Klohn Crippen Berger

Yukon Government

Faro Mine Remediation Project

Dam Breach and Inundation Study

February 2014
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CANADA'S BEST MANAGED COMPANIES

February 28, 2014

Yukon Government
Faro Mine Remediation Project
Suite 2C-4114-4th Ave
PO Box 2703 (K-419)
Whitehorse, Yukon
Y1A 2C6

Karen Furlong, EIT
Project Manager

Dear Ms. Furlong:

Faro Mine Remediation Project
Dam Breach and Inundation Study

This report presents our assessment of a hypothetical dam breach of the Intermediate Dam, Cross Valley Dam and Little Creek Dam of the Faro Mining Complex, and the potential inundation of downstream areas along Rose Creek, Pelly River and Vangorda Creek (including the Town of Faro). The assessment was carried out at a preliminary level, using empirical charts and formulas based on dam failure case histories.

Potential downstream impacts of the failure of these dams are also described in the Emergency Response Plan, which is to be issued in March 2014. Based on the result of this study, we confirm that the dam classifications following the current Canadian Dam Association Dam Safety Guidelines, based on failure consequence of each dam are:

- Intermediate Dam – High;
- Cross Valley Dam – High; and
- Little Creek Dam – Significant or High.

It is our opinion that no further inundation study would be needed for the Intermediate Dam and Cross Valley Dam. However, we believe that it would be beneficial to carry out a more detailed dam breach and inundation study for the Little Creek Dam in the future. The refined study could confirm its classification definitely as well as enhance the emergency preparedness and response plan in the more developed area along the downstream reach of the Vangorda Creek, especially in the vicinity of the Town of Faro.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Robert C. Lo

Robert C. Lo, P.Eng.
Project Manager

MD/RL:dl

Yukon Government

Faro Mine Remediation Project

Dam Breach and Inundation Study

EXECUTIVE SUMMARY

Notice: This Executive Summary is provided solely for purposes of overview. Any party who relies on this report must read the full report. The Executive Summary omits a number of details, any one of which could be crucial to the proper application of this report.

This report summarizes our assessment of a hypothetical breach of the Intermediate Dam, the Cross Valley Dam, and the Little Creek Dam, and potential inundation of the areas along Vangorda, Rose and Anvil Creeks and Pelly River downstream of the dams.

The dam break and inundation study was carried out at a preliminary level, using empirical charts and formulas based on dam-failure case histories. The methodology used for the study is outlined below:

1. Estimate the peak discharge resulting from a breach at the dam using empirical charts and/or formulas.
2. Estimate the peak flood flows along the downstream creeks and Pelly River using flow attenuation charts and/or equations.
3. Estimate the maximum flood depths along the downstream creeks and Pelly River assuming steady-state flow conditions corresponding to the peak discharge estimated in step 2 above.
4. Use the estimated flood depths to delineate the potential inundation areas on a topographic map.

The following failure modes were considered for this analysis:

- Intermediate Dam: rainy-day failure;
- Cross Valley Dam: sunny-day and rainy-day failures;
- Intermediate Dam and Cross Valley Dam: rainy-day cascading failure; and
- Little Creek Dam: sunny-day and rainy-day failures.

Distances used for hydraulic analyses have been measured along the creek and river channels, but some distances quoted in the interpretation or summary of the results are measured as straight distance between two points. Unless indicated otherwise, distances given in this report are along the river or creek channel.

Rose Creek flows approximately 16 km downstream of the Cross Valley Dam and Intermediate Dam before joining Anvil Creek. Anvil Creek flows another 34 km before joining Pelly River 45 km (straight distance) downstream of the Town of Faro. No infrastructure has been identified along Rose or Anvil Creeks downstream of the dams. The nearest community on Pelly River downstream of the Cross Valley and Intermediate Dams is Pelly Crossing, about 180 km (straight distance) to the northwest of the Town of Faro.

The flood route from the Little Creek Dam follows Vangorda Creek for approximately 12 km before joining Pelly River. Along Vangorda Creek the flood wave would pass a number of local road crossings, the Town of Faro (including the road crossing at Campbell Street), and the Vangorda Creek bridge downstream of the town. The bridge carries vehicles and a sewer line. On Pelly River, the nearest community downstream of Faro is Pelly Crossing, about 180 km (straight distance) northwest of Faro.

Our conclusions based on the preliminary dam breach and inundation analysis of the Intermediate Dam, the Cross Valley Dam and the Little Creek Dam are as follows:

- The dam breach and inundation analysis presented herein was carried out at a preliminary level, using empirical charts and formulas based on dam-failure case histories. The purpose of this study was to determine potential major consequences of a failure of the dams to their downstream areas and to confirm the hazard classification for each dam. The National Topographic Series map, with 100 ft (30 m) contours, was the best available topography at the time the study was undertaken. While topography with such large contour intervals is not ideal for flood inundation mapping, it was considered adequate for meeting the objectives of the study. The accuracy of the analysis and the inundation maps produced is limited by the accuracy of the data used as inputs to the analysis, and this limitation should be kept in mind when using the results of this study.
- Failures of the Cross Valley Dam under sunny-day or rainy-day conditions, and the cascading failure of the Intermediate Dam and Cross Valley Dam under rainy-day conditions, result in significant flooding along Rose and Anvil Creeks, as well as Pelly River. This failure could result in potential water quality impacts to the downstream watercourses for wildlife and fish, as well as potential loss of life to recreational users of the creeks or river. No infrastructure has been identified along the flood route between the dams and the downstream flood impact limits. The current dam safety classification of High is considered to be appropriate for both dams and, in our opinion, no further dam break and inundation studies are required.
- A failure of the Little Creek Dam may result in potential damage and/or loss of life in the Town of Faro due to potential washout of:
  - the foot bridge on the Vangorda Falls hiking trail;
  - the Campbell Street road embankment across Vangorda Creek - Campbell Street is the main road into the town; and
  - the Vangorda Creek bridge located south of the town.
- The washout of the foot bridge on the Vangorda Falls trail, the Campbell Street embankment and/or the Vangorda Creek Bridge might cause loss of life if someone was present in the area at the time the flood wave passes through. The washout of the Campbell Street embankment would also result in the loss of the main access into the town. For this reason, a reclassification of the Little Creek Dam is recommended from Low to Significant or High consequence category based on 2007 Dam Safety Guidelines. Further study on the likelihood of road and bridge failure will be required to confirm the classification of Significant or High.

We recommend that a more detailed dam break and inundation study be carried out for the Little Creek Dam, in order to develop a more accurate downstream inundation map, particularly in the vicinity of the Town of Faro. The detailed study should include hydrodynamic modelling of the dam breach and routing of the resulting flood along the streams downstream of the dam. Detailed digital topographic maps, with appropriate contour intervals, will be required for this study. In addition to more accurately defining the downstream impacts, the detailed study would also enhance the Emergency Preparedness and Response (EPR) plan for the dam by providing:

- a better understanding of the likelihood of washout of the Campbell Street road embankment across Vangorda Creek at Faro;
- a better understanding of the time required to breach the dam;
- the flood travel times and flood durations; and
- more refined flood limits for the purposes of notification and evacuation of downstream areas within the potential flood zone.

Klohn Crippen Berger is currently updating the Emergency Response Plan (ERP) for dams and water diversion structures at the mine site, including the Intermediate Dam, the Cross Valley Dam and the Little Creek Dam. The results of this dam break and inundation study have been incorporated into the ERP. The ERP should be updated if a detailed dam break and inundation analysis for the Little Creek Dam is completed.

Estimates of 1,000 year flows, the PMF, and the Inflow Design Flood (IDF) were made during this study. These flows are rough estimates only for the purpose of ascertaining approximate incremental impacts of dam breaches along the watercourses downstream of the dams. These estimates should not be used for any other purpose such as design of drainage works, flood routing and/or sizing of spillways for any of the dams.

The dam breach and inundation analyses are based on hypothetical modes of failure. Therefore, the results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dams.

CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of Klohn Crippen Berger Ltd. (KCB). The report has been prepared for the exclusive use of the Yukon Government for the specific application to the Faro Mine Remediation Project. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

As protection to the contributing parties and the public, the report and drawings are issued for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts from or regarding the report and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending contributing parties' written approval. An original paper copy of this report is on file at KCB and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from the report published by others.

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1 INTRODUCTION

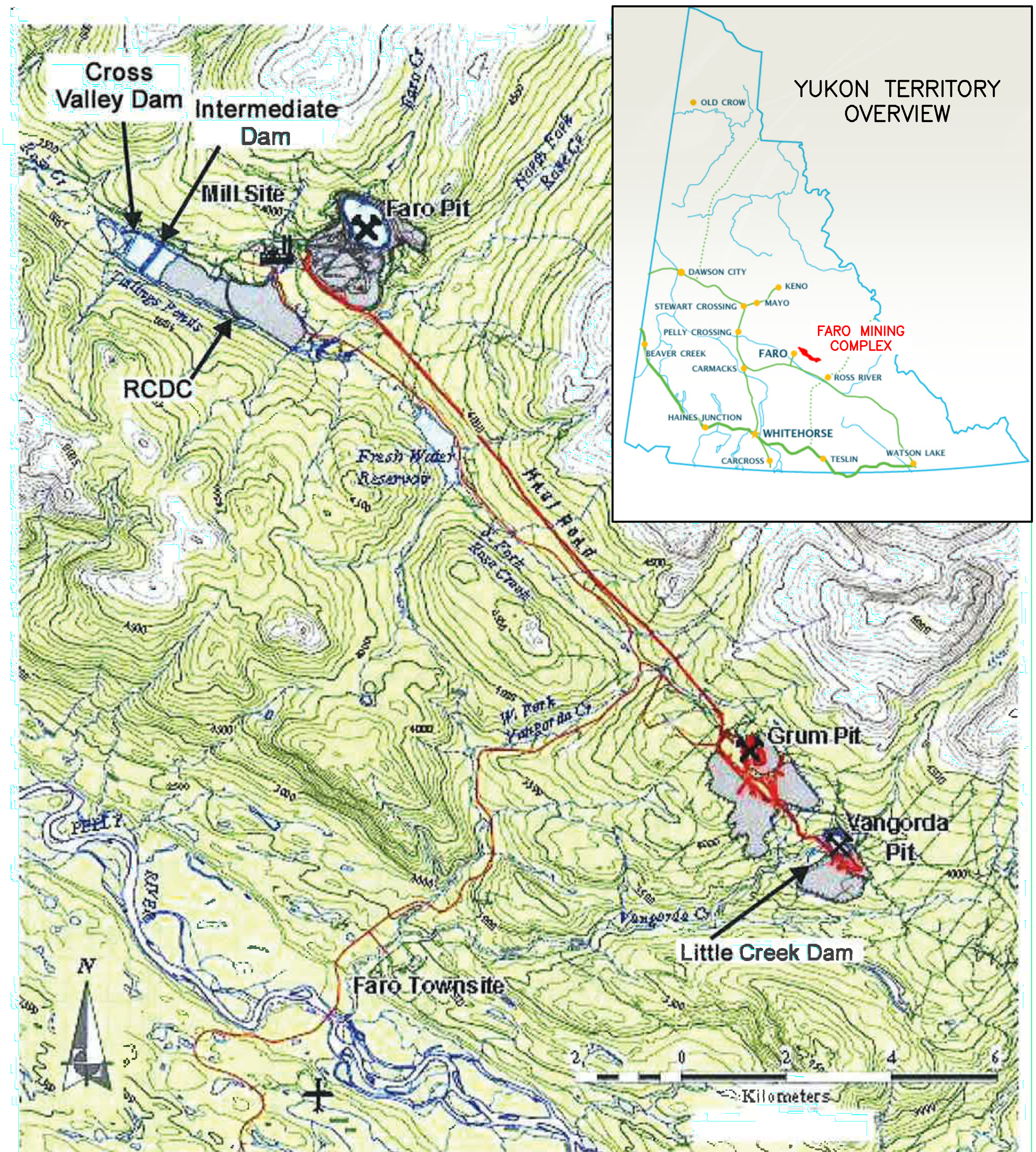
The Faro lead-zinc mining complex is located approximately 200 km (straight distance) north-northeast of Whitehorse, Yukon, as shown on the location plan in Figure 1.1. It consists of the Faro Mine which was in production from 1969 to 1992, and the Vangorda Plateau Mine which was in production from 1986 to 1998. From 1998 to 2008, the mine site was under the management of Deloitte & Touche Inc., who were the court-appointed interim receiver. From 2009 to date, the Yukon Government has been actively managing the mine complex. Tlicho Engineering and Environmental Services (TEES) has been responsible for care and maintenance activities on the site since 2012.

Two dam safety reviews have been carried out: Klohn Crippen Consultants (2002) and Klohn Crippen Berger (2008). In addition, BGC Engineering (BGC) updated in 2008 an Emergency Response Plan (ERP) and an Operations, Maintenance and Surveillance (OMS) Manual for the following tailings and/or water retention structures:

- Intermediate Dam
- Cross Valley Dam
- Little Creek Dam

Based on discussions with Ms. Karen Furlong of the Yukon Government on December 5, 2012, the need for a study of a hypothetical breach of each of the above structures, and the resulting inundation of the downstream areas, was identified. The flood resulting from a breach of the Intermediate and Cross Valley Dams would discharge into Rose Creek and eventually into Pelly River, about 45 km (straight distance) downriver of the Town of Faro. A breach of the Little Creek Dam would discharge into Vangorda Creek, which passes through the Town of Faro en route to Pelly River. A full dam breach and inundation study would require modelling of the dam breach and routing of the resulting flood wave along the channel downstream of the dam. This type of study, which requires numerical hydrodynamic modelling, is typically time consuming and expensive. It also requires high-resolution topographical data for the entire extent of the impacted area, which is not currently available. Therefore, a preliminary dam breach and inundation analysis was carried out as part of this study in order to determine the potential consequences of a failure of each of the above-mentioned structures.

Distances used for hydraulic analyses have been measured along the creek and river channels, but some distances quoted in the interpretation or summary of the results are measured as straight distance between two points. Unless indicated otherwise, distances given in this report are along the river or creek channel.



Note: Base map figure provided by Gartner Lee Limited

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CLIENT	PROJECT
YUKON GOVERNMENT	FARO MINE COMPLEX DAM BREACH AND INUNDATION STUDY
Klohn Crippen Berger	TITLE SITE LOCATION PLAN
	PROJECT No. M09770A02 02 — FIG. No. 1.1

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Date: 3/15/2013
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Xref File(s):
Image File(s): yukon map – faro mine location

KCB-R-MPA

2 PROJECT SETTING

2.1 Intermediate Dam and Cross Valley Dam

The Intermediate Dam is located at the west end of the Intermediate Pond, just east of the Polishing Pond. It retains tailings, supernatant, and run-off water on the upstream side and the Polishing Pond water on the downstream side. The dam is approximately 700 m long, 7 m wide at the crest and 32 m high. The dam crest elevation is at nominal 1049.2 m, and the spillway invert elevation is at 1047.7 m. The Starter Dam, which forms the upstream toe of the Intermediate Dam, has a vertical core, which was modified to an upstream sloping core during subsequent dam raises. The rest of dam zones consist of gravel shells and filters. The ultimate tailings storage capacity of the Intermediate Dam was intended to be 20 Mm^3, based on an assumed 2% tailings deposition slope (Golder 1980 and 1982). Although, at the time of writing this report, no data could be located to indicate the final volume of deposited tailings, a review of the deposited geometry indicates that this volume may be in the range of 19 Mm^3 to 20 Mm^3. A cross section of the Intermediate Dam is shown in Figure 2.1.

The Cross Valley Dam impounds the Polishing Pond at the downstream limit of the Rose Creek Tailings Facility. The Polishing Pond is designed for the 60 day retention capacity for seepage from the tailings storage facility and discharge from the Faro Water Treatment Plant. The Cross Valley Dam is 500 m long, 7 m wide at the crest and 17 m high. The dam crest elevation is at nominal 1033.1 m, while the spillway channel invert is at 1031.7 m. The dam has a central silty till core with gravel shells and filters. KCB (2008) indicates that the Cross Valley Dam is classified as a High hazard structure, based on CDA Dam Safety Guidelines (CDA 2007). The Inflow Design Flood (IDF) associated with this hazard classification is defined as 1/3 between the 1,000 year flood and the Probable Maximum Flood (PMF). A hypothetical breach of the Cross Valley Dam would result in a release of impounded water into Rose Creek downstream of the dam. Rose Creek flows into Anvil Creek, which flows into Pelly River approximately 50 km downstream of the Cross Valley Dam. A cross section of the Cross Valley Dam is shown in Figure 2.2.

As with the Cross Valley Dam, the Intermediate Dam has a High consequence classification per CDA (2007), and is required to safely handle an Inflow Design Flood (IDF) of 1/3 between the 1,000 year flood and the PMF. A hypothetical breach of the Intermediate Dam would release impounded tailings and water into the Cross Valley Dam impoundment, potentially resulting in overtopping of the Cross Valley Dam.

