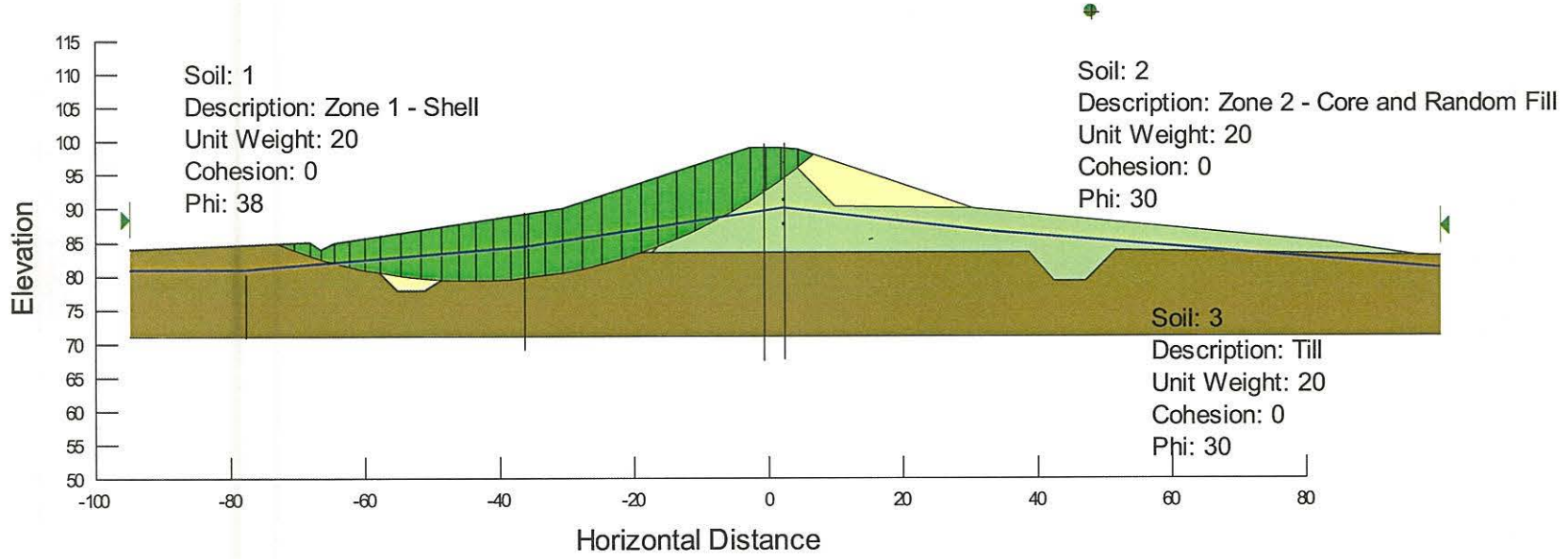


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Seismic Coefficient: Horizontal





APPENDIX D3
Hydrotechnical Assessment

Leaders in
• • • •
water resource
• • • •
technology

nhc

3-3803

April 3, 2003

Cam Scott
Principal Engineer
SRK Consulting
800 - 1066 West Hastings Street
Vancouver, BC.
V6E 3X2
FAX 604 687-5532

Attention: Mr. Cam Scott

Re: Final Faro FWSD Hydro-Design Report

Please find attached our final *Faro Fresh Water Supply Dam Design Report*, prepared for including in the final design report. We have incorporated all the design changes as discussed and comments provided at our meeting on March 24th, 2003.

Please contact me if you have any questions or comments.

* * * * * * *

Yours,

northwest hydraulic consultants

original signed by

Barry Chilibeck P.Eng.
Principal

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The natural physical processes within the stream system provide characteristic habitats for both fish and the biological processes that support fish and fish habitat. Within the context of restoring the channel, maximizing pool depth was a key design constraint for the purposes of providing overwintering fish habitat for arctic grayling, which utilize this creek system. The natural profile, material roughness and expected hydraulics are intended to provide ideal fish passage conditions over a wide range of flow conditions as do natural channels.

