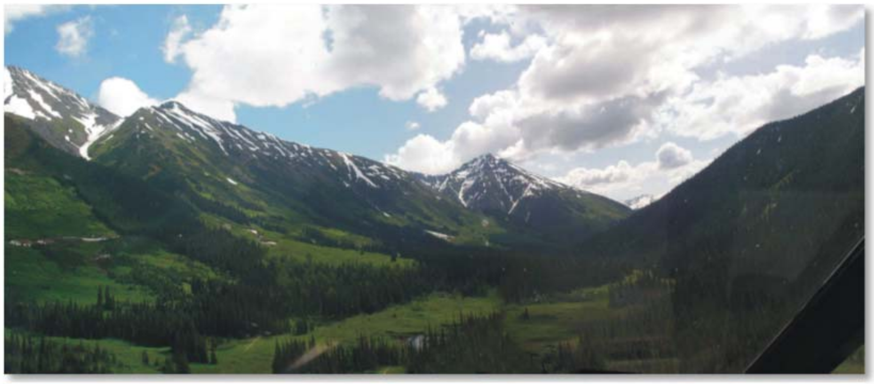
APPENDIX 35-C

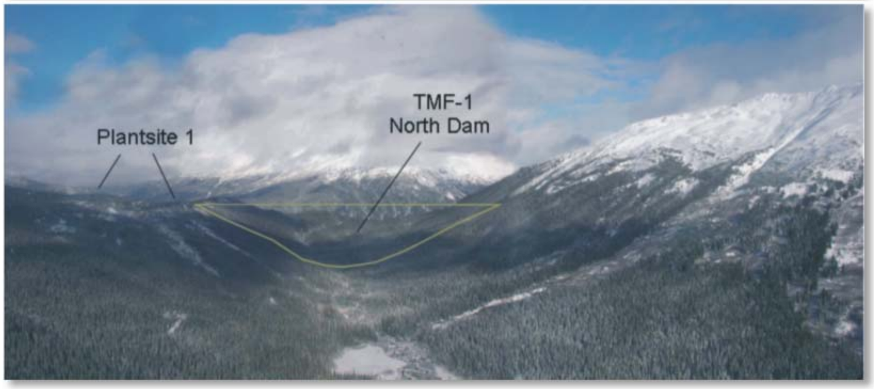
DAM BREAK AND INUNDATION STUDY FOR TAILING MANAGEMENT FACILITY

Klohn Crippen Berger

Seabridge Gold Inc.

KSM Project





Dam Break and Inundation Study for Tailings Management Facility

October 2012
M09480A04.730

ISO 9001:2008
Certificate No. FS 62747

Klohn Crippen Berger

October 15, 2012

Seabridge Gold Inc.
106 Front Street East, Suite 400
Toronto, Ontario
M5A 1E1

Brent Murphy
V.P. Environmental Affairs

Dear Mr. Murphy:

KSM Project
Dam Break and Inundation Study for Tailings Management Facility

We are pleased to submit our Final Report on the dam break and inundation study for the proposed Tailings Management Facility at the KSM Project.

Yours truly,
KLOHN CRIPPEN BERGER LTD.

Graham Parkinson, P.Geo., P.Geoph.
Project Manager

AD/SS/JGP:tc/jc

Seabridge Gold Inc.

KSM Project

Dam Break and Inundation Study for Tailings Management Facility

Klohn Crippen Berger

October 2012

EXECUTIVE SUMMARY

The purpose of this Dam Break and Inundation Study is to assess the consequences of hypothetical dam failure modes for the proposed Tailings Management Facility (TMF), at the KSM Project in British Columbia, as recommended in the Canadian Dam Association (CDA) Dam Safety Guidelines. The purpose of the dam break assessments is to guide the selection of dam safety design criteria.

The method consisted of dam breach and inundation analyses wherein a dam is assumed to fail due to: 1) an overtopping failure due to an extreme flood; or 2) a “sunny- day” failure where the dam fails due to piping. The resulting discharge is routed along the streams and rivers downstream of the dam using a hydrodynamic model.