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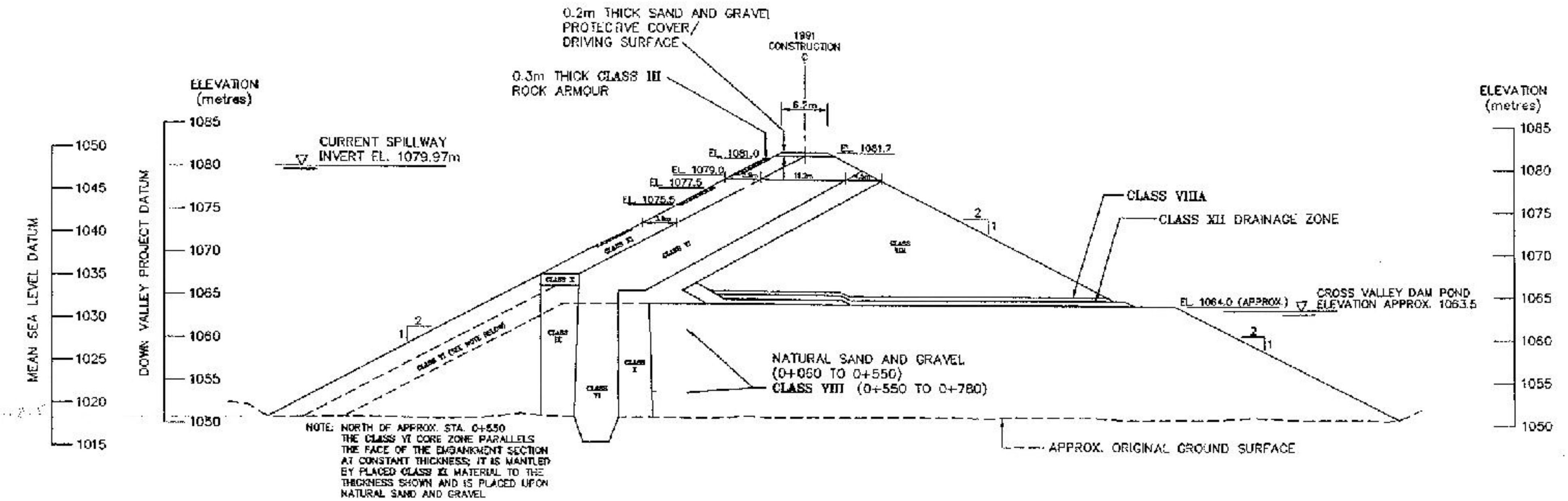

NOTES :

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

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

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

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

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0 5 10 15 20 25 metres

CLIENT: YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT: FARO MINE REMEDIATION PROJECT DAM BREACH AND INUNDATION STUDY

TITLE: INTERMEDIATE DAM CROSS SECTION

PROJECT No. M09770A02

FIG. No. 2.1

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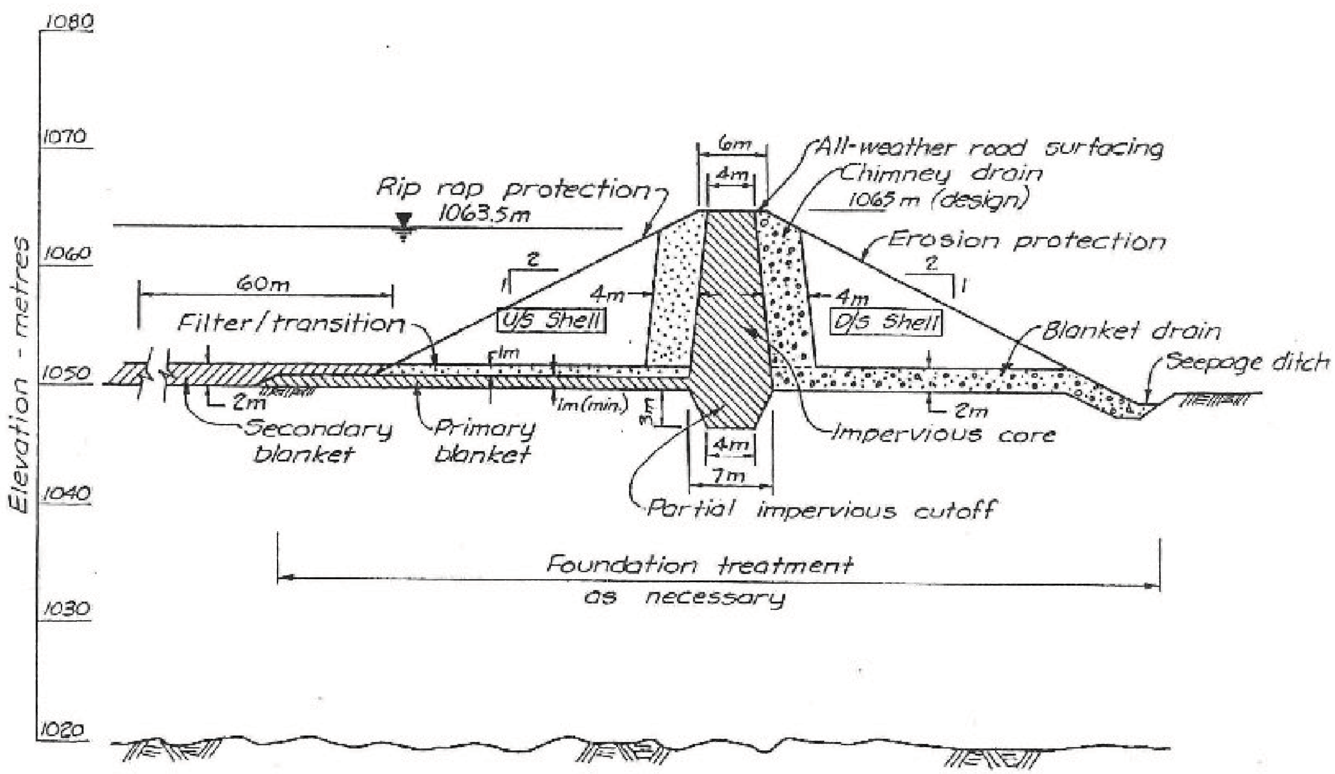

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TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED FEB. 2014

NOTES:
FIGURE SHOWING THE TYPICAL DESIGN SECTION OF THE CROSS VALLEY DAM TAKEN FROM GOLDER ASSOCIATES REPORT TO CYPRUS ANVIL MINING DATED JUNE 1980.

CLIENT: YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT: FARO MINE REMEDIATION PROJECT
DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
CROSS SECTION

PROJECT No. M09770A02

FIG. No. 2.2

KCR–R–MLA4

2.1.1 Area Downstream of Cross Valley and Intermediate Dams

The Cross Valley Dam is located on the upper reaches of Rose Creek. Except for the flatter areas immediately downstream of the dam, the Rose Creek flows in a V-shaped channel with relatively steep sparsely forested slopes. Approximately 16 km downstream of the dam, Rose Creek joins Anvil Creek and flattens out into a wide U-shaped valley. Rose and Anvil Creeks flow roughly parallel to the Pelly River, separated by the Rose Mountain range before joining Pelly River approximately 50 km downstream of the dam. The creek falls from an elevation of approximately 1030 m at the dam to 620 m at the confluence with Pelly River, corresponding to an average channel slope of about 0.8%.

The Pelly River downstream of the confluence with Anvil Creek is a wide, flat valley with many channel meanders. The river channel ranges from approximately 80 m to 140 m in width, and has an approximate average channel slope of 0.08%. Satellite imagery from Google™ Earth indicates that the valley bottom is sparsely treed.

No significant infrastructure has been identified along Rose Creek, Anvil Creek or Pelly River within the potential flood zone downstream of the dam. The nearest community on Pelly River downstream of the dams is Pelly Crossing, about 180 km (straight distance) to the northwest of Faro. A highway bridge crosses the Pelly River at Pelly Crossing.

2.2 Little Creek Dam

The Little Creek Dam is located northwest of the Vangorda Waste Dump, and collects contact water from the dump in the form of seepage and surface runoff. Water collected here is pumped to the Vangorda Pit Lake.

The Little Creek Dam is a homogeneous embankment constructed of local glacial till. It has a cutoff trench, and a granular base drains under the downstream slope. The crest is about 14 m above natural ground, ranging in elevation from 1114.5 m to 1120 m. Side slopes are 2H:1V on the downstream side and 2.5H:1V on the upstream side (SRK 1990 and 1991). A 900 mm diameter Corrugated Steel Pipe (CSP) emergency spillway is located at the south abutment (SRK 1998).

From KCB (2008), the Little Creek Dam is classified as a Low consequence structure, per CDA (2007). The IDF associated with the Low hazard classification is the 100 year flood. A hypothetical failure of the Little Creek Dam would result in a release of impounded water into Vangorda Creek. Vangorda Creek flows along the northwest side of the Town of Faro before flowing into Pelly River approximately 12 km downstream of the dam. A cross section of the Little Creek Dam is shown in Figure 2.3.

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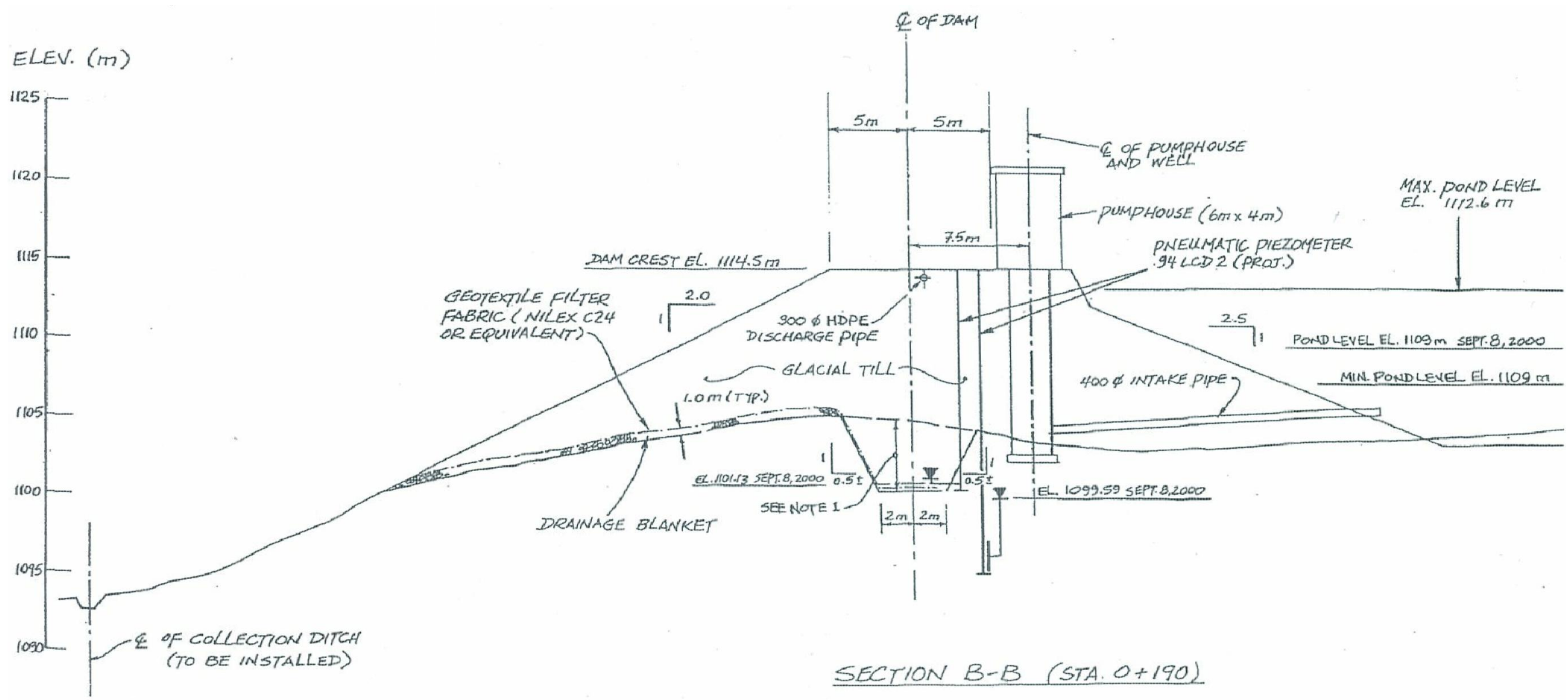

SOURCE OF FIGURE
LITTLE CREEK DAM, SECTION, ANVIL RANGE MINE COMPLEX,
2002 BASELINE ENVIRONMENTAL INFORMATION, DeLOITTE & TOUCHE,
FIGURE 3.6, DATED APRIL, 2002.

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TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED FEB. 2014

CLIENT: YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT: FARO MINE REMEDIATION PROJECT DAM BREACH AND INUNDATION STUDY

TITLE: LITTLE CREEK DAM CROSS SECTION

PROJECT No. M09770A02

FIG. No. 2.3

KCR-R-MLA4

2.2.1 Area Downstream of Little Creek Dam

The Little Creek Dam is located on the southeast bank of Vangorda Creek. The Vangorda Creek channel flows in a well-defined, forested V-shaped channel before discharging into Pelly River. The creek drops from approximate elevation 1070 m to 640 m, at an average channel slope of about 3.6%. The channel is steeper in the upper reaches and flattens out in the vicinity of the Town of Faro, where it passes under Campbell Street through a set of culverts with an estimated total capacity of 10 m^3/s to 40 m^3/s. The Campbell Street crossing is approximately 6 m to 8 m above the creek bed, and it is the main access road into the Town of Faro from the Robert Campbell Highway. A vehicle bridge and a sewer line cross Vangorda Creek just upstream of the confluence with Pelly River. The bridge would provide a secondary access between the Town of Faro and the Robert Campbell Highway. The base of the bridge deck was measured by TEES staff as approximately 3.2 m above the creek level.

Google™ satellite imagery and National Topographic Series maps show several roads across Vangorda Creek between the Little Creek Dam and the Town of Faro. However, based on discussions with mine site staff, we understand that these roads are not maintained and are not passable by vehicles, except for the access ramps to the haul road between Faro and Vangorda sites. Mine staff have also indicated that there is a foot bridge on the Vangorda Falls hiking trail upstream of the town.

The Pelly River channel between the confluences with Vangorda Creek and Anvil Creek is wide and flat-bottomed with an average slope of about 0.06%. Immediately downstream of the confluence with Vangorda Creek, the river is spanned by the Pelly River Bridge which connects Faro to the Robert Campbell Highway. The base of the bridge deck was measured by TEES staff as approximately 10.7 m above the river level.

3 DAM BREACH AND INUNDATION ANALYSIS

3.1 Methodology

The following methodology was employed for the preliminary dam breach and inundation analysis:

1. Estimate peak discharges resulting from a breach of each of the abovementioned dams due to a rainy-day or a sunny-day failure using empirical charts and/or formulas.
2. Estimate the peak flood flows along the downstream flood route using flow attenuation charts and/or equations.
3. Estimate the maximum flood depths along the flood route assuming steady-state flow conditions corresponding to the peak discharges estimated in Step 2, above.
4. Use the estimated flood depths to delineate the potential inundation areas on a topographic map, and compare to non-breached conditions to assess incremental impacts of the breach.

Rainy-day failures are caused by overtopping of the dam, typically due to flows in excess of the capacity of the spillway which cause the water level in the impoundment to rise high enough to overtop the dam. Sunny-day failures include slumping of the dam slope in static condition or during an earthquake, or failure of the dam due to internal erosion (piping) through the embankment or the foundation, and typically occur when the pond is at its normal operating level.

The 1:50,000 scale Yukon Territory National Topographic Series (NTS) maps were used to determine the profile and channel cross sections for the flood paths in this study, including the Pelly River. Given that these maps show topographic information at 100 ft (~30 m) contour intervals, the information derived from the maps was supplemented by available satellite imagery from Google™ Earth.

3.2 Dam Breach Scenarios

The following dam failure scenarios were considered for this preliminary dam break study:

- Intermediate Dam rainy-day failure;
- Cross Valley Dam sunny-day failure;
- Cross Valley Dam rainy-day failure;
- Intermediate and Cross Valley Dams rainy-day cascading failure;
- Little Creek Dam sunny-day failure; and
- Little Creek Dam rainy-day failure.

There is very little difference in the volume of water for the sunny day failure and the rainy day failure of the Intermediate Dam, and the volume of water for both failure scenarios is only about 5% of the total tailings plus water storage volume (see Table 3.1). Given the small difference in total storage volumes, the peak dam breach flows for the sunny day failure and the rainy day failure would be almost the same. Since there is no public infrastructure or population centres downstream of the dam, the consequences of a dam failure would mostly be related to environmental impacts. Therefore, we pursued only the rainy day failure scenario for the Intermediate Dam because it would have a larger extent of flooding and environmental impact than the sunny day failure.

For the sunny-day failures, the concurrent flows in the downstream creeks and rivers were assumed to be the maximum average annual flows. For the rainy-day failures, the concurrent flows in the downstream creeks and rivers were assumed to be the IDF. The intermediate Dam and the Cross Valley Dam are classified as High hazard structures which, according to the CDA Dam Safety Guidelines, would have an IDF of 1/3 between the 1,000 year flood and the PMF. The Little Creek Dam is currently classified as a Low hazard structure, which would have an IDF of 100-year flood. However, an IDF of 1/3 between the 1,000 year flood and the PMF was used for the Little Creek Dam because results of the sunny-day failure analysis for the dam indicate that the dam could potentially be classified as Significant or High.

Once the peak outflow resulting from the dam breach was determined, the potential attenuation of the peak discharge was estimated using the data presented in BC Hydro (1986). The peak flood depths, corresponding to the estimated discharges, were calculated using Manning's equation assuming steady-state flow conditions corresponding to the peak flow.

3.3 Peak Breach Outflows

The peak outflows resulting from a breach of each of the aforementioned dams were calculated using the following empirical data:

1. historical dam failure charts compiled by MacDonald et al. (1984);
2. historical dam failure charts compiled by Wahl (1998); and
3. empirical equations derived by Xu and Zhang (2009).

MacDonald correlated the peak discharge to the "breach formation factor", which is equal to the impoundment storage volume times the storage height at the time of dam failure. Wahl correlated the peak discharge to the storage volume, and to the storage height or depth of water at dam failure.

Xu and Zhang's equation for estimating the peak discharge from a dam breach is as follows:

$$\frac{Q_p}{\sqrt{g V_w^{5/3}}} = 0.133 \left(\frac{V_w^{1/3}}{H_w} \right)^{-1.276} e^{C_4}$$

Where: Q_p = peak outflow rate (m^3/s)
H_w = depth of water above breach invert (m)
V_w = volume of water above breach invert (m^3)
$C_4 = b_4 + b_5$
b_4 = a constant
b_5 = a constant

The constant b_4 is based on the type of dam failure. Its values are -0.788 and -1.232 for overtopping and erosion/piping failures, respectively. The constant b_5 is based on dam erodibility, and its values are -0.089, -0.498 and -1.433 for high, medium and low erodibility, respectively. The erodibility of each of the dams was conservatively assumed to be high.