The section of channel inundated by the reservoir had an irregularly sinuous single thread morphology, about a 5 m width and a low, shrub dominated floodplain as illustrated by sections above the reservoir (Photo 7, SRK, 2003a). The bed material appears to be gravel-cobble, which is consistent with a 1% gradient. Natural streams with a 1% gradient tend to exhibit a braided or pool-riffle morphology depending on the relative bank strength, sediment supply and hydrology (Knighton, 1998). The 2 year return period discharge and stream gradient of South Fork Rose Creek appears consistent with a straight (pool-riffle) morphology.

A fundamental assumption in this approach is that the natural delivery of sediment, bed-load in particular, through the dewatered reservoir to the reconstructed channel will be re-established. This approach will allow the channel to evolve and change as it adjusts to the natural hydrologic and sediment supply regime of the site. The overall floodplain slope and channel gradients will direct the long-term evolution of a reconstructed channel which may result in changes in surface sediment texture and minor channel adjustments.

At the upstream end of the dam site, where the slope increases from 0.2 to 1%, the channel will have a tendency to degrade as it attempts to reduce the gradient difference between the steeper downstream channel and the flatter upstream channel. At the downstream end of the site, where stream gradients flatten to near 0%, bed load transported through the steeper gradients of the site will tend to deposit in the channel creating a slightly aggraded section. The following final design specification was selected:

- Total channel length 290 meters
- Elevation change 2.9 meters
- Bankfull channel width 8 meters
- Mean bank height 1 meter
- Assumed bank slope 1.5:1 H:V (33.7°)
- Meander wavelength 90 - 110 meters
- Meander radius 20 to 30 meters
- Floodplain width 20 meters
- Floodplain slope 1%
- Channel slope ~ 1%
- Sinuosity 1.1

The channel was iteratively designed using a series of numerical equations for flow, channel regime, riprap and bed material sizing using various plan layouts, slopes and widths. The designed channel strives for a balance between the design equations and the available geometry. We suggest that the channel be roughed in the existing floodplain materials to the basic design dimensions in a parabolic shape rather than a traditional trapezoidal channel. Erosion and re-sorting of bed and bank materials will provide channel section adjustment in response to flows.

Once the design was selected, the hydraulics were estimated and recorded for the design flow (water surface elevations and mean velocities). The channel has been designed to just contain a flood with a return period of 2 years. Floods larger than this will be spilled into the rehabilitated floodplain. It is important that the floodplain be gently angled toward the channel and be planted with appropriate vegetation to prevent the loss of fines and increase overbank roughness. A total cut width of 25.4 m is required through the dam to allow room for the breach protection without encroaching on the finished 20 m wide floodplain.

A pool depth of 1.5 m for winter fish habitat is desirable (SRK 2003a), however the low stream power (a function of slope and discharge) is unlikely to maintain this pool depth without artificial constriction of the channel by wood or rock. Therefore, we propose a pool depth of 0.7 to 1.0 m will result, which would be maintained by riffles 0.7 m in height and riffle slopes of 8:1 H:V. The stream should maintain a pool-pool spacing of 50 m (Buffington 2002, Walker *in prep*). A mean flow depth varying from 0.2 to 0.6 m across the riffles and main channel is predicted for bankfull conditions using a Manning's n of 0.03.

We anticipate flow depths of 0.8 to 1.0 m above the floodplain for the 200 year to 500 year flood events. Shear associated with this depth of flow on a 1% gradient are sufficient to initiate new channels and therefore appropriate initial revegetation and succession of floodplain vegetation is important to maintaining a single thread channel morphology through the breach, and maximizing bank strength which will increase the tendency for formation of a pool-riffle channel planform.