The proposed TMF is located on the divide between Teigen Creek and Treaty Creek catchments, and would ultimately be formed with four dams impounding three cells: North Cell, South Cell and the interior lined CIL Cell. The North Dam and a Splitter Dam would impound the North Cell during the first phase (Years 0 to 29). The Southeast Dam and the Saddle Dam would impound the South Cell during the second phase (Years 30 to 53). The Saddle Dam and Splitter Dam would impound the CIL Cell, located centrally between the North and South Cells; This Cell would be operational from Year 0 through Year 53.

A failure of the Splitter Dam would have no external consequences as the Saddle and North Dam would further contain the tailings. A failure of the Saddle Dam during the first phase would release CIL tailings. A failure of the Saddle Dam during the second phase would not release CIL tailings as the Southeast Dam would retain the tailings. A failure of either the North or Southeast Dam at any phase would release only non-sulphide bearing flotation tailings solids and water into downstream waters.

Failure of either the North Dam or Southeast Dam would result in a larger flood than a failure of the Saddle dam as the North and South Cells have the potential to contain more water than the CIL cell.

This report assesses both the volume of water released in potential failures and the volume and distribution of any tailings releases.

The flood route downstream of the North Dam consists of the following: 12 km along Teigen Creek; 5 km east along Snowbank Creek; 81 km southeast along the Bell Irving River; and 200 km along Nass River. The Nass River discharges into Portland Inlet on the Pacific Ocean. The flood route downstream of the Southeast Dam consists of the following: approximately 2 km along a local stream which discharges into Treaty Creek; about 18 km along Treaty Creek up to the Bell Irving River; about 60 km along the Bell Irving River; and 200 km along Nass River to its mouth.

The area downstream of the North Dam, up to the Nass River is relatively undeveloped. Bell 2 Lodge is located on the south bank of the Bell Irving River, about 3.4 km upstream of the Snow Bank Creek/Bell Irving River confluence. Services provided at the lodge include a gas station, a restaurant, chalet style accommodation, RV hook-ups and camping, a gift shop, and helicopter landing and fuel. The lodge is visited by tourists during the summer via Highway 37 and the lodge is used for heli-skiing in the winter. Seabridge is proposing to construct an access road along Treaty Creek from Highway 37 to the mill facilities and the TMF. Highway 37 follows Snowbank Creek and the Bell Irving River to a

point just downstream of Bowser River. The highway crosses the Bell Irving River at two locations within this reach. Most of the area along the Nass River downstream of the Bell Irving River is also relatively undeveloped and sparsely populated.

The largest population centers downstream of the TMF include Vandyke Camp, and the villages of New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville) and Gingolx (Kincolith). The populations of the villages range between 200 and 800. The village of Laxgalts'ap and the site of the old village of Aiyansh have historically been subject to flooding from the Nass River.

The proposed dams are designed as compacted cyclone sand embankments constructed by the centreline method with crest widths of 20 m, and downstream slope of 3H:1V. Ultimate heights of the North and Southeast Dams would be approximately 215 m and 239 m, respectively. A vertical till core, with a minimum width of 20 m, is provided in each dam to restrict seepage; in addition the Splitter and Saddle dams incorporate geomembrane liners to isolate the CIL Residue tailing. Given their size and storage capacity, the North, Saddle, and Southeast dams were assigned the "Extreme" consequence classification, which is the highest classification provided in the CDA Dam Safety Guidelines and the seismic and flood design criteria for the dams were set accordingly. The internal Splitter Dam was assigned the "Significant" consequence classification based on repair costs as no foreseeable downstream impact or loss of life exists.

Two failure conditions were considered for the conventional dam break analysis: flood-induced dam failure (e.g., overtopping of the dam); and sunny-day dam failure (e.g., piping without concurrent flooding). Sensitivity analyses were conducted by varying the assumed dam breach parameters such as breach formation time, volume of tailings released and Manning's roughness coefficient (n) for the downstream flood route. The HEC-RAS hydrodynamic computer model, developed by the US Army Corps of Engineers, was used with the geographic information system ARC-GIS to simulate dam failures and to estimate flood inundation limits along streams and rivers downstream of the dams.