The databases used by MacDonald, Wahl and Xu and Zhang to derive their empirical relationships are based on failures of water storage dams. Tailings stored in tailings ponds have higher viscosity than water and, in the event of a dam failure, usually not all the tailings are released from the pond. A review of historical tailings dam failures indicates that anywhere between 20% and 100% of the impounded tailings can be released from the impoundment during a breach. This figure is dependent on a number of factors, including deposited tailings properties, breach geometry and impoundment geometry. For the breach of the Intermediate Dam, we have calculated a range of tailings run-out volumes based on the geometry of the breach (calculated using Xu and Zhang's equations), and assumed final tailings slopes above the breach invert ranging from 5% to 1%. This equates to 20% and 65% of the total impounded tailings. The tailings released from the impoundment have been conservatively assumed to behave like water when flowing downstream. In addition, it is assumed in each case that 100% of the impounded water is released during the breach.

The dam breach parameters assumed for this study are shown in Table 3.1, and the estimated peak outflows are shown in Table 3.2.

Table 3.1 Assumed Dam Breach Parameters

Dam	Dam Crest Elev. (m)	Dam Height (m)	Dam Crest Length (m)	Normal Max Operating Elev. (m)	Tailings Volume (Mm^3)	Water Volume	
						Normal Water Level (Mm^3)	Water Level 0.5 m Above Dam Crest* (Mm^3)
Intermediate Dam	1,048.8	32	700	1,047.7	19.6	1.0	1.3
Cross Valley Dam	1,033.1	17	500	1,031.7	0	1.5	2.2
Little Creek Dam	1,114.5	14	300	1,112.6	0	0.12	0.20

*For rainy-day (i.e., overtopping) failures, the pond water level is assumed to be 0.5 m above the dam crest.

Table 3.2 Estimated Peak Dam Breach Outflows

Dam	Failure Type	Final Tailings Slope	Volume of Tailings and/or Water Released (Mm^3)	Calculated Peak Outflow (m^3/s)					
				(Xu and Zhang 2009)	(Xu and Zhang 2009) Simplified Model	(Wahl 1998) Based on Height of Dam or Water	(Wahl 1998) Based on Reservoir Volume	(MacDonald et al 1984) Based on Breach Formation Factor	Selected Peak Outflow (m^3/s)
Intermediate Dam	Rainy-day	5%	4.80	6,290	7,750	5,000 to 11,500	2,700 to 8,000	2,830 to 9,340	9,000
	Rainy-day	1%	14.0	9,010	11,100	5,000 to 11,500	4,000 to 13,000	3,960 to 13,580	13,000
Cross Valley Dam	Rainy-day	n/a	2.06	2,120	2,270	1,200 to 3,500	1,500 to 4,500	1,460 to 4,670	4,500
	Sunny-day	n/a	1.88	1,280	1,190	1,400 to 4,500	1,500 to 4,500	1,490 to 4,950	5,000
Little Creek Dam	Sunny-day	n/a	0.12	350	270	900 to 2,700	320 to 900	430 to 1,420	1,400
	Rainy-day	n/a	0.2	770	540	1,000 to 3,000	420 to 1,150	510 to 1,700	1,700

n/a = not applicable

In the case of the failure of the Intermediate Dam, a cascading failure of the Cross Valley Dam is also expected. Although the calculated breach formation times for the two dams differ (calculated as approximately 1 hour for the Intermediate Dam, and 0.5 hours for the Cross Valley Dam), the larger spillway capacity at the Cross Valley Dam may result in a slower breach formation for this dam, as the initial stages of the inflow from the Intermediate Dam breach could be discharged via the spillway. Therefore, it is conservatively assumed that the timing of the peak outflow from the Intermediate Dam corresponds to the peak outflow from the Cross Valley Dam. The estimated peak flows for the cascading failure case are shown in Table 3.3.

Table 3.3 Estimated Peak Dam Breach Outflows for Cascading Failure of Intermediate and Cross Valley Dams

Dam		Final Tailings Slope	Volume of Tailings and Water Released (Mm^3)	Estimated Peak Outflow (m^3/s)
Cascading Breach Intermediate and Cross Valley Dams	Rainy-day	5%	6.86	13,500
	Rainy-day	1%	16.1	17,500

3.4 Natural Stream Flows

Sunny-day Maximum Annual Flows

In order to determine the incremental impact of a sunny-day failure, the breach discharge is compared to the average maximum annual flows along the flood route. Data from five Environment Canada stream flow stations exist for Pelly River. There are no Environment Canada stream flow stations in Vangorda Creek or Rose/Anvil Creeks. Data for the stations located on Pelly River is shown in Table 3.4.

Table 3.4 Environment Canada Stream Flow Stations on Pelly River

Station Number	Station Name	Drainage Area (km^2)	Period of Record	Average Maximum Annual Flow (m^3/s)
09BA002	Pelly River below Fortin Creek	5,020	1986-1994	453
09BC002	Pelly River at Ross River	18,400	1955 - 1974	1,123
09BC004	Pelly River below Vangorda Creek	22,100	1973-2008	1,031
09BC001	Pelly River at Pelly Crossing	49,000	1953-2008	1,989
09BA001	Ross River at Ross River	7,250	1961-2008	406

Based on this data, a relationship for Average Maximum Daily Annual Flow to Drainage Area is calculated using a regression relationship as shown in Figure 3.1. As there is no data available for

Vangorda or Rose/Anvil Creeks, the same relationship is assumed to be valid for all of the creeks in the study area.

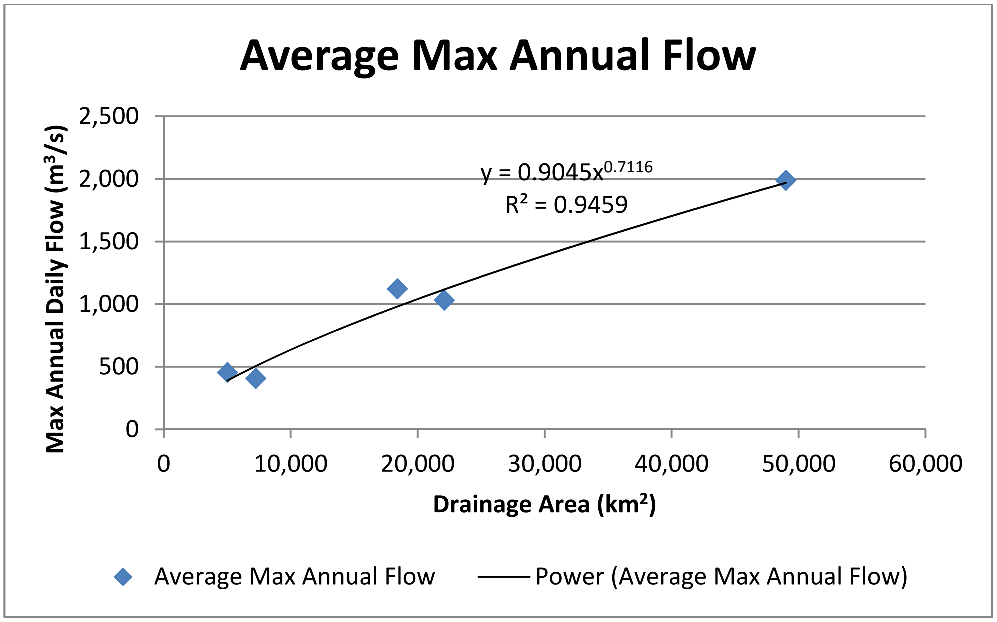


Figure 3.1 Average Annual Maximum Daily Flow versus Drainage Area

Rainy-day IDF Flows

In the case of a rainy-day failure, the breach is assumed to occur due to overtopping during the IDF event, and the incremental impact of this breach is compared to the natural IDF flood flow in the downstream watercourses. The IDF for the Cross Valley Dam and the Intermediate Dam is “1/3 between the 1,000 year flood and the PMF” and, as noted in Section 3.2, the IDF of “1/3 between the 1,000 year flood and the PMF” was used for the Little Creek Dam as well.

The method for calculating the 1,000 year flood uses data from the Environment Canada stations listed in Table 3.4. A statistical analysis was performed on the annual peak instantaneous flows for each station in order to calculate the peak flow with a return period of 1,000 years for each station.

Table 3.5 Calculated 1,000 year Return Period Flows in Pelly River

Station	Name	Drainage Area (km^2)	Period of Record	Number of Years (N)	Average Annual Peak Instantaneous Flow (m^3/s)	Standard Deviation (m^3/s)	1,000 Year Flow (LogNormal Distribution) (m^3/s)
09BA002	Pelly River below Fortin Creek	5,020	1986-1994	9	459	102.8	915
09BC002	Pelly River at Ross River	18,400	1955 - 1974	14	1,180	407.2	3,050
09BC004	Pelly River below Vangorda Creek	7,250	1961-2008	33	1,062	239.6	2,080
09BC001	Pelly River at Pelly Crossing	22,100	1973-2008	45	2,006	628.7	4,760
09BA001	Ross River at Ross River	7,250	1961-2008	39	422	120.1	945

As part of a review of the capacity of the Rose Creek Diversion Channel (RCDC), a summary of PMF flows for a number of catchments in the vicinity of the Cross Valley and Intermediate Dams was prepared (KCB 2007), as shown in Table 3.6.

Table 3.6 Calculated PMF Flows for RCDC Design

Watershed Location	Catchment Area (km^2)	Calculated PMF Value (from KCB 2007) (m^3/s)	Unit Runoff (m^3/s/km^2)
North Fork Rose Creek	122.5	384	3.13
South Fork Rose Creek	83.5	290	3.47
Entrance - RCDC	206	674	3.27
RCDC tributary areas	11.3	18	1.59
Exit - RCDC	217.3	692	3.18
Additional North Catchment	12.14	38	3.13
Total	229.42	730	3.18

The catchments used in these calculations are relatively small. When extrapolated to the larger catchments of Pelly River, the resulting flows are considered to be unrealistically large. Instead, these flows were compared to those generated using the equations from the Probable Maximum Flood Estimator for British Columbia (Abrahamson 2010). For catchments with drainage areas greater than 8,320 km^2, the general equation is used. For smaller catchments, the “BC Interior” zone appears to correlate best with the previously calculated data from KCB (2007), as shown in Figure 3.2, and is used for small catchment areas.

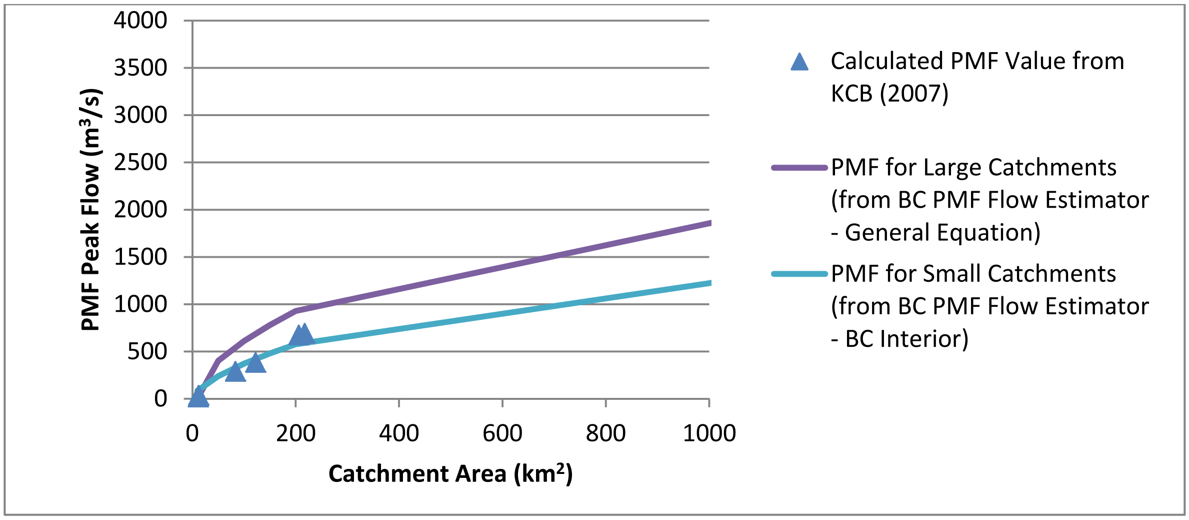


Figure 3.2 PMF Values from KCB 2007 and from PMF Estimator for BC

The equations from the PMF Estimator for BC are shown below:

For Drainage Areas < 8,320 km^2, $Q = 19.933A^{0.6321}$
For Drainage Areas > 8,320 km^2, $Q = 37.805A^{0.6042}$

Where:

Q = Peak PMF Flow (m^3/s)
A = Drainage Area (km^2)

From the 1,000 year flood and the PMF, the IDF is calculated for different areas and represented by the regression curve shown in Figure 3.3.

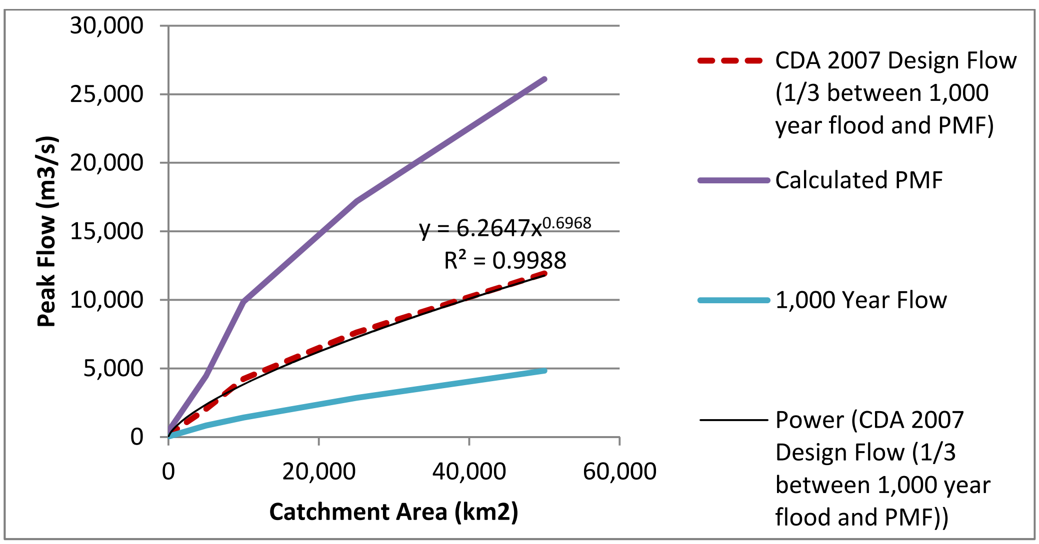


Figure 3.3 Calculated IDF Flow by Catchment Area

The estimates of 1,000 year flows, the PMF and the IDF presented in this report are rough estimates only for the purpose of ascertaining approximate incremental impacts of dam breaches. These estimates should not be used for any other purpose such as flood routing and/or sizing of spillways for any of the dams.

3.5 Breach Flood Attenuation

Flood flows resulting from a dam breach tend to attenuate as the flood wave travels downstream, due to valley storage and frictional resistance. The degree of attenuation depends on the breach hydrograph and flow, and channel properties such as cross section, grade, type of floodplain and channel roughness. A number of empirical charts and equations have been generated to allow quick estimation of attenuation, but these should be used for preliminary estimates only because the amount of attenuation is highly dependent on site-specific characteristics. In order to obtain more accurate results, numerical hydraulic modelling of the flood wave is required. As discussed previously, this requires a relatively large degree of effort and cost, as well as detailed topographic and floodplain data for the entire flood route. Flood attenuation for this study was estimated using BC Hydro procedures (1986). The formula is:

$$Q = 10^{\log(Q_B - 0.01X)}$$

Where:

Q = Peak discharge (cfs) at distance X;
Q_B = Peak discharge (cfs) from breached dam; and,
X = distance (miles) along river channel.

Note that this attenuation is based on distance from the dam only, and does not consider losses due to storage, for example due to backwatering where Vangorda or Anvil Creeks join Pelly River.

The dam breach flows are assumed to be substantially attenuated when the following criteria are met:

1. For a sunny-day failure, the total flow (breach plus natural flow) falls below the 75th percentile of the recorded maximum annual flows. These percentiles are interpolated in Pelly River between Vangorda Creek and Pelly Crossing, based on recorded data at the associated Environment Canada stations, as demonstrated in Figure 3.4, Figure 3.5 and Figure 3.6.
2. For a rainy-day failure, the total flow (breach plus natural flow) falls below the natural river IDF flow plus 10%.