Riffle Design

A series of five riffles have been designed along the 290 m length of the channel at an average spacing of 50 m. The riffles have been oriented at 40° from perpendicular to the flow to promote channel sinuosity and pool scour against the riprap abutments. The riffles are designed to have a 2:1 H:V upstream slope, an 8:1 H:V downstream slope, a crest height of 0.7 m, and a nominal crest width of 1.0 m. At the crest, the riffle is sloped toward the centre at a 4%.

The riffles are designed to be stable during smaller, more frequent flood events, with some movement and sorting during larger, less frequent events. In order the meet this criteria, a design median (D_{50}) rock size of 400 mm is required for 1:50 return period

flows. To accommodate scour, the riffles should be keyed a 0.75 m in to the bed of the floodplain. A uniform gradation is required in the riffle in with a D_{85}/D_{15} less than 2. If available, the upstream side of the riffles should be backfilled with 150 mm minus alluvial gravels to provide materials for initial riffle adjustments

Upstream Control

The upstream rock riffle is designed to prevent the natural headcutting that would occur at the break in the slope between the steep-reconstructed channel and the flatter reservoir bottom. As a result, it is constructed of rock that is not mobile during a bankfull event (2 year return period). The riffle will be angled to match the alignment of the upstream cofferdam, or 10° to 40° from perpendicular to the flow. The riffle is designed with a 4:1 H:V upstream slope, and a 12:1 H:V downstream slope. The riffle will project 0.5 m from the channel bed, with a nominal crest width of 1 m. As for the other riffles, the crest should be sloped towards the centre of the channel at an angle of about 4% (25:1 H:V). A typical (D_{50}) rock size of 450 mm is required to ensure that the riffle is stable during the bankfull event. The rock should be keyed 2.5 m into the bed on the upstream edge and 1.7 m on the downstream edge and should wrap around the front of the cofferdam, extending 10 m to either side of the channel along the face of the dam section.

Floodplain Bank Protection

The rock protection along the edge of the floodplain of the breach is to prevent erosion of the remaining earth-fill structure by the stream during a foreseeable flood event. It has been designed to protect the existing edges of the dam against a 500 year flood event. Specific design requirements are:

- Side slope — 2:1 H:V
- Median rock size (D_{50}) — 400 mm - 90 kg (see Table 2),
- Riprap thickness (2 x D_{50}) — 800 mm
- Riprap material — Angular, clean durable rock
- Design scour depth — 2.5 m below the elevation of the channel bed

Riprap should be placed and extend up to 1.5 m above the level of the floodplain. The toe may be constructed with standard river engineering practices. However, site conditions, such as winter construction, ice and groundwater, may limit the depth of possible excavation. A suitable alternative is to place an increased volume of riprap concentrated in a rock "toe" to limit the depth of cut required for the installation.

Table 2 Recommended Riprap Gradation for Abutment Protection

Percent Smaller Than (%)	Diameter (mm)	Mass (kg)
D_{100}	680	440
D_{85}	480	160
D_{50}	400	90
D_{15}	260	30

Downstream Channel

Downstream of the dam, South Fork Rose Creek was diverted through a modified straight channel that extends for about 250 m before rejoining the natural stream. Like the breach, this section of the channel may have restoration elements completed prior to the reintroduction of the full flow of the creek. The downstream channel will have a stream slope of 1% like the upstream channel and therefore should have a similar bankfull width of about 8 m.

It is expected that all work required in the downstream channel will be done on site with a qualified river engineer with experience in habitat restoration and geomorphology at the time of construction. Rock riffles may be required at locations further downstream on an "as needed" basis during construction. A figure of a typical riffle is enclosed with the design report. If required, these riffles should have the following features:

- Upstream slope 2:1 H:V
- Downstream slope 8:1 H:V
- Crest Height (above bed) 0.6 meters
- Key into bed (depth below bed) 0.5 meters
- Downstream length 5.0 meters
- Key into bank 3.0 meters
- Median rock size (D_{50}) 400 mm