Our conclusions based on the results of this dam break and inundation study are as follows:

- The dam break and inundation analyses completed for the TMF are based on hypothetical modes of failure under extreme and highly unlikely events. For example, for a dam to be overtopped, not only would the flood storage capacity provided for the Probable Maximum Flood (PMF) and the freeboard have to be used up, but the overflow spillway would also have to be non-functional at the same time (in the closure case). The results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dams.
- The discharge rate at the dam resulting from a dam failure is sensitive to the assumed breach formation time. The shorter the breach formation time, the higher the dam breach peak discharge. The influence of the selected breach formation time is larger at the dam and becomes less significant as the flood moves further downstream and attenuates.
- The attenuation of the flood as it travels downstream is dependent on the assumed Manning's roughness coefficient (n). The larger the roughness coefficient, the larger the attenuation. The influence of the selected roughness coefficient is small at the dam site, but

becomes more significant with respect to flood depth and flood arrival times as the wave moves further downstream.

- Existing and/or proposed facilities which would be affected by a failure of the Southeast Dam based on the model's outputs include:
    - Several sections of Highway 37 would be flooded along the Bell Irving River and the Nass River.
    - Sections of Highway 113 between New Aiyansh and Laxgalts'ap would be flooded.
    - Some of the bridges along Highway 37 and other roads that cross the Bell Irving and Nass Rivers could be overtopped.
    - Existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains could be flooded.
    - An overtopping failure of the dam resulting from the PMF or similar event would not cause additional flooding at the downstream villages over and above which might occur during a naturally occurring PMF. The wave resulting from the dam failure would be fully attenuated before it reaches the downstream villages.
    - A piping failure of the dam would not cause flooding in the downstream villages but a relatively small flood depth above the mean annual flow would be apparent.
- Existing and/or proposed facilities which would be affected by a failure of the North Dam include the affected facilities listed above for the Southeast Dam above plus the following:
    - Bell 2 Lodge would be flooded, however the difference in flooding at Bell 2 Lodge between a dam breach coincident with a PMF, and a PMF event alone, is expected to be relatively small.
    - The proposed road along Treaty Creek which provides access to the mill facilities and the TMF.
    - Highway 37, north of Bell 2 Lodge and at some local areas upstream of the confluence of Bell Irving River and Teigen Creek.

The rate of rise of the flood wave from the overtopping failure is in the order of 1 m/hr to 2 m/hr near the Bell Irving/Nass confluence, reducing to in the order of 0.02 m/hr to 0.1 m/hr near the Nass River at Gitwinksihlkw (Canyon City). The rate of rise of the flood wave from the piping failure is in the order of 1.5 m/hr to 3 m/hr near the Bell Irving/Nass confluence, reducing to in the order of 0.1 m/hr to 0.3 m/hr near the Nass River at Gitwinksihlkw (Canyon City).

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.

TABLE OF CONTENTS

List of Tables

TABLE OF CONTENTS
(continued)

List of Figures

List of Appendices

DEFINITIONS AND ACRONYMS

Acronym	Name	Definition
CDA	Canadian Dam Association	-
CIL	Carbon-in-Leach	Type of tailings contained in the CIL Residue Cell
DEM	Digital Elevation Model	Digital data used in production of terrain maps
MAF	Mean Annual Flow	Inter-annual average flow
LIDAR	Laser distance and ranging	Laser terrain mapping
TMF	Tailings Management Facility	-
UTM	Universal Transverse Mercator	Map Coordinate System
WSC	Water Survey of Canada	Federal Hydrographic Agency
	“sunny day” failure	Piping failure that occurs in the absence of flooding (MAF)
	“rainy day” failure	Overtopping failure that occurs during flooding (PMF)
	Piping Failure	Internal failure or leakage of a dam caused by construction defects
	Overtopping	Water flow over dam crest caused by flooding during storm, possibly leading to dam failure by erosion
	Cyclone sand	Coarse fraction of tailings separated from tailings in cyclone for construction of tailings dam
	Tailings Cell	Impoundment formed between two dams

1 INTRODUCTION

Klohn Crippen Berger Ltd. (KCB) was retained by Seabridge Gold Inc. to undertake dam break and inundation analyses for the proposed Water Storage Dam (WSD) and the Tailing Management Facility (TMF) at the KSM Project. Results of the dam break and inundation analyses for the TMF are presented in this report.