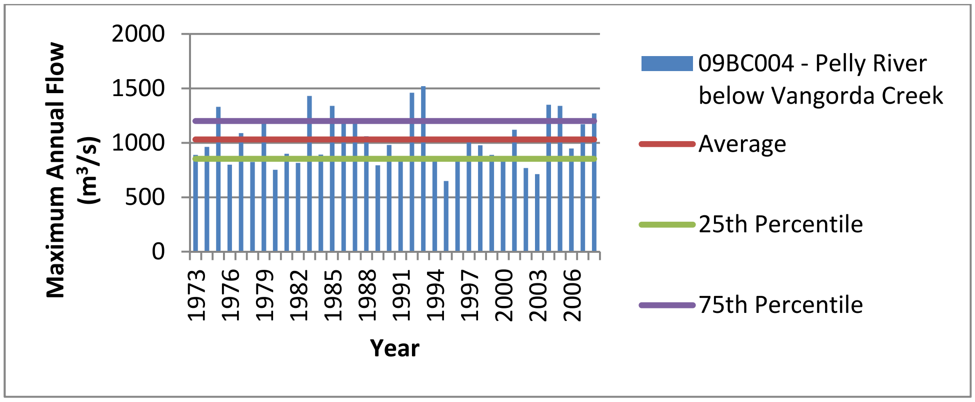


Figure 3.4 Recorded Maximum Annual Flows at Environment Canada Station "Pelly River below Vangorda Creek"

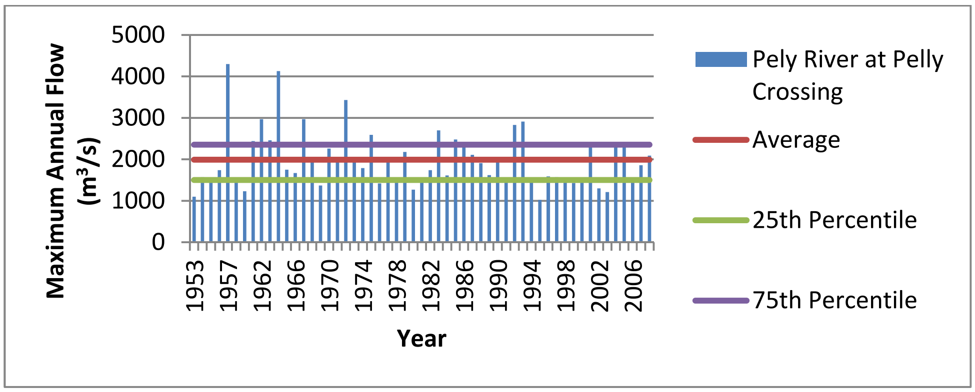


Figure 3.5 Recorded Maximum Annual Flows at Environment Canada Station "Pelly River at Pelly Crossing"

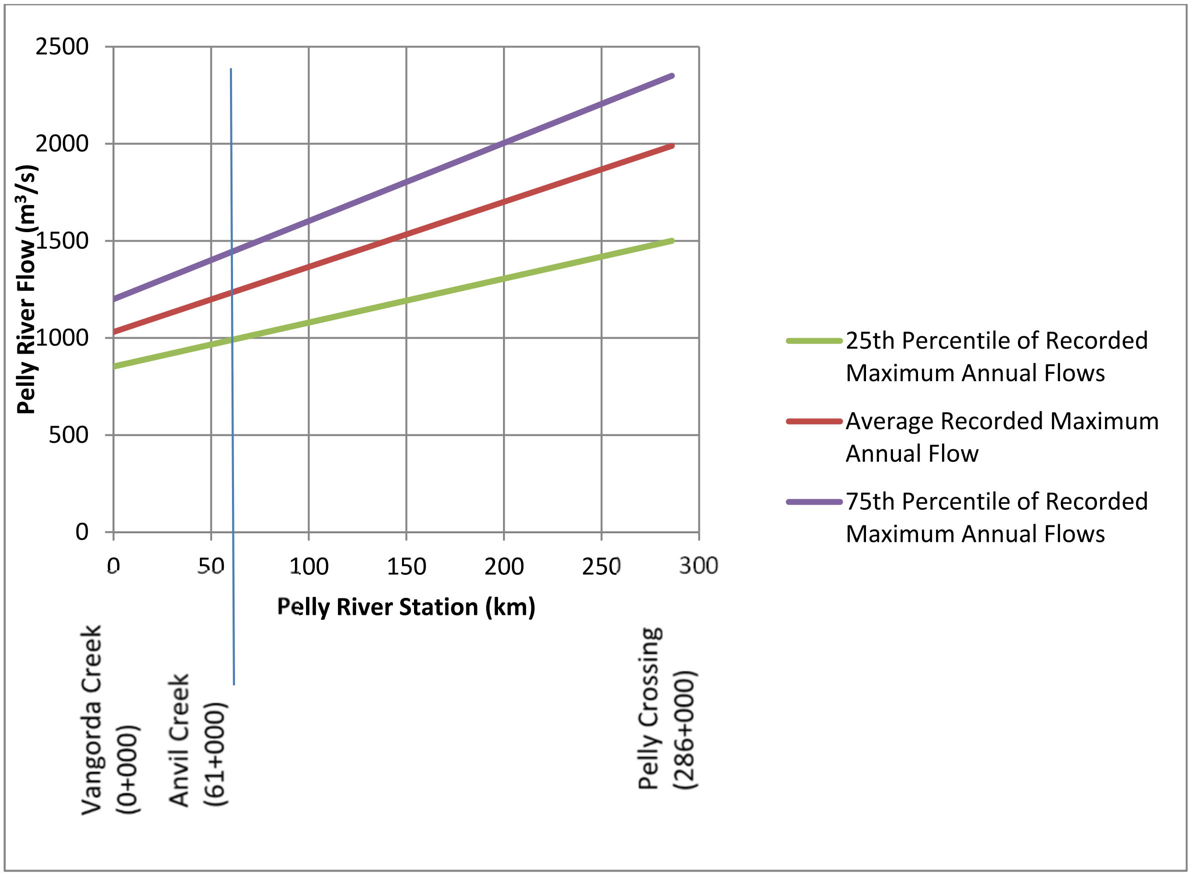


Figure 3.6 Interpolated Average, 25th and 75th Percentiles of Recorded Maximum Annual Flows in Pelly River between Vangorda Creek and Pelly Crossing

In calculating the flood discharges, we have assumed that the existing structures along the flood routes have negligible impact on the discharge. In reality, water is likely to pond behind the Campbell Street road crossing. This could result in a secondary flood wave, should the road embankment fail.

3.5.1 Intermediate and Cross Valley Dams – Rainy-day Cascading Failure

The attenuated rainy-day breach flow for the Intermediate and Cross Valley Dams cascading failure for three tailings runout scenarios are shown in Table 3.7.

Table 3.7 Breach Flows – Intermediate and Cross Valley Dam Rainy-day Cascading Failure

Creek/River	Chainage (m)	Drainage Area (km^2)	Q_1 IDF Flow (m^3/s)	1% Final Impounded Tailings Back Scarp Slope			3% Final Impounded Tailings Back Scarp Slope			5% Final Impounded Tailings Back Scarp Slope		
				Rainy-day Breach Flow (m^3/s)	Q_2 IDF Flow plus Breach Flow (m^3/s)	Ratio Q_2/Q_1	Rainy-day Breach Flow (m^3/s)	Q_3 IDF Flow plus Breach Flow (m^3/s)	Ratio Q_3/Q_1	Rainy-day Breach Flow (m^3/s)	Q_4 IDF Flow plus Breach Flow (m^3/s)	Ratio Q_4/Q_1
Rose Creek	0+000	220	271	17,500	17,771	66	15,500	15,771	58	13,500	13,771	51
	16+000	340	363	13,919	14,282	39	12,329	12,692	35	10,738	11,101	31
Anvil Creek	16+000	730	621	13,919	14,540	23	12,329	12,950	21	10,738	11,359	18
	25+000	880	708	12,238	12,945	18	10,839	11,547	16	9,440	10,148	14
	50+000	1,050	799	8,558	9,356	12	7,580	8,378	10	6,602	7,400	9.3
Pelly River	61+000	23,590	6,980	8,558	15,538	2.2	7,580	14,560	2.1	6,602	13,582	1.9
At Pelly Crossing	286+000	49,000	11,616	342	11,958	1.0	303	11,919	1.0	264	11,880	1.0

NOTES:

1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. IDF Flow (Q_1) is 1/3 between 1,000 year flood and PMF.

The high Q_2/Q_1, Q_3/Q_1 and Q_4/Q_1 ratios in Table 3.7 indicate that the incremental impact of a cascading rainy-day breach of the Intermediate and Cross Valley Dams is significant over the entire length of Rose and Anvil Creeks, and extends past the confluence with Pelly River. As shown in Figure 3.7, in all tailings runout cases, the breach flow is substantially attenuated, (i.e., to 110% of the IDF) approximately 139 km downstream of the confluence of Anvil Creek and Pelly River (140 km straight distance downstream of the Town of Faro).

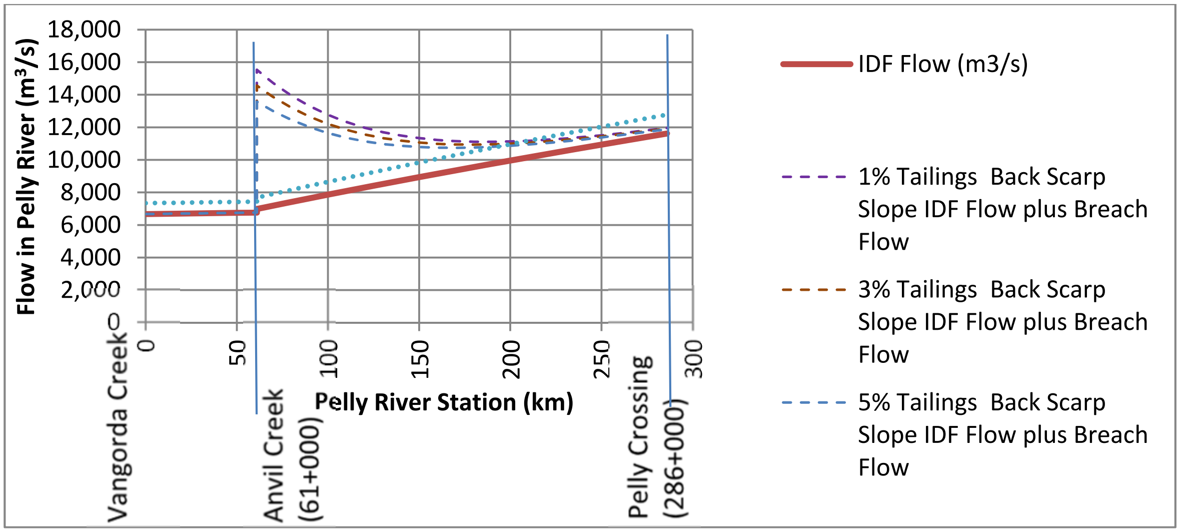


Figure 3.7 Breach Flood Attenuation for Intermediate and Cross Valley Dams Rainy-day Cascading Failure

3.5.2 Cross Valley Dam – Sunny-day Failure

The attenuated sunny-day breach flows compared to the Average Maximum Annual Flow for the Cross Valley Dam failure are shown in Table 3.8.

Table 3.8 Breach Flows – Cross Valley Dam Sunny-day Failure

Creek/River	Chainage (m)	Drainage Area (km^2)	Q_1 Average Max Annual Flow (m^3/s)	Sunny-day Breach Flow (m^3/s)	Q_2 Average Max Annual Flow plus Breach Flow (m^3/s)	Note	Ratio Q_2/Q_1
Rose Creek	0+000	220	42.3	5,000	5,042	At dam	119
	16+000	340	57.1	3,977	4,034	U/S of Anvil Creek Confluence	71
Anvil Creek	16+000	730	98.8	3,977	4,076	D/S of Rose Creek Confluence	41
	25+000	880	113.0	3,496	3,609	D/S of Confluence with Unnamed Creek	32
	50+000	1,050	127.8	2,445	2,573	Before Pelly River	20
Pelly River	61+000	23,590	1,170	2,445	3,615	D/S of Anvil Creek Confluence	3.1
Pelly Crossing	286+000	49,000	1,968	98	2,065	Pelly Crossing	1.0

NOTE: Chainages shown are measured along the river channel, and are not straight distances between points.

The high Q_2/Q_1 ratios in the above table indicate that the incremental impact of a sunny-day breach of the Cross Valley Dam is significant over the entire extent of Rose and Anvil Creeks, and past the confluence with Pelly River. As shown in Figure 3.8, the breach flow is attenuated to the 75th percentile of the recorded average maximum annual flow in the Pelly River approximately 139 km downstream of the confluence of Anvil Creek and Pelly River (140 km straight distance downstream of the Town of Faro).

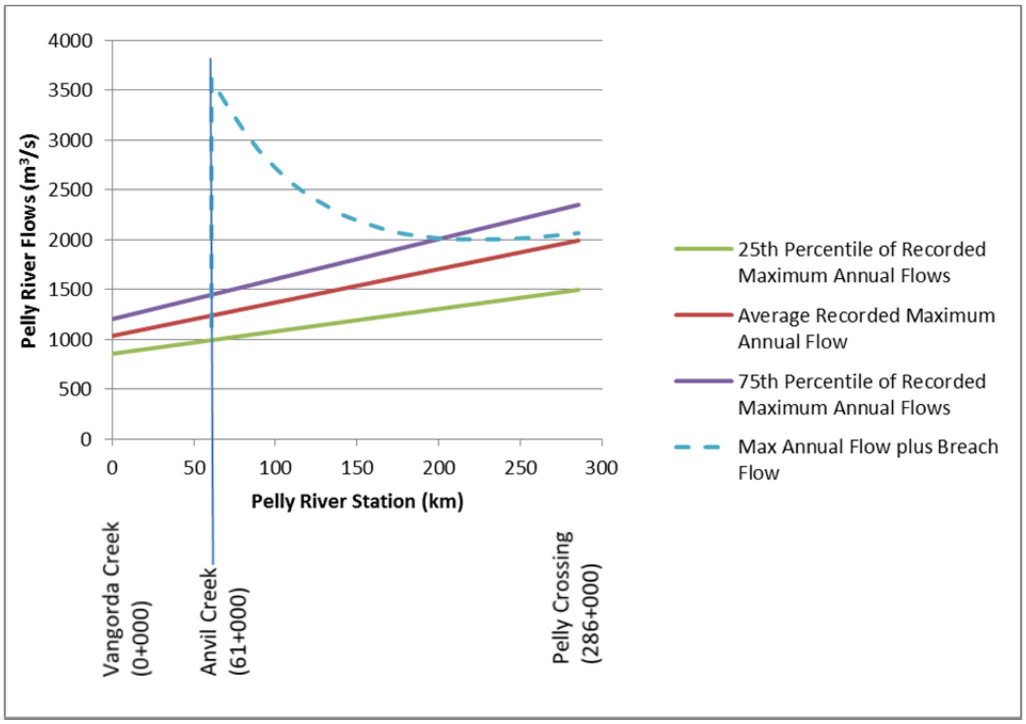


Figure 3.8 Breach Flood Attenuation for Cross Valley Dam Sunny-day Failure

3.5.3 Cross Valley Dam – Rainy-day Failure

The attenuated rainy-day breach flow is shown compared to the IDF flow for the Cross Valley Dam failure, along Rose Creek, Anvil Creek and Pelly River, in Table 3.9.

Table 3.9 Breach Flows – Cross Valley Dam Rainy-day Failure

Creek/River	Chainage (m)	Drainage Area (km^2)	Q_1 IDF Flow (m^3/s)	Rainy-day Breach Flow (m^3/s)	Q_2 IDF Flow plus Breach Flow (m^3/s)	Note	Ratio Q_2/Q_1
Rose Creek	0+000	220	271	4500	4,771	At dam	18
	16+000	340	363	3579	3,942	U/S of Anvil Creek Confluence	11
Anvil Creek	16+000	730	621	3579	4,200	D/S of Rose Creek Confluence	6.8
	25+000	880	708	3147	3,855	D/S of Confluence with Unnamed Creek	5.4
	50+000	1,050	799	2201	2,999	Before Pelly River	3.8
Pelly River	61+000	23,590	6,980	2201	9,181	D/S of Anvil Creek Confluence	1.3
Pelly Crossing	286+000	49,000	11,616	88	11,704	Pelly Crossing	1.0

NOTES:
1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. IDF Flow (Q_1) is 1/3 between 1,000 year flood and PMF.

As with the previously seen cases, the incremental impact of a rainy-day breach of the Cross Valley Dam is significant over the entire length of Rose and Anvil Creeks, and extends past the confluence with Pelly River. As shown in Figure 3.9, the breach flow is attenuated to within 10% of the IDF flow in the Pelly River approximately 64 km downstream of the confluence of Anvil Creek and Pelly River (105 km straight distance downstream of the Town of Faro).

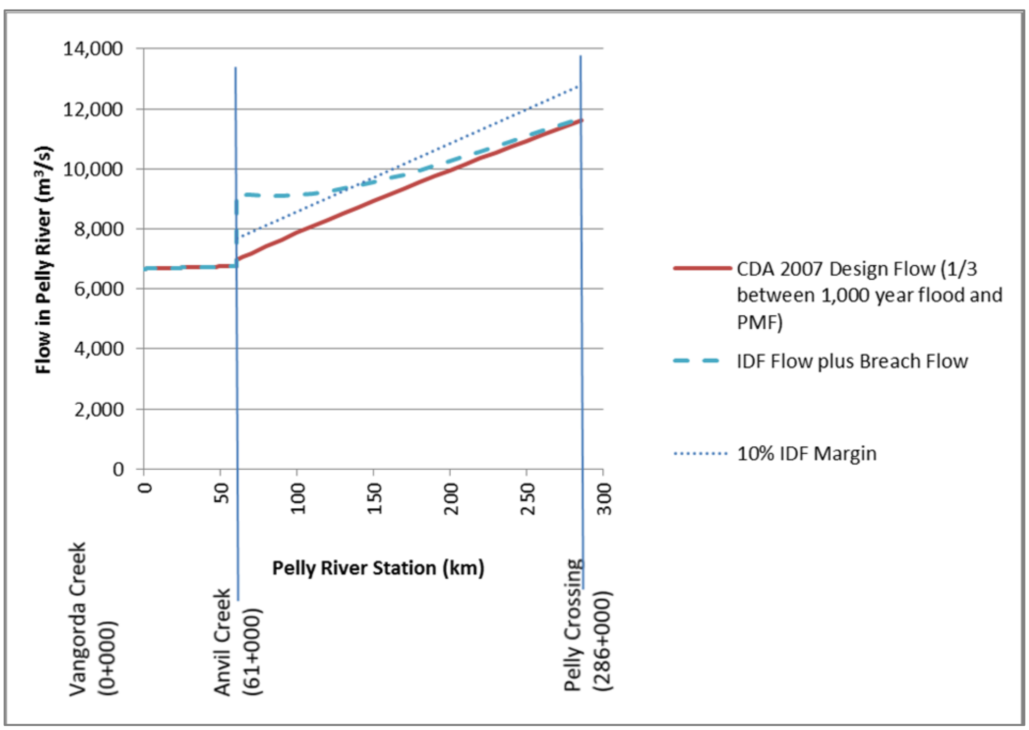


Figure 3.9 Breach Flood Attenuation for Cross Valley Dam Rainy-day Failure

3.5.4 Little Creek Dam – Sunny-day Failure

The attenuated sunny-day breach flows for the Little Creek Dam, compared to the Average Maximum Annual Flow in Vangorda Creek and Pelly River, are shown in Table 3.10.