Summary

The reconstructed channel at Faro FWSD dam has been designed to have an adjustable boundary. The stream slope and stream discharges to be passed through the channel suggest that a single thread, straight channel with low sinuosity is a stable channel form. The channel is designed by iteratively adjusting the channel dimensions to the channel forming discharge until the bankfull discharge, approximately the 2 year return period event, is just contained within the channel boundaries. The channel has been designed to maximize the naturally maintained pool depth by adjusting the pool-pool spacing and angling riffles towards the dam abutments and protecting riprap.

nhc

* * * * * * *

Prepared by,

northwest hydraulic consultants

original signed by

Barry Chilibeck M.A.Sc. P.Eng.
Principal

References

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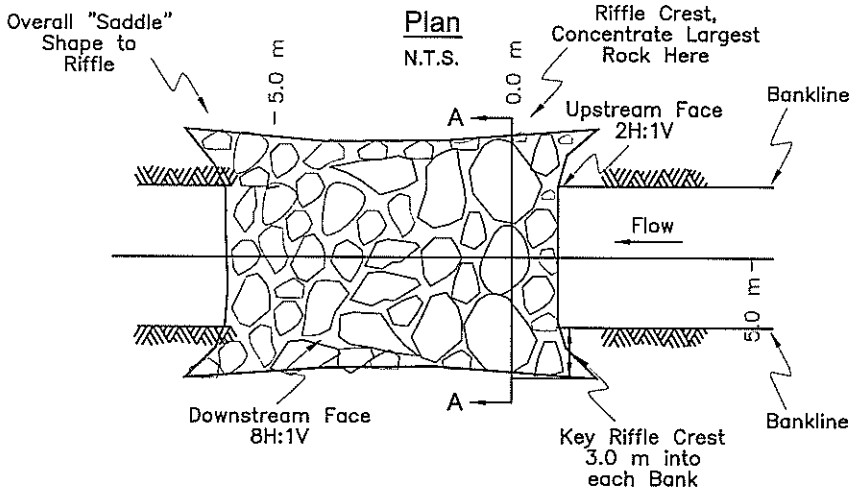
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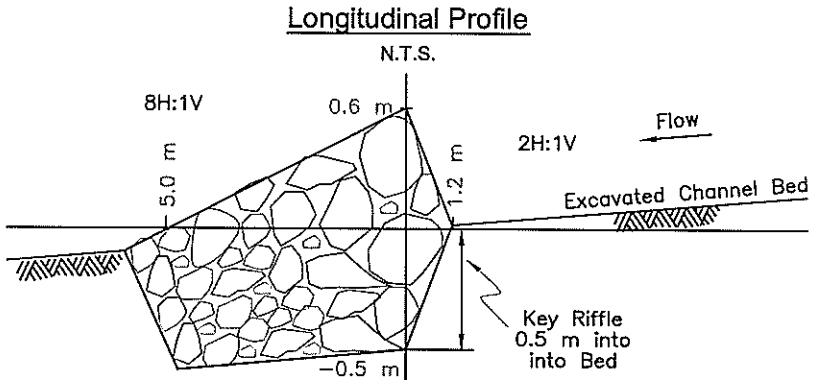
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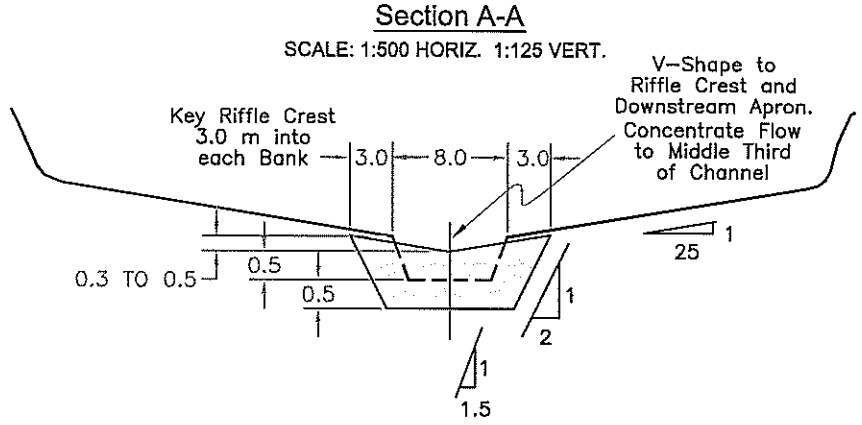
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Construction Notes:

1) Riffle constructed of rock with a D50 of 400 mm.
2) Key riffle 0.5 m into channel bed and 3.0 m into each bank.
3) Concentrate flow in center third of channel by sloping rock up towards top of banks (4%) and leaving gaps between the rocks of the middle third of the riffle crest.
4) Concentrate larger stones at riffle crest and space 0.2 m to 0.3 m apart on downstream slope to dissipate energy.
5) Place riffles perpindicular to flow, spaced 50±5 m apart.
6) Construct riffles so crest is 0.6 m above channel bed elevation.

NHCV wrp-056

FARO FWSD DAM

REHABILITATED CHANNEL
D/S OF DAM BREACH
TYPICAL ROCK RIFFLE

northwest hydraulic consultants

APPENDIX E
QA/QC Program

SRK Consulting
Engineers and Scientists

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Canada
V6E 3X2

email: vancouver@srk.com
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Fax: 604.687.5532

PROJECT MEMORANDUM

To:	File	**Pages:**	1 of 5
Attention:		**Date:**	April 17, 2003
CC:			
From:	Cam Scott / Gerry Ferris	**Project Number:**	1CD003.22
Subject:	**QA/QC Aspects of the FWSD Breach, Faro Mine**		

This memorandum describes the quality control and quality assurance procedures required for the construction of the FWSD breach. It is expected that, prior to construction, these procedures will be finalized as part of a technical specification that will accompany the final design drawings when they are issued for construction.

PART 1: GENERAL

1.01 DESCRIPTION

The intent of this Section is to define the construction Quality Control/Quality Assurance (QA/QC) requirements for the FWSD breach. The **RESIDENT ENGINEER** will be responsible for all QA/QC requirements, as outlined in this SPECIFICATION and as indicated by the **OWNER**, unless otherwise noted in the DESIGN REPORT, SPECIFICATIONS or the DRAWINGS.

1.02 CONSTRUCTION QUALITY CONTROL/QUALITY ASSURANCE:

The **RESIDENT ENGINEER** will be responsible for maintaining an effective Construction QA/QC program. The Construction QA/QC program will include all actions related to reservoir drawdown, selection of construction material sources and on-site and off-site production of construction materials, WORK placement procedures, workmanship, monitoring, and testing.

1.03 ASSURANCE TESTING AND FREQUENCY:

QA/QC activities, tests and testing frequencies to be conducted in the field by the **RESIDENT ENGINEER** are provided in Tables QAQC-1 and QAQC-2. The frequencies indicated are minimums only, and do not include retests of failed materials.

1.04 QUALITY OF MATERIALS AND LABOUR:

All materials used on this contract shall be new and the best market quality, unless specified or shown otherwise. All labour on this contract shall be competent and skilled for the WORK. All WORK executed under this contract shall be done in the best, most thorough, substantial and workmanlike manner. All material and labour shall be subject to the approval of the **RESIDENT ENGINEER** as to quality and fitness, and shall be immediately removed if it does not meet with this approval. The **OWNER** or his agent may refuse to issue any certificate or payment until all defective materials or WORK have been removed, and other material of proper quality substituted therefore.

1.05 RESIDENT ENGINEER'S RESPONSIBILITIES:

A. The **RESIDENT ENGINEER** is responsible for monitoring related to reservoir drawdown, including collection and review of the data and identifying and reporting construction deficiencies, unusual or unsafe conditions.

B. The **RESIDENT ENGINEER** is responsible for deciding whether the overall breach side slopes are to be excavated at 2.5H:1V or 3H:1V.