Table 3.10 Breach Flows – Little Creek Dam Sunny-day Failure

Creek/River	Chainage (m)	Drainage Area (km^2)	Q_1 Average Max Annual Flow (m^3/s)	Sunny-day Breach Flow (m^3/s)	Q_2 Average Max Annual Flow plus Breach Flow (m^3/s)	Note	Ratio Q_2/Q_1
Vangorda Creek	0+000	20	7.7	1,400	1,408	At dam	183
	3+000	45	13.5	1,341	1,355		100
	9+500	90	22.6	1,222	1,245	Campbell Street Culvert Crossing at Faro	55
	12+000	100	23.6	1,179	1,203	Vangorda Creek Bridge D/S of Faro	51
Pelly River	0+000	22,100	1,117	585	1,701	Confluence Vangorda Creek/Pelly River	1.5
	61+000	22,540	1,132	244	1,377	Upstream of Anvil Creek	1.2
	61+000	23,590	1,170	244	1,414	Downstream of Anvil Creek	1.2
	286+000	49,000	1,968	10	1,977	At Pelly Crossing	1.0

NOTE: Chainages shown are measured along the river channel, and are not straight distances between points.

It can be seen from the above table that the incremental impact of a sunny-day breach of the Little Creek Dam is significant over the entire extent of Vangorda Creek, and past the confluence with Pelly River. As shown in Figure 3.10, the breach flow is attenuated to the 75th percentile of the recorded average maximum annual flow in the Pelly River approximately 45 km (straight distance) downstream of the Town of Faro.

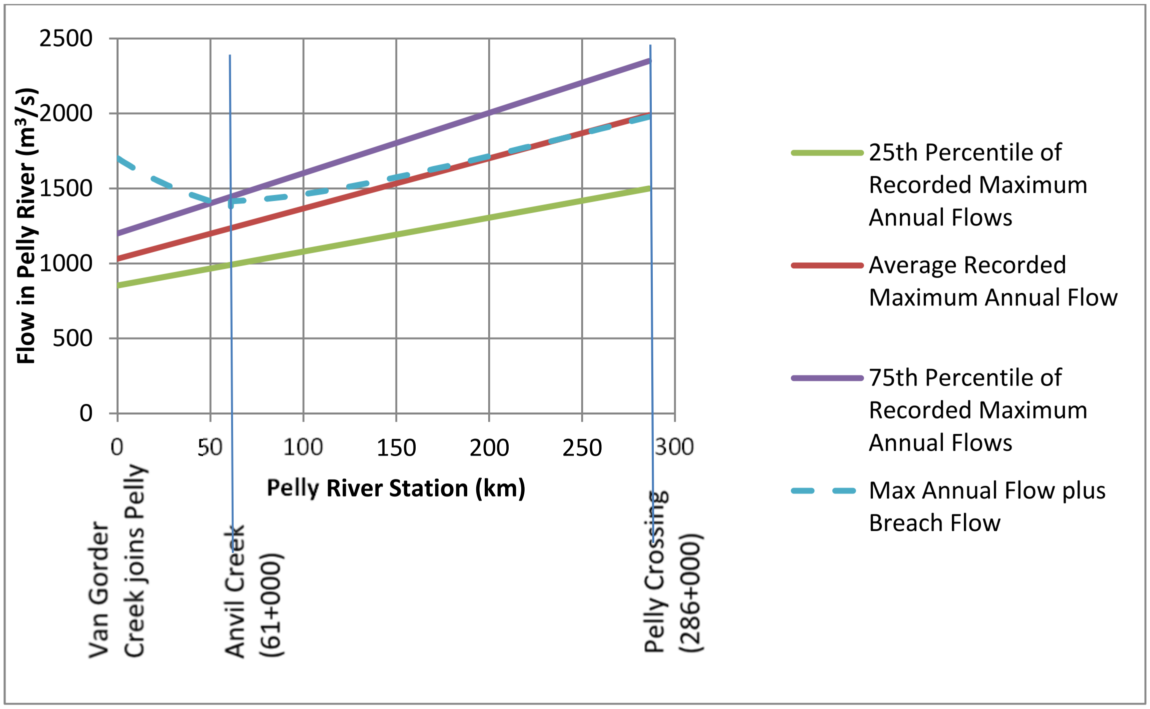


Figure 3.10 Breach Flood Attenuation for Little Creek Dam Sunny-day Failure

3.5.5 Little Creek Dam – Rainy-day Failure

The attenuated rainy-day breach flows are shown compared to the IDF flow for the Little Creek Dam failure, along Vangorda Creek and Pelly River, in Table 3.11.

Table 3.11 Breach Flows – Little Creek Dam Rainy-day Failure

Creek/River	Chainage (m)	Drainage Area (km^2)	Q_1 IDF Flow (m^3/s)	Rainy-day Breach Flow (m^3/s)	Q_2 IDF Flow plus Breach Flow (m^3/s)	Note	Ratio Q_2/Q_1
Vangorda Creek	0+000	20	50	1700	1750	At dam	35
	3+000	45	90	1630	1720		19.1
	9+500	90	140	1480	1620	Campbell Street Culvert Crossing at Faro	11.6
	12+000	100	160	1430	1590	Vangorda Creek Bridge D/S of Faro	9.9
Pelly River	0+000	22,100	6670	710	7380	Confluence Vangorda Creek/Pelly River	1.1
	61+000	22,540	6760	300	7060	Upstream of Anvil Creek	1.0
	61+000	23,590	6980	300	7280	Downstream of Anvil Creek	1.0
	286+000	49,000	11600	10	11610	At Pelly Crossing	1.0

NOTES:
1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. IDF Flow (Q_1) of 1/3 between 1,000 year flood and PMF has been used because results of sunny-day failure analysis indicate that the dam could potentially be classified as Significant or High.

It can be seen from Table 3.11 that the incremental impact of a rainy-day breach of the Little Creek Dam is significant over the entire extent of Vangorda Creek, but the impact is minimal in Pelly River. A comparison of the results presented in Table 3.10 and Table 3.11 indicate that the sunny-day failure has a larger incremental impact in terms of discharge ratios with and without dam failure (i.e., the Q_2/Q_1 ratio for sunny-day failure is larger), and the sunny-day failure impact extends further downstream than the rainy-day failure.

3.5.6 Extent of Downstream Impact – Summary

The extents of downstream impacts for the various breach scenarios are summarized in Table 3.12 For the cascading failure of the Intermediate and Cross Valley Dams, depths are calculated using the most conservative value (1% tailings back scarp slope, resulting in a discharge of 65% of the impounded tailings).

Table 3.12 Extent of Downstream Incremental Impact of Dam Breaches

Breach Scenario	Extent of Downstream Impact
Intermediate and Cross Valley Dams, Rainy-day Cascading Failure	Along Rose and Anvil Creeks to Pelly River, and along Pelly River up to 140 km d/s of Town of Faro
Cross Valley Dam, Sunny-day	Along Rose and Anvil Creeks to Pelly River, and along Pelly River up to 140 km d/s of Town of Faro
Cross Valley Dam, Rainy-day	Along Rose and Anvil Creeks to Pelly River, and along Pelly River up to 105 km d/s of Town of Faro
Little Creek Dam, Sunny-day	Along Vangorda Creek to Pelly River, and along Pelly River up to 45 km d/s of Town of Faro
Little Creek Dam, Rainy-day	Along Vangorda Creek to Pelly River

Note: Distances shown are straight distance between two points.

3.6 Downstream Flood Depths and Impacts

Manning's equation was used to calculate the flood depths along the flood route described in the previous section. Manning's roughness coefficient (n) depends on the characteristics of the stream channel, and the overbank areas which carry water at high flood stages. Based on observations of satellite imagery from Google™ Earth, the apparent geometry of the channels and KCB's experience on similar projects, Manning's roughness values were selected as shown in Table 3.13.

Historical floodplain data from FWHA (2000) and USGS (2001) was used as reference for the selection of these parameters.

Table 3.13 Selected Manning's Roughness Coefficients

Creek/River	Selected Channel Roughness (n)	Selected Overbank Roughness (n)
Vangorda Creek	0.028	0.12
Rose/Anvil Creeks	0.030	0.12
Pelly River	0.028	0.10

Key infrastructure that could potentially be impacted by the dam breaches is shown in Table 3.14.

Table 3.14 Infrastructures along Dam Breach Flood Routes

Breach Scenario	Infrastructure / Community within Flood Zone	Approximate Location
Intermediate and Cross Valley Dams, Rainy-day Cascading Failure	None identified*	Flood wave dissipates in Pelly River approximately 140 km (straight distance) downstream of the Town of Faro
Cross Valley Dam, Sunny-day	None identified*	Flood wave dissipates in Pelly River approximately 140 km (straight distance)downstream of the Town of Faro
Cross Valley Dam, Rainy-day	None identified*	Flood wave dissipates in Pelly River approximately 105 km (straight distance) downstream of the Town of Faro
Little Creek Dam, Sunny-day and Rainy-day	Local roads upstream of the Town of Faro (Mine staff report these roads are not maintained and are not passable)	On Vangorda Creek, 4.5 km and 7.0 km downstream of the dam
	Foot bridge on Vangorda Falls hiking trail	On Vangorda Creek upstream of Faro
	Town of Faro and Campbell St. road crossing (entrance to the town)	On Vangorda Creek, 9.5 km downstream of the dam
	Vangorda Creek bridge (including sewer line)	On Vangorda Creek just before confluence with Pelly River
	Pelly River Bridge	Downstream of confluence of Vangorda Creek and Pelly River

*The closest community along Pelly River downstream of the Town Faro is Pelly Crossing, approximately 180 km (straight distance) northwest of Faro.

The available NTS maps do not show channel bathymetry. The channel shape was therefore estimated using Manning's equation assuming the average maximum annual flows are at the top of the riverbanks. The top width of the channel was estimated based on satellite imagery. Breach and IDF flow depths were then measured taking into account this adjusted channel/overbank geometry. The resulting flood depths for selected dam breach scenario described above are shown in Table 3.15 through Table 3.19.

Table 3.15 Intermediate and Cross Valley Dam Rainy-day Cascading Failure Peak Flow Depths

Creek/River	Creek/River Chainage (m)	Estimated Channel Invert (m)	Natural IDF Flow		Natural IDF Flow + Breach Flow		Incremental Flood Depth (m)	Notes
			Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Water Level (m)		
Rose/Anvil Creek	0+000	1,029.4	271	1,034.7	17,771	1,050.8	16.1	Cross Valley Dam
	10+000	968.4	330	972.9	15,497	982.6	9.7	-
	20+000	876.4	660	883.5	13,805	895.2	11.7	-
	25+000	803.1	708	811.6	12,945	823.8	12.2	-
	30+000	774.8	723	782.4	12,280	793.8	11.4	-
	40+000	679.8	759	691.6	10,775	710.1	18.5	-
	50+000	620.4	799	622.5	9,356	627.1	4.6	See Note 2
Pelly River	61+000	601.9	6,980	621.6	15,538	627.6	6.0	See Note 2
	71+000	596.4	7,188	616.2	14,712	623.1	6.9	-
	81+000	586.7	7,417	604.7	13,937	608.9	4.3	-
	101+000	568.9	7,864	590.8	12,762	595.7	4.9	-
	121+000	551.9	8,301	570.9	11,980	573.0	2.1	-
	151+000	530.7	8,938	547.4	11,333	548.4	0.9	-
	161+000	523.0	9,146	542.8	11,222	543.8	1.0	-
	181+000	509.1	9,556	530.3	11,116	531.1	0.8	-
	200+000	496.0	9,959	517.0	11,130	517.6	0.6	Breach flow attenuated

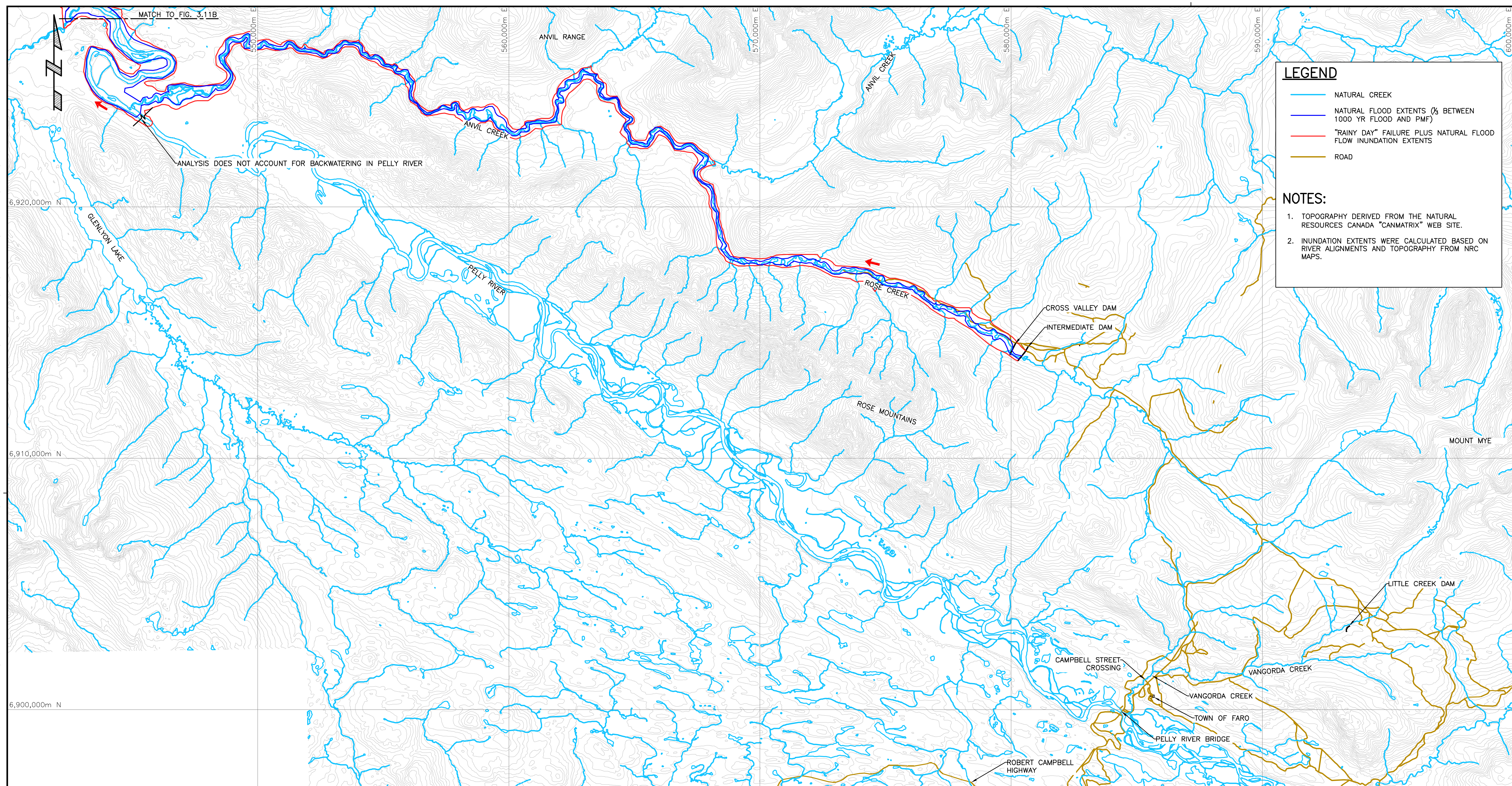
NOTES:
1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. Sta. 50+000 on Anvil Creek and Sta. 61+000 on Pelly River are not at the same location. Sta. 50+000 on Anvil Creek is upstream of the Anvil Creek/Pelly River confluence, and Sta. 61+000 on Pelly River is downstream of the confluence.

The results presented in Table 3.15 indicate that a cascading failure of the Intermediate Dam and the Cross Valley Dam would release significant flows into Rose Creek, Anvil Creek and Pelly River. These will result in very large increase of flow depths along the smaller and narrower Rose Creek and Anvil Creek channels. However, the flow-depth increase is expected to be dissipated relatively quickly in the larger Pelly River channel. The flood wave is expected to dissipate to negligible height approximately 140 km (Straight distance) downstream of the Town of Faro. As mentioned above, no infrastructure was identified within the flooded area. The estimated flood limits for the Intermediate and Cross Valley Dam rainy-day cascading failure are shown in Figure 3.11A, 3.11B and 3.11C. The extents of the natural IDF flood are also shown in the figures for comparison purposes.

Additional observations relating to the impact of a rainy-day cascading failure of the Intermediate and Cross Valley Dams are as follows:

- The Intermediate Dam retains tailings, supernatant, and run-off water on the upstream side and Polishing Pond water on the downstream side. As discussed above, the Cross Valley Dam impounds the Polishing Pond which stores seepage from the tailings storage facility and discharge from the Faro Water Treatment Plant. Although contaminant concentrations during a rainy-day failure might be diluted by the inflow of large volume of fresh water into the tailings pond as well as higher river flows, the quality of the water in downstream Rose and Anvil Creeks as well as Pelly River could potentially be affected by the release of stored tailings and water into the environment.

- Loss of life for recreational boaters, fisherman or hunters in the vicinity of the Rose and Anvil Creeks and Pelly River is a possibility. However, the probability of the presence of recreational users is reduced during extreme weather and flood events.