C. The **RESIDENT ENGINEER** is responsible for deciding which channel rehabilitation option is to be constructed.

D. The **RESIDENT ENGINEER** is responsible for deciding if excavated material is Potentially Acid Generating (PAG) and identifying an appropriate spoil area for this material.

E. The **RESIDENT ENGINEER** is responsible for monitoring sediment within Construction Water.

F. The QA/QC requirements related to reservoir drawdown are specified in Table QAQC-1.

TABLE QAQC-1
QA/QC MONITORING DURING RESERVOIR DRAWDOWN

Item/area	Test	Minimum Test Frequency[2]	
		Time Interval[3]	Quantity
1.1 Condition of FWSD	Visual inspection	1 per day	NA
1.2 Water level elevation at the reservoir	Measurement using field gauge and/or survey	3 per week	NA
1.3 Piezometric levels within the dam	Measurements using appropriate hardware	3 per week	NA
1.4 Piezometric levels within the standpipe piezometers downstream of dam	Measurement using appropriate hardware	2 per month	NA

1.06 CONTRACTOR'S RESPONSIBILITIES:

A. The **CONTRACTOR** is responsible for the quality of the WORK of the CONTRACT.

B. The **CONTRACTOR** shall make good all WORK for which any test result indicates the WORK does not conform to the requirements of the CONTRACT.

C. The **CONTRACTOR** shall certify that all equipment used in the WORK is in accordance with the provisions of the CONTRACT. Certification does not relieve responsibility for providing satisfactory materials, equipment and workmanship.

D. Any inspection and/or testing done for or on behalf of the **CONTRACTOR** shall not relieve the **CONTRACTOR** from any responsibility for the quality of the WORK.

E. The **CONTRACTOR** shall be aware of all testing activities (Table QAQC-2) and shall account for those activities in the construction schedule.

F. The **CONTRACTOR** shall be responsible for cooperating with the **RESIDENT ENGINEER** during all testing activities. **CONTRACTOR** shall provide equipment and labour to assist the **RESIDENT ENGINEER** in sampling, if requested, and shall also provide access to all areas requiring testing activities.

TABLE QAQC-2
EARTHWORK CONSTRUCTION QA/QC TESTING FREQUENCY

Material/Area	Test	Minimum Test Frequency[2]	
		Time Interval[3]	Quantity
2.1 Slopes and Rough Grade	Visual verification	1 per week	500 m^3
2.2 Rip Rap Supply	Visual verification	1per day	NA
2.3 Rip Rap Placement	Visual verification	1per day	NA
2.4 Floodplain & Channel	Visual verification	1per day	NA
2.5 Grout[4]	Compressive Strength	1 per day or 2 per pour	NA
2.6 Fills	Visual verification	1per day	NA

Notes:

1. Perform tests routinely as and when the borrow material characteristics change.
2. Presented as a guide to QC monitors. Testing frequency may be higher due to material variability. Specified time interval testing frequencies are for continuous construction activities, and should be modified accordingly for intermittent tasks.
3. Time interval refers to periods during which active work of the type indicated is being performed.
4. Grout sampling for test cylinders will be at a variable rate depending on the size of the "pour."

PART 4: MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

The details of the measurement will be established prior to the finalization of the CONTRACT. Current expectations regarding survey measurements are as follows:

A. The rip rap stockpile (D_{50} = 450mm) developed after processing rip rap from the existing stockpile will be surveyed prior to construction.

B. The rip rap stockpile stockpile (D_{50} = 400mm) will be surveyed after rip rap stockpile (D_{50} = 450mm) has been developed, but prior to construction.

C. Following excavation of the breach, but prior to placement of the rip rap, the breach will be surveyed to establish the rough cut excavation quantity.

D. The final floodplain and channel will be surveyed.

E. The rip rap stockpile (D_{50} = 450mm) developed after processing rip rap from the existing stockpile will be surveyed after construction.

F. The rip rap stockpile stockpile (D_{50} = 400mm) will be surveyed after construction.

G. The PAG rock stockpile will be surveyed after construction.

4.02 PAYMENT:

(Not Applicable)