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CLIENT: YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT: FARO MINE REMEDIATION PROJECT
DAM BREACH AND INUNDATION STUDY

TITLE: INTERMEDIATE & CROSS VALLEY DAM
RAINY DAY CASCADING FAILURE
INUNDATION EXTENTS SHEET 1 OF 3

PROJECT No. M09770A02

FIG. No. 3.11A

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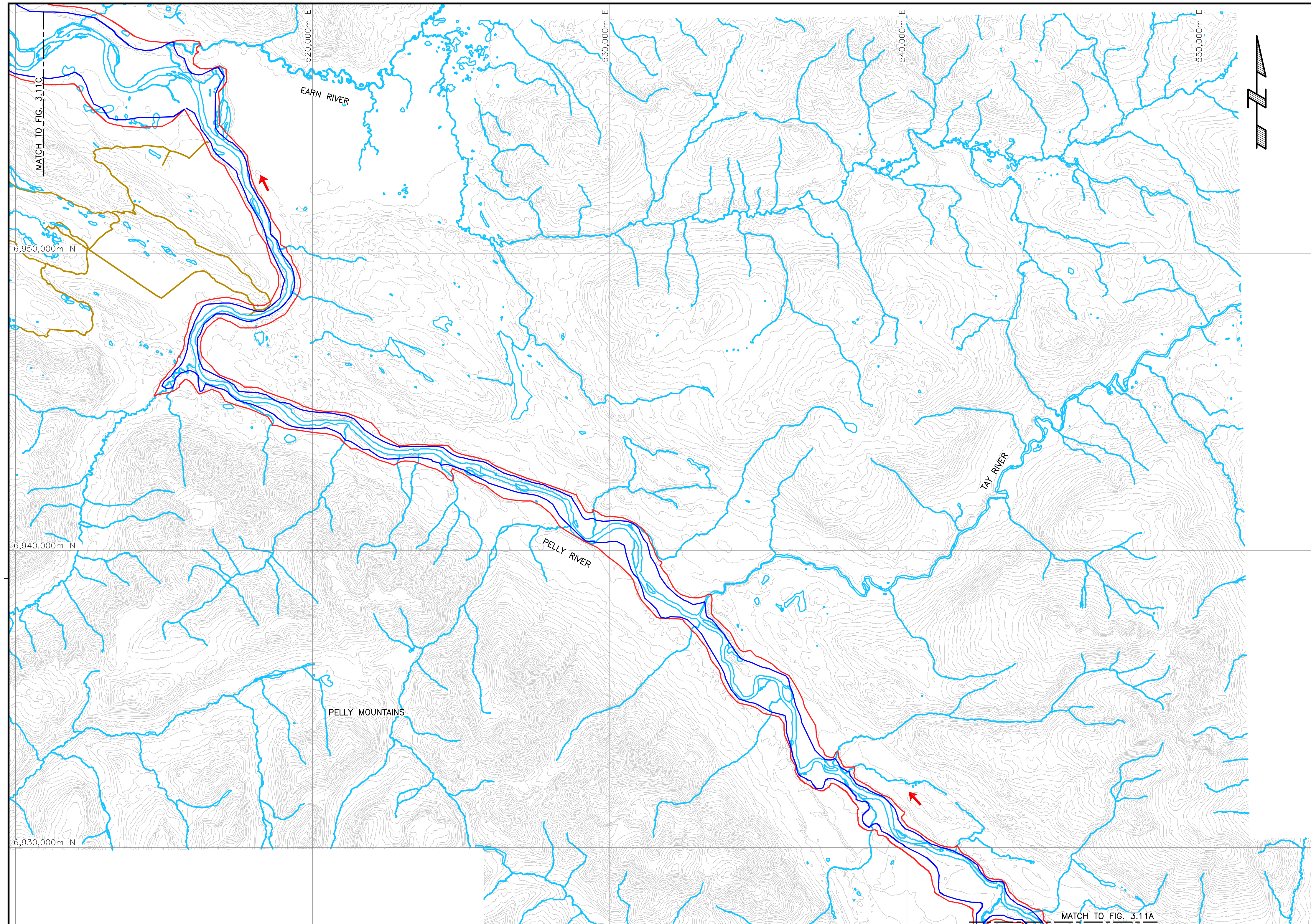
Drawing File: Z:\M\VCR\M09770A02 – Gov't Yukon-Faro Complex\400 Drawings\CAD\Dam Breach and Inundation Study\Fig 3.11 – Intermediate and Cross Valley Dam –Rainy Day Cascading Failure.dwg (persyem)



LEGEND

- NATURAL CREEK
- NATURAL FLOOD EXTENTS (½ BETWEEN 1000 YR FLOOD AND PMF)
- "RAINY DAY" FAILURE PLUS NATURAL FLOOD FLOW INUNDATION EXTENTS
- ROAD

NOTES:

1. TOPOGRAPHY DERIVED FROM THE NATURAL RESOURCES CANADA "CANMATRIX" WEB SITE.
2. INUNDATION EXTENTS WERE CALCULATED BASED ON RIVER ALIGNMENTS AND TOPOGRAPHY FROM NRC MAPS.

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TITLE: INTERMEDIATE & CROSS VALLEY DAM
RAINY DAY CASCADING FAILURE
INUNDATION EXTENTS SHEET 2 OF 3

PROJECT No. M09770A02

FIG. No. 3.11B

KCB-R-MLD

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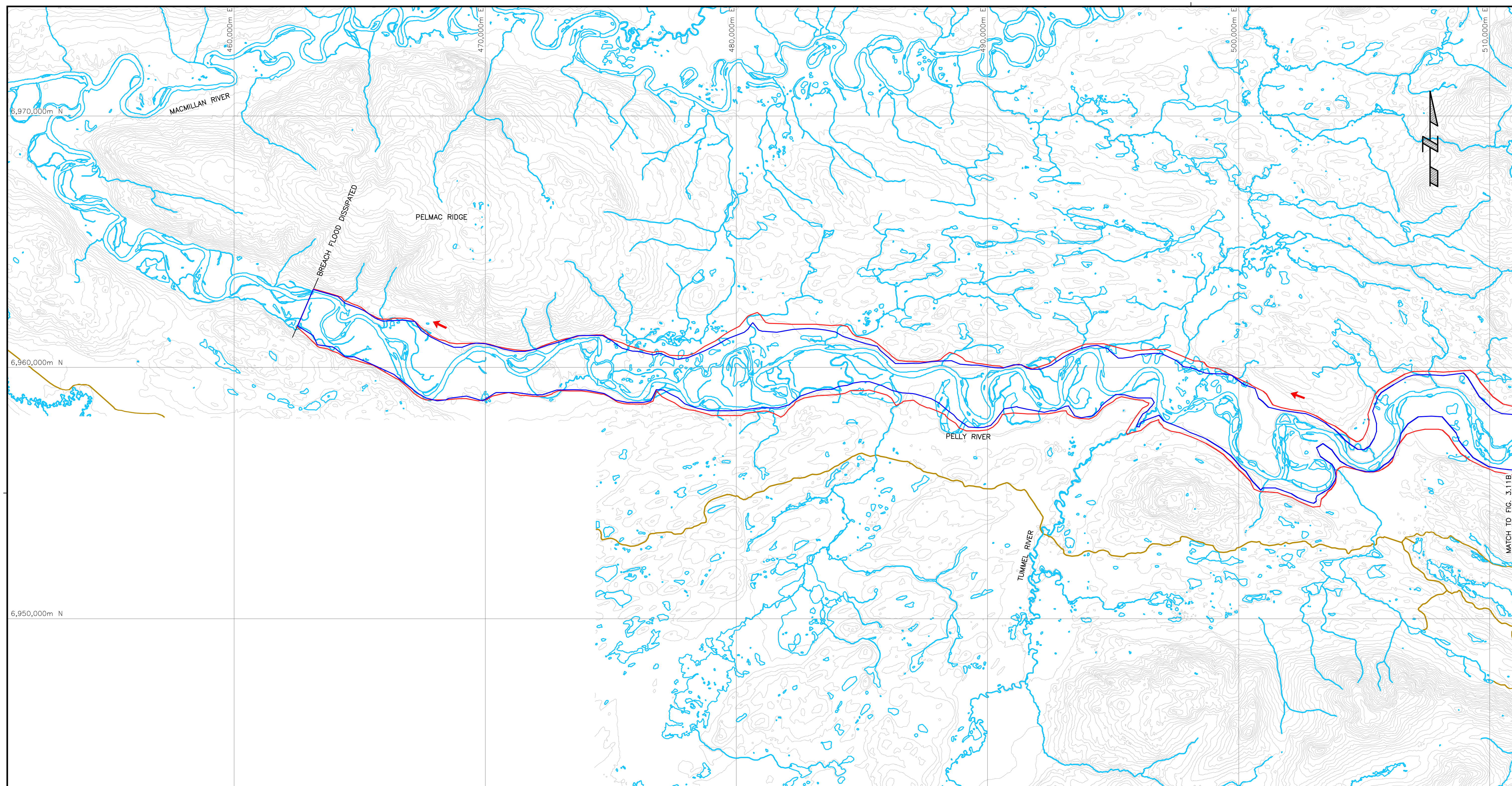

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LEGEND

- NATURAL CREEK
- NATURAL FLOOD EXTENTS (⅓ BETWEEN 1000 YR FLOOD AND PMF)
- "RAINY DAY" FAILURE PLUS NATURAL FLOOD FLOW INUNDATION EXTENTS
- ROAD

NOTES:

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CLIENT: YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT: FARO MINE REMEDIATION PROJECT DAM BREACH AND INUNDATION STUDY

TITLE: INTERMEDIATE & CROSS VALLEY DAM RAINY DAY CASCADING FAILURE INUNDATION EXTENTS SHEET 3 OF 3

PROJECT No. M09770A02

FIG. No. 3.11C

KCB-R-MLD

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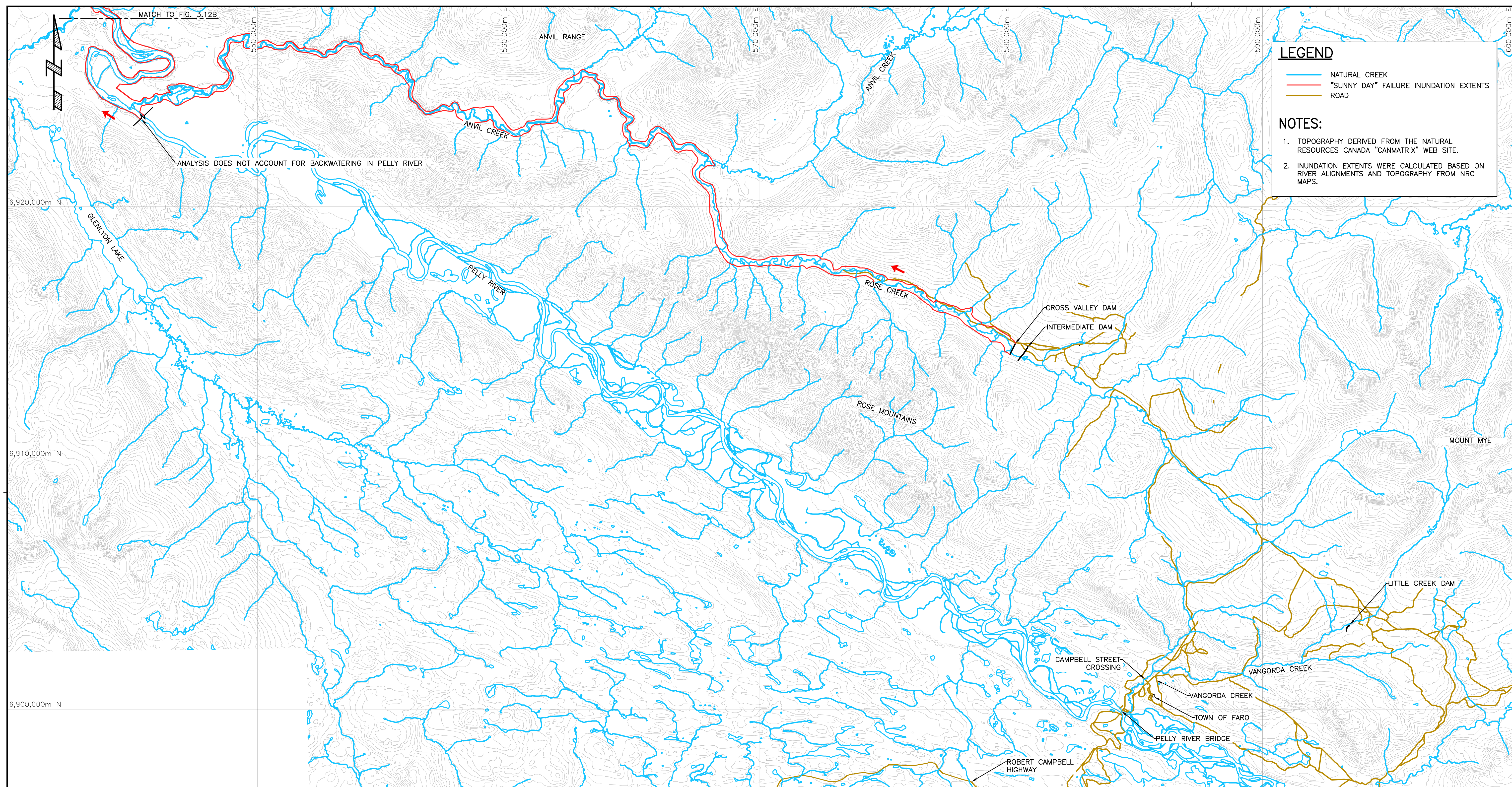
Table 3.16 Cross Valley Dam Sunny-day Failure Peak Flow Depths

Creek/River	Creek/River Chainage (m)	Estimated Channel Invert (m)	Max. Annual Flow		Max. Annual Flow + Dam Breach Flow		Incremental Flood Depth (m)	Notes
			Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Water Level (m)		
Rose/Anvil Creek	0+000	1,029.4	42	1,031.4	5,042	1,042.7	11.3	Cross Valley Dam
	10+000	968.4	52	970.4	4,385	977.5	7.1	-
	20+000	876.4	105	879.0	3,861	888.5	9.5	-
	25+000	803.1	113	806.4	3,609	816.9	10.5	-
	30+000	774.8	115	777.4	3,417	787.3	9.9	-
	40+000	679.8	121	683.8	2,983	699.0	15.2	-
	50+000	620.4	128	622.0	2,573	624.2	2.2	See Note 2
Pelly River	61+000	601.9	1,170	609.1	3,615	617.7	8.6	See Note 2
	71+000	596.4	1,205	601.1	3,355	609.5	8.4	-
	81+000	586.7	1,244	592.4	3,107	600.3	7.9	-
	101+000	568.9	1,321	575.3	2,721	582.7	7.4	-
	121+000	551.9	1,396	559.3	2,447	565.5	6.2	-
	151+000	530.7	1,506	538.6	2,190	543.2	4.6	-
	161+000	523.0	1,541	531.9	2,135	538.2	6.3	-
	181+000	509.1	1,612	518.3	2,058	523.8	5.5	-
	200+000	496.0	1,681	505.4	2,016	510.6	5.2	Breach flow attenuated

NOTES:
1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. Sta. 50+000 on Anvil Creek and Sta. 61+000 on Pelly River are not at the same location. Sta. 50+000 on Anvil Creek is upstream of the Anvil Creek/Pelly River confluence, and Sta. 61+000 on Pelly River is downstream of the confluence.

Although the incremental flood depths for the Cross Valley Dam sunny-day failure shown in Table 3.16 are significant, no infrastructure has been identified within the flood route of the Cross Valley Dam. The flood is considered to be dissipated approximately 140 km (straight distance) downstream of the Town of Faro. The estimated flood limits for the Cross Valley Dam sunny-day failure are shown in Figure 3.12A, 3.12B and 3.12C.



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DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
SUNNY DAY FAILURE
INUNDATION EXTENTS SHEET 1 OF 3

PROJECT No. M09770A02

FIG. No. 3.12A

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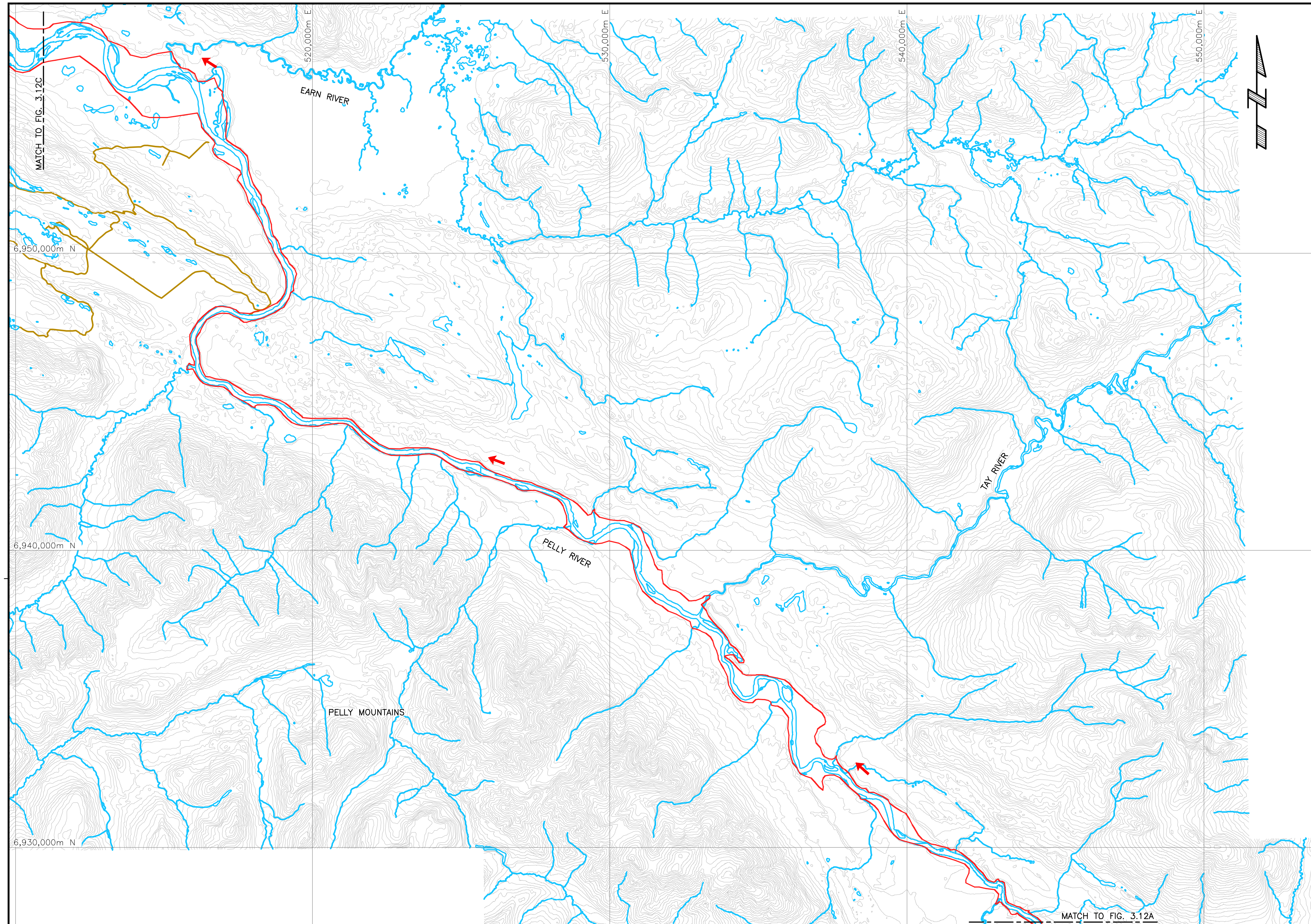

LEGEND

- NATURAL CREEK
- "SUNNY DAY" FAILURE INUNDATION EXTENTS
- ROAD

NOTES:

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DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
SUNNY DAY FAILURE
INUNDATION EXTENTS SHEET 2 OF 3

PROJECT No. M09770A02

FIG. No. 3.12B

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LEGEND

- NATURAL CREEK
- "SUNNY DAY" FAILURE INUNDATION EXTENTS
- ROAD

NOTES:

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DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
SUNNY DAY FAILURE
INUNDATION EXTENTS SHEET 3 OF 3

PROJECT No.	FIG. No.
M09770A02	3.12C

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Table 3.17 Cross Valley Dam Rainy-day Failure Peak Flow Depths

Creek/River	Creek/River Chainage (m)	Estimated Channel Invert (m)	Natural IDF Flow		Natural IDF Flow + Breach Flow		Incremental Flood Depth (m)	Notes
			Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Water Level (m)		
Rose/Anvil Creek	0+000	1,029.4	271	1,034.7	4,771	1,042.5	7.8	Cross Valley Dam
	10+000	968.4	330	972.9	4,230	977.4	4.5	-
	20+000	876.4	660	883.5	4,040	888.7	5.2	-
	25+000	803.1	708	811.6	3,855	817.2	5.6	-
	30+000	774.8	723	782.4	3,695	787.7	5.3	-
	40+000	679.8	759	691.6	3,335	699.8	8.2	-
	50+000	620.4	799	622.5	2,999	624.5	2.0	See Note 2
Pelly River	61+000	601.9	6,980	621.6	9,181	623.4	1.8	See Note 2
	71+000	596.4	7,188	616.2	9,123	618.4	2.2	-
	81+000	586.7	7,417	604.7	9,093	606.0	1.3	-
	101+000	568.9	7,864	590.8	9,124	592.2	1.4	-
	121+000	551.9	8,301	570.9	9,247	571.5	0.6	Breach flow attenuated at 125+000
	151+000	530.7	8,938	547.4	9,554	547.7	0.3	

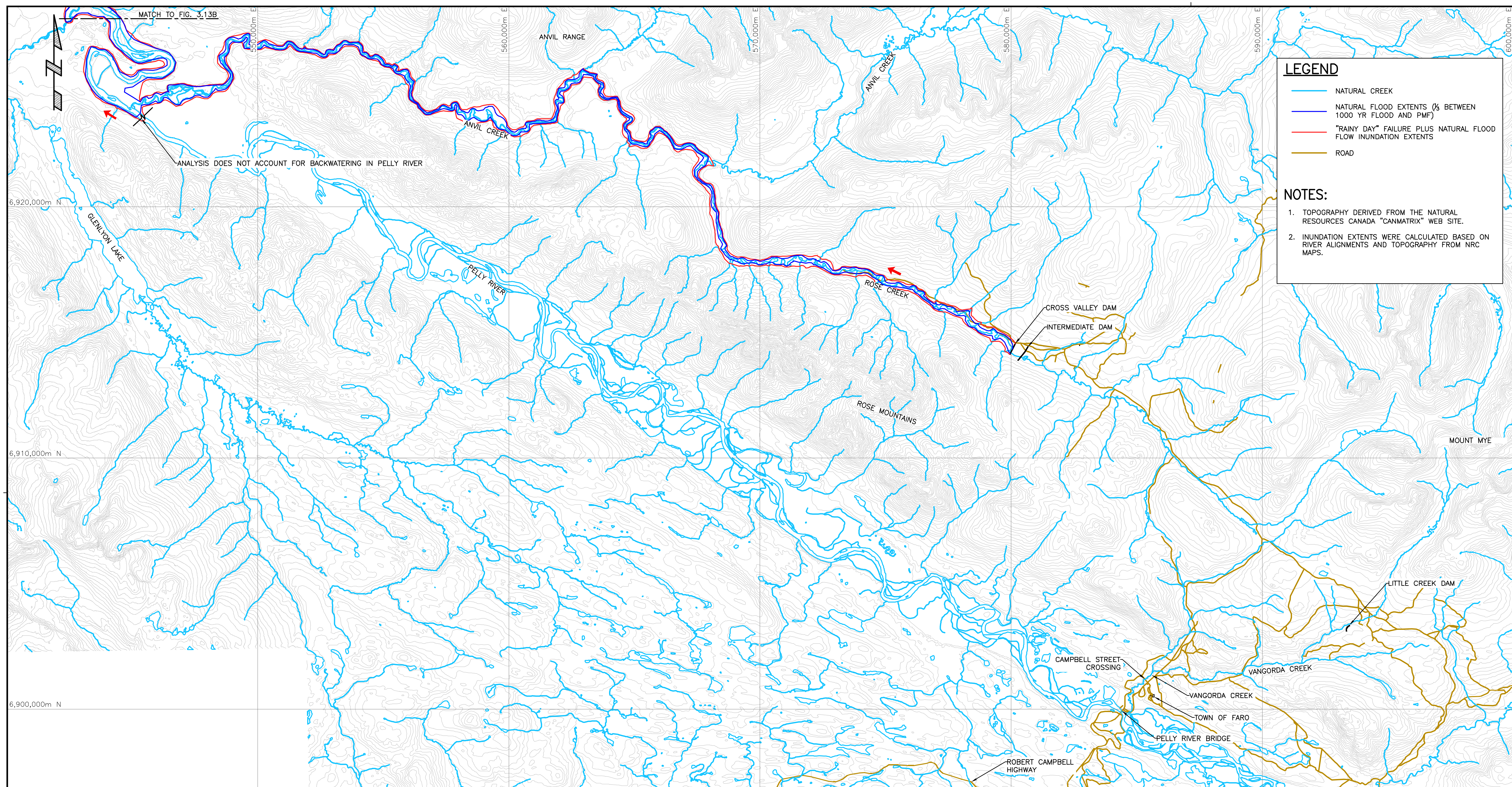
NOTES:
1. Chainages shown are measured along the river channel, and are not straight distances between points.
2. Sta. 50+000 on Anvil Creek and Sta. 61+000 on Pelly River are not at the same location. Sta. 50+000 on Anvil Creek is upstream of the Anvil Creek/Pelly River confluence, and Sta. 61+000 on Pelly River is downstream of the confluence.

The incremental flow depths shown in Table 3.17 for the Cross Valley Dam rainy-day failure are much lower than those for the sunny-day failure, due to the magnitude of the flows already present in the creeks and river during the natural IDF event. The flood wave is considered to be dissipated approximately 105 km (straight distance) downstream of the Town of Faro, and no infrastructure has been identified in the flooded area. The estimated flood limits for the Cross Valley Dam rainy-day failure are shown along with the extents of the natural IDF flood in Figure 3.13A, Figure 3.13B and Figure 3.13C.

Additional observations relating to the impact of a sunny-day and rainy-day failure of the Cross Valley Dam are as follows:

- The Cross Valley Dam impounds the Polishing Pond at the downstream limit of the Rose Creek Tailings Facility. The Polishing Pond is designed for the 60 day retention capacity for seepage from the tailings storage facility and discharge from the Faro Water Treatment Plant. Water in the Polishing Pond may not have gone through required residence time, and the pond bottom may contain sediments deposited from polishing process. The quality of the water in Rose and Anvil Creeks as well as Pelly River could potentially be affected by the release of water stored in the Polishing Pond. During a rainy-day failure the water quality impact is expected to be less than that due to a sunny-day failure because of the dilution effect of higher flow in the river.

- With the exception of mine access roads immediately downstream of the Cross Valley Dam, no roads, bridges or other infrastructure have been identified along Rose or Anvil Creeks, or Pelly River within the flooded areas. However, loss of life for recreational boaters, fisherman or hunters in the vicinity of the river is a possibility. This is considerably less likely during a rainy-day flood event than a sunny-day flood event. The high breach flood depths along Anvil Creek could also displace trees and other vegetation and debris.



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DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
RAINY DAY FAILURE
INUNDATION EXTENTS SHEET 1 OF 3

PROJECT No. M09770A02

FIG. No. 3.13A

KCB-R-MLD

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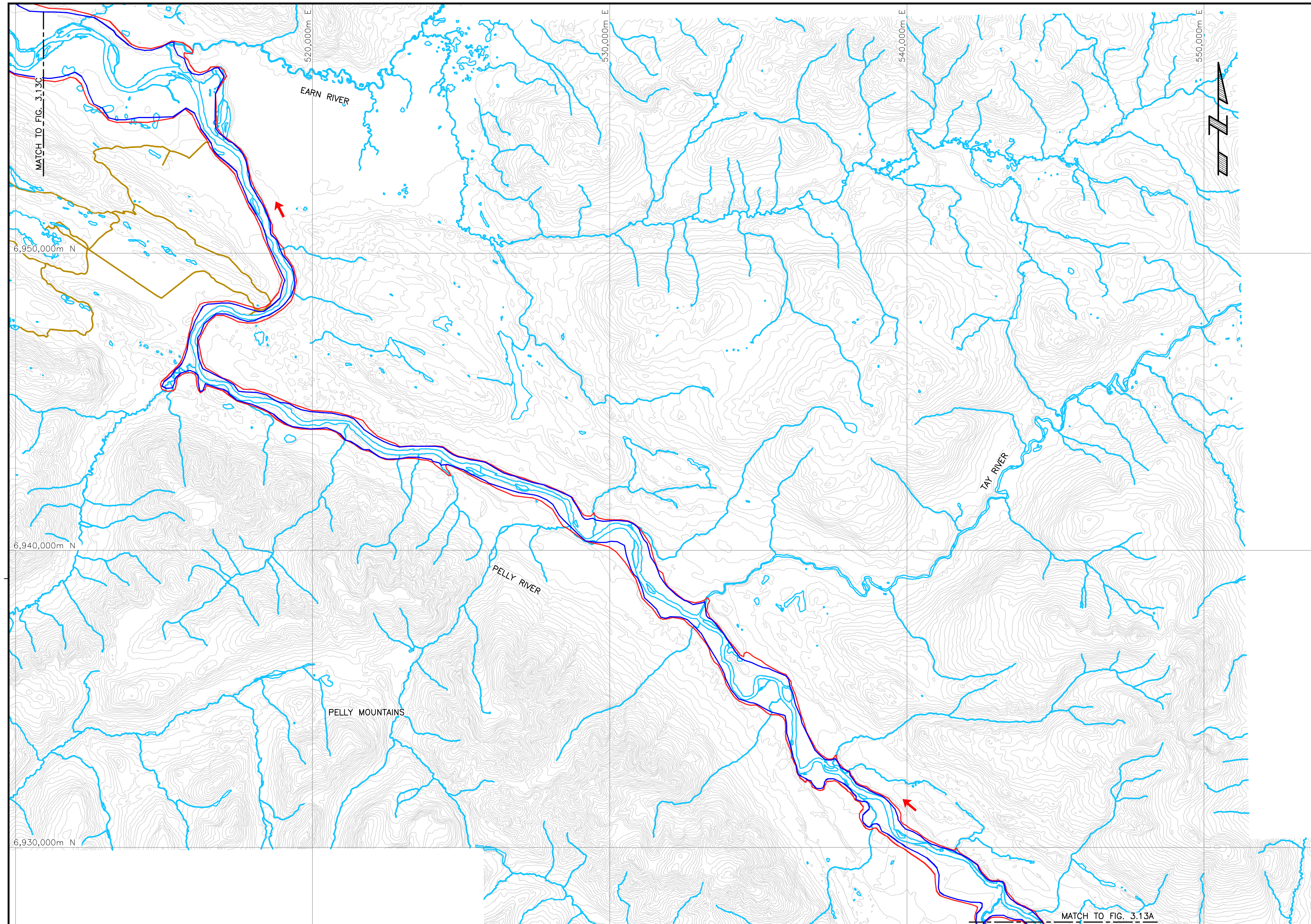

LEGEND

- NATURAL CREEK
- NATURAL FLOOD EXTENTS (⅓ BETWEEN 1000 YR FLOOD AND PMF)
- "RAINY DAY" FAILURE PLUS NATURAL FLOOD FLOW INUNDATION EXTENTS
- ROAD

NOTES:

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TITLE: CROSS VALLEY DAM
RAINY DAY FAILURE
INUNDATION EXTENTS SHEET 2 OF 3

PROJECT No. M09770A02

FIG. No. 3.13B

KCB-R-MLD

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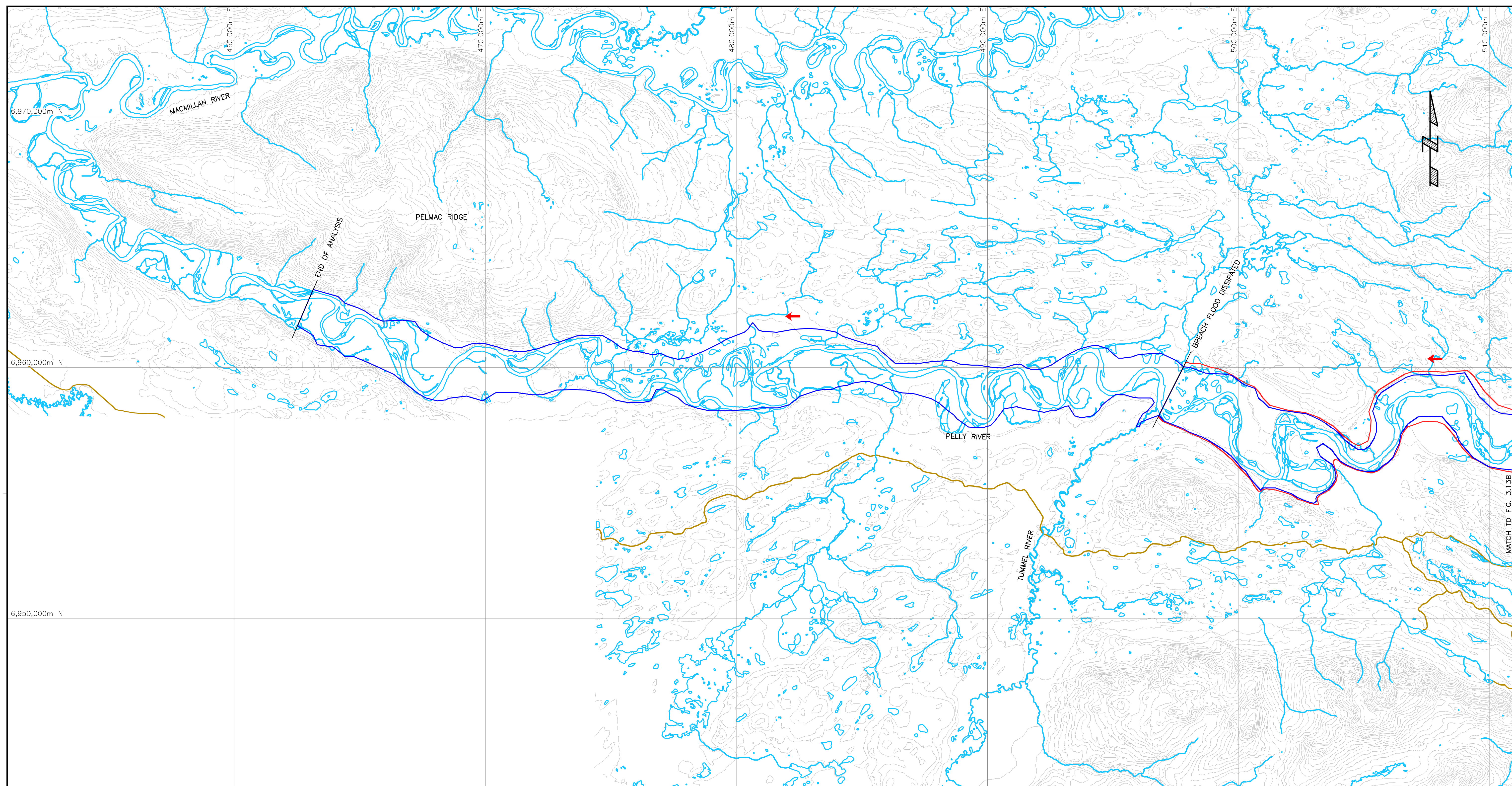

LEGEND

- NATURAL CREEK
- NATURAL FLOOD EXTENTS (½ BETWEEN 1000 YR FLOOD AND PMF)
- "RAINY DAY" FAILURE PLUS NATURAL FLOOD FLOW INUNDATION EXTENTS
- ROAD

NOTES:

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DAM BREACH AND INUNDATION STUDY

TITLE: CROSS VALLEY DAM
RAINY DAY FAILURE
INUNDATION EXTENTS SHEET 3 OF 3

PROJECT No. M09770A02

FIG. No. 3.13C

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The results of the Little Creek Dam sunny-day and rainy-day failures are summarized in Table 3.18 and Table 3.19, respectively. The following observations are made based on the results of the sunny-day failure:

- The breach flood might overtop the road crossing at Campbell Street at the Town of Faro resulting in potential washout of the road, as the capacity of the culverts under the street (10 m^3/s to 40 m^3/s) is insignificant compared to the breach flow (1250 m^3/s), and the culverts are likely to be either fully or partially blocked with debris during a breach event.
- The Campbell Street embankment over the culverts is approximately 6 m to 8 m high. A rough estimate of available water storage capacity upstream of the embankment based on the available topography indicates that it is approximately the same volume as the amount of water released from the Little Creek Dam. Therefore, it is possible that the breached flood volume from the Little Creek Dam during a sunny-day event may not, in fact, overtop the road. Detailed topography would be required to confirm the likelihood of a washout of the road embankment.
- The flood depth at the Vangorda Bridge is approximately 6.9 m above the natural water level, which is expected to overtop and possibly wash out the bridge and the sewer line, located approximately 3.2 m above the creek level.
- The flood depth at the Pelly River Bridge crossing is less than 1 m higher than the natural flood level. It is therefore unlikely that the bridge will overtop, or suffer any serious damage.
- The breach flow is attenuated in Pelly River before the confluence with Anvil Creek. No other infrastructure has been identified within the extent of the flood path.
- The Little Creek Dam is a water retaining structure, and contains seepage and runoff from the Vangorda waste rock dump. The contact water is pumped from the retention pond to the Vangorda water treatment plant prior to release. The quality of the water in Vangorda Creek and Pelly River could potentially be affected by the release of this water into the environment.
- Local roads and bridges located along Vangorda Creek, in addition to the crossing at Campbell Street in Faro, are located within the flood zone of the Little Creek Dam and could be washed out. Loss of life for travelers on the roads is a possibility. Washout of the Campbell Street crossing could restrict access for emergency vehicles or evacuation routes. Existing buildings in the Town of Faro are not expected to be inundated by the flood.

Table 3.18 Little Creek Dam Sunny-day Failure Peak Flow Depths

Creek/River	Creek/River Chainage (m)	Estimated Channel Invert (m)	Max. Annual Flow		Max. Annual Flow + Dam Breach Flow		Incremental Flood Depth (m)	Comments
			Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Water Level (m)		
Vangorda Creek	0+000	1,066.3	7.7	1,067.1	1,408	1,073.5	6.4	Little Creek Dam
	1+000	996.0	9.8	997.0	1,390	1,004.9	7.9	-
	2+000	943.7	11.7	945.1	1,372	953.7	8.6	-
	3+000	912.6	13.5	914.6	1,355	922.5	7.9	-
	4+000	897.5	15.0	899.4	1,337	906.7	7.3	Local road at 4+500 washed out
	5+000	876.3	16.5	878.0	1,320	884.0	6.0	-
	6+000	842.7	17.9	844.5	1,303	850.3	5.8	-
	7+000	809.4	19.3	811.0	1,286	817.1	6.1	Local road washed out
	8+000	757.5	20.6	759.1	1,269	764.2	5.1	Foot bridge on Vangorda Falls trail washed out
	9+000	696.1	21.9	698.2	1,253	704.9	6.7	-
	9+500	689.1	22.0	692.1	1,251	703.1	11.0	Campbell St. crossing over-topped*
	10+000	664.9	22.6	667.7	1,245	674.2	9.3	-
	12+000	637.8	23.6	640.2	1,203	644.7	6.9	Vangorda Creek Bridge and Sewer Line Crossing overtopped
Pelly River	0+000	637.6	1,117	640.2	1,701	641.1	0.9	Pelly River Bridge
	10+000	631.6	1,119	634.2	1,626	635.7	1.4	-
	20+000	625.5	1,122	628.2	1,561	630.5	2.3	-
	30+000	618.5	1,124	622.2	1,510	623.5	1.3	-
	40+000	613.9	1,127	616.2	1,461	616.9	0.7	-
	50+000	607.9	1,130	610.2	1,416	610.8	0.6	Breach flow attenuated

Chainages shown are measured along the river channel, and are not straight distances between points.
*Assumes Campbell St. culvert in Town of Faro are blocked and there is limited flood storage capacity in the channel upstream of the culverts.

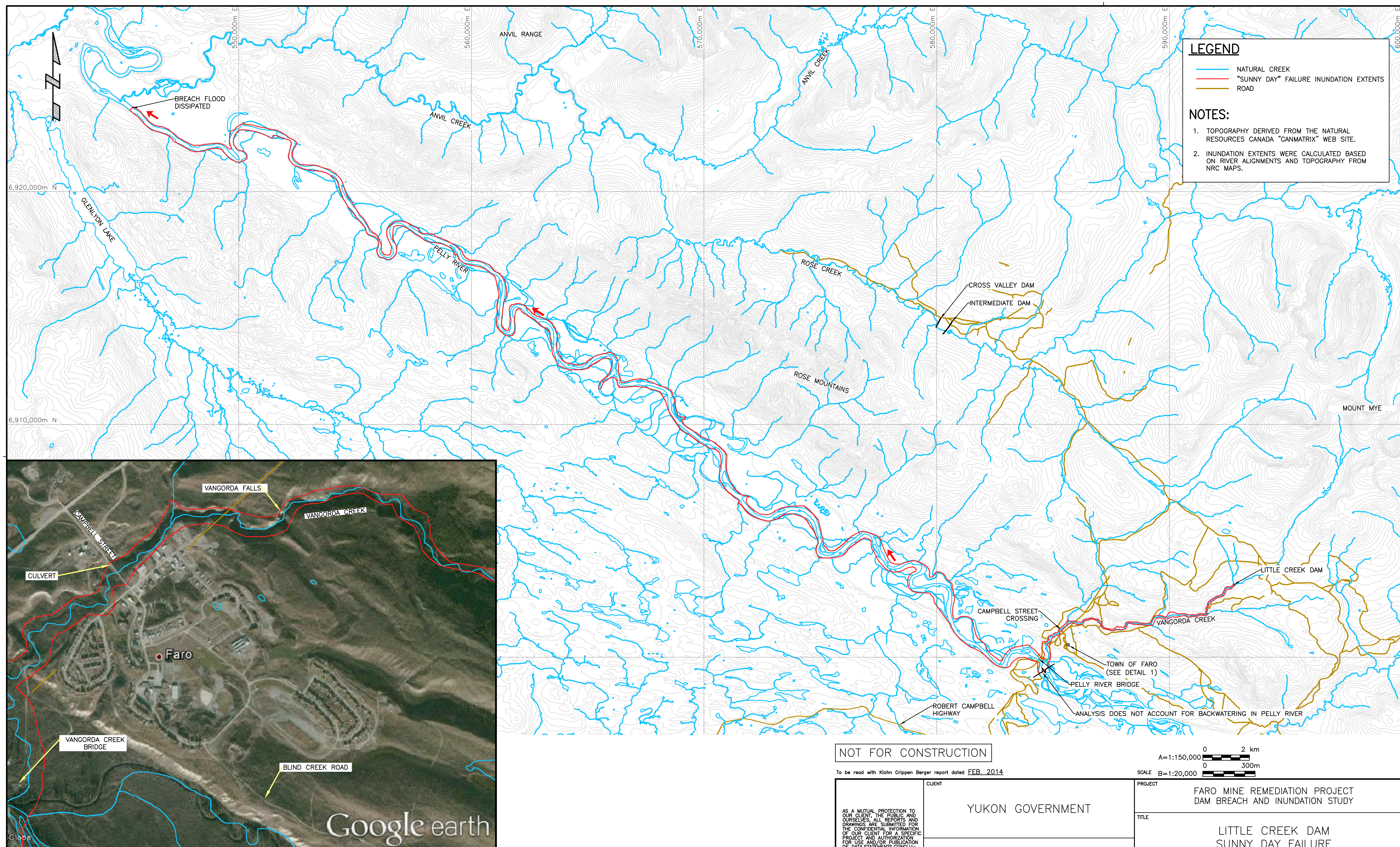
Table 3.19 Little Creek Dam Rainy-day Failure Peak Flow Depths

Creek/River	Creek/River Chainage (m)	Estimated Channel Invert (m)	Natural IDF Flow		Natural IDF Flow + Dam Breach Flow		Incremental Flood Depth (m)	Comments
			Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Water Level (m)		
Vangorda Creek	0+000	1,066.3	50	1068.6	1750	1074.1	5.5	Little Creek Dam
	1+000	996.0	65	999.0	1785	1005.8	6.7	-
	2+000	943.7	75	947.5	1815	954.7	7.2	-
	3+000	912.6	90	917.2	1720	923.3	6.1	-
	4+000	897.5	100	901.9	1710	907.5	5.6	Local road at 4+500 washed out
	5+000	876.3	105	880.1	1685	884.5	4.4	-
	6+000	842.7	115	846.6	1675	850.9	4.2	-
	7+000	809.4	120	813.3	1660	817.8	4.5	Local road washed out
	8+000	757.5	130	761.1	1640	764.9	3.7	Foot bridge on Vangorda Falls trail washed out
	9+000	696.1	135	700.8	1625	705.6	4.8	-
	9+500	689.1	140	700.7	1620	703.7	3.0	Campbell St. crossing over-topped*
	10+000	664.9	145	670.4	1555	674.8	4.5	-
	12+000	637.8	160	642.2	1590	645.2	3.0	Vangorda Creek Bridge and Sewer Line Crossing overtopped
Pelly River	0+000	637.6	6670	644.2	7380	644.5	0.3	Breach flow attenuated in Pelly River
	10+000	631.6	6680	639.3	7320	639.6	0.3	-
	20+000	625.5	6700	635.1	7280	635.5	0.4	-
	30+000	618.5	6710	626.0	7220	626.1	0.1	-
	40+000	613.9	6730	620.0	7170	620.1	0.1	-
	50+000	607.9	6740	614.2	7040	614.3	0.1	-

Chainages shown are measured along the river channel, and are not straight distances between points.
*Assumes Campbell St. culvert in Town of Faro are blocked and there is limited flood storage capacity in the channel upstream of the culverts.

A comparison of the results presented in Table 3.19 with those in Table 3.18 indicate that, although the flood water levels for the rainy-day failure are higher than those for the sunny-day failure, the incremental increase in flood depths are lower for the rainy-day failure. This is because the Vangorda Creek and Pelly River are assumed to be at the natural flood stage for the rainy-day failure. The tables also indicate that the dam breach flood for the rainy-day failure is attenuated sooner than that for the sunny-day failure. Other observations presented above for the sunny-day failure apply to the rainy-day failure as well.

The estimated flood limits for the Little Creek Dam sunny-day failure are shown in Figure 3.14. As it can be seen from Table 3.18 and Table 3.19, there is very little difference in maximum flood levels between the sunny-day failure and the rainy-day failure along Vangorda Creek where the majority of the impacts due to a dam failure are expected. Since the resolution of the available topographic data (30 m contours) is not fine enough to distinguish between the flood levels for the two failure scenarios, Figure 3.14 could also represent the rainy-day scenario for the current study.



DETAIL 1 TOWN OF FARO
SCALE B

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated FEB. 2014

A=1:150,000 0 2 km
B=1:20,000 0 300m
SCALE

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CLIENT
YUKON GOVERNMENT

Klohn Crippen Berger

PROJECT
FARO MINE REMEDIATION PROJECT
DAM BREACH AND INUNDATION STUDY

TITLE
LITTLE CREEK DAM
SUNNY DAY FAILURE
INUNDATION EXTENTS

PROJECT No. M09770A02
FIG. No. 3.14

KCB-R-MLD

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Drawing File: \\int.klohn.com\ProjData\M\VCR\M09770A02 – Gov't Yukon-Faro Complex\400 Drawings\CAD\Dam Breach and Inundation Study\Fig 3.14 – Little Creek Dam – Sunny Day Failure.dwg (persyem)

4 DAM CLASSIFICATION

This section presents our recommended consequence classification based on CDA (2007) guidelines for each of the dams reviewed in this study. Table 4.1 outlines the CDA (2007) dam consequence classification system.

Table 4.1 CDA (2007) Dam Consequence Classification System

Dam Class	Population at Risk (note 1)	Incremental Losses		
		Loss of Life (note 2)	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
Very High	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

Note 1. Definitions for population at risk:

None - There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary - People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent - The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (High, Very High, Extreme) are proposed to allow for more detailed estimates of potential loss of life (lo assist in decision-making if the appropriate analysis is carried out).

Note 2. Implications for loss of life:

Unspecified - The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions- A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Based on the CDA guidelines, the results of the dam inundation study presented herein indicate the classification for the Intermediate Dam, the Cross Valley Dam, and the Little Creek Dam as shown in Table 4.2.

Table 4.2 Recommended Dam Consequence Classification for Reviewed Dams

Dam	Current Dam Safety Classification	Recommended Dam Safety Classification	Justification for Recommended Dam Safety Classification
Little Creek Dam	Low	Significant or High	Potential damage or washout of Campbell Street crossing and Vangorda Creek bridge; Potential for loss of life due to washout of crossings such as Campbell Street, Vangorda Creek bridge, and foot bridge on Vangorda Falls hiking trail; and Potential release of non-compliant water to Vangorda Creek and Pelly River.
Cross Valley Dam	High	High	Potential for loss of life likely restricted to seasonal recreational users; and Potential release of non-compliant water to Rose and Anvil Creeks and Pelly River.
Intermediate Dam	High	High	Potential for loss of life likely restricted to seasonal recreational users; and Potential release of tailings and non-compliant water to Rose and Anvil Creeks and Pelly River.

5 CONCLUSIONS AND RECOMMENDATIONS

Our conclusions based on the preliminary dam breach and inundation analyses for the three reviewed dams are as follows:

- The dam breach and inundation analysis presented herein was carried out at a preliminary level, using empirical charts and formulas based on dam-failure case histories. The purpose of this study was to determine potential major consequences of a failure of the dams to their downstream areas and to confirm the hazard classification for each dam. The National Topographic Series map, with 100 ft (30 m) contours, was the best available topography at the time the study was undertaken. While topography with such large contour intervals is not ideal for flood inundation mapping, it was considered adequate for meeting the objectives of the study. The accuracy of the analysis and the inundation maps produced is limited by the accuracy of the data used as inputs to the analysis, and this limitation should be kept in mind when using the results of this study.
- Failures of the Cross Valley Dam under sunny-day or rainy-day conditions, and cascading failure of the Intermediate Dam and Cross Valley Dam under rainy-day conditions would result in significant flooding along Rose and Anvil Creeks, as well as Pelly River. This failure could result in potential water quality impacts to the downstream watercourses for wildlife and fish, as well as potential loss of life to recreational users of the creeks or river. No infrastructure has been identified along the flood route between the dams and the downstream flood impact limits. The current dam safety classification of High is considered to be appropriate for both dams and, in our opinion, no further dam break and inundation studies are required.
- A failure of the Little Creek Dam may result in potential damage and/or loss of life in the Town of Faro due to potential washout of:
  - the foot bridge on the Vangorda Falls hiking trail;
  - the Campbell Street road embankment across Vangorda Creek - Campbell Street is the main road into the town; and
  - the Vangorda Creek bridge located south of the town.
- The washout of the foot bridge on the Vangorda Falls trail, the Campbell Street embankment and/or the Vangorda Creek bridge might cause loss of life if someone was present in the area at the time the flood wave passes through. The washout of the Campbell Street embankment would also result in the loss of main access into the town. For this reason, a reclassification of the Little Creek Dam is recommended from Low to Significant or High consequence category based on the 2007 Dam Safety Guidelines (CDA 2007). Further study on the likelihood of road and bridge failure will be required to confirm the classification of Significant or High.

We recommend that a more detailed dam break and inundation study be carried out for the Little Creek Dam, in order to develop a more accurate downstream inundation map, particularly in the vicinity of the Town of Faro. The detailed study should include hydrodynamic modelling of the dam breach and routing of the resulting flood along the streams downstream of the dam. Detailed digital topographic maps, with appropriate contour intervals, will be required for this study. In addition to more accurately defining the downstream impacts, the detailed study would also enhance the Emergency Preparedness and Response (EPR) plan for the dam by providing:

- a better understanding of the likelihood of washout of the Campbell Street road embankment across Vangorda Creek;
- a better understanding of the time required to breach the dam to partial or full failure;
- the flood travel time and flood duration; and,
- more refined flood limits for the purposes of notification and evacuation of downstream areas within the potential flood zone.

Klohn Crippen Berger is currently updating the Emergency Response Plan (ERP) for dams and water diversion structures at the mine site, including the Intermediate Dam, the Cross Valley Dam and the Little Creek Dam. The results of this dam break and inundation study have been incorporated into the ERP. The ERP should be updated if a detailed dam break and inundation analysis for the Little Creek Dam is completed.

The estimates of 1,000 year flows, the PMF and the IDF presented in this report are rough estimates only. The estimates are used for the purpose of ascertaining approximate incremental impacts of dam breaches. These estimates should not be used for any other purpose such as design of drainage works, flood routing and/or sizing of spillways for any of the dams.

The dam breach and inundation analyses are based on hypothetical modes of failure. Therefore the results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dams.

KLOHN CRIPPEN BERGER LTD.

Michael Dabiri, P.Eng. (BC)
Water Resources Engineer

Arvind Dalpatram, P.Eng. (BC)
Senior Water Resources Engineer

PROFESSIONAL ENGINEER YUKON TERRITORY ROBERT C. LO

Robert C. Lo February 28, 2014

Robert C. Lo, P.Eng. (YT)
Project Manager

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