As recommended by the Canadian Dam Association (CDA), dam break and inundation studies are done for all major water and tailings dams and consider hypothetical failure modes of a dam and assess potential impacts of the dam failure on areas along the receiving waters downstream of the dam relative to guidelines and criteria established for dam safety. The modeled impacts relative to consequence levels in the dam safety guidelines are used to establish design criteria requirements for the dam. These studies are also a requirement of the environmental assessment as mandated by the Canadian Environmental Assessment Agency (CEAA).

Analyses were undertaken to assess potential failure of the TMF dams. The method consisted of dam breach and inundation analyses wherein a dam is assumed to failure due to: 1) an overtopping failure due to an extreme flood ("rainy-day" failure); or 2) a "sunny-day" failure where the dam fails due to piping. The resulting discharge is routed along the streams and rivers downstream of the dam using a hydrodynamic model. Further details of the analyses are presented in Sections 4 and 5.

Outflows resulting from a breach of the dam are estimated and the flow is routed along the stream by a hydraulic model to estimate flood flows, flood depths and the likely extent of flooding downstream of the dam. Typically the flooding levels are referenced to natural flooding levels of various return periods and the Probable Maximum Flood (PMF), which is the largest probable natural flood level. The dam break analyses examined in this report are based on hypothetical modes of failure under extreme and unlikely events, therefore the results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dams.

A sensitivity analysis of parameter selection effects on modeled flood levels due to parameter variations was conducted by varying Manning's roughness coefficient (n), and breach formation time.

Dam break flood modeling and inundation studies are presented in this report for two stages of the mine life:

- End of year 29; hypothetical failure of the North Dam, and hypothetical cascading failures of the Splitter and Saddle Dams.
- End of mine life; hypothetical worst case (maximum tailings level) failures of the North Dam and of the Southeast Dam at their final stages.

These two stages result in the highest potential consequences during the course of the mine life and have been selected for presentation in this report.

This report is an instrument of service of Klohn Crippen Berger Ltd. and has been prepared for the use of Seabridge Gold Inc. The content of this report reflects Klohn Crippen Berger’s best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Klohn Crippen Berger Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

2 PROJECT SETTING

2.1 Project Location

The KSM Project is located in the coastal mountains of north-western BC, approximately 70 km northwest of Stewart, British Columbia, Canada (Figure 2.1). An overview of the study area is presented in Figure 2.2. A KSM project site plan, showing the proposed locations of the mine site, the WSD and the TMF Dams, is presented in Figure 2.3. The TMF and the WSD are located in two separate watersheds, the Bell Irving River watershed and the Unuk River watershed, respectively.

The TMF is located on the divide between Teigen Creek and Treaty Creek catchments.

2.2 Configuration of the TMF

The TMF will to ultimately be formed by four dams, impounding three cells: North Flotation Tailings Cell (North Cell), South Flotation Tailings Cell (South Cell) and the CIL Residue Tailings Cell (CIL Cell).

The North Dam would impound the North Cell of the TMF during the first phase of operation (Years 0 to 29). The Southeast Dam would impound the South Cell of the TMF during the second phase of operation (Years 30 to 53). The Saddle and Splitter Dams would impound the CIL Cell, which would be ultimately located centrally between the North and South Cells; the CIL Cell would be operational from Year 0 through Year 53.

The North Dam, the Saddle Dam and the Southeast Dam would have a Seepage Recovery Dam located downstream to collect seepage from the tailings impoundment. Given the relatively small height and storage of the Seepage Recovery Dams compared to the TMF dams, the Seepage Recovery Dams have negligible impact on the flood, and they are thus not included in the dam break and inundation analyses.

Appendix I of this report presents design sections of the proposed TMF as drawings D-4101, D-4105, D-4106 and D-4107. The 2012 TMF Design Report presents further details of the TMF designs.

2.3 TMF Operational Management Plan

An Operational Management Plan (OMP) will be included in the design of TMF structures to provide a basis for safe operational principles and to define required safeguards such as monitoring, training, inspections of dam operation and dam safety aspects.

An Operations Management Plan identifies procedures for managing pond level and beach exposure by adjusting reclaim rates and discharge schedules. Included will be schedules for raising cyclone sand dams in order to maintain design freeboard to contain the PMF.

In addition, the OMP will provide for regular monitoring of dam stability indicators such as water level piezometers, settlement gauges, seepage pond flow rates, drain flow rates and drain turbidity as well as pond level monitoring. Action plans for out of normal ranges will be identified in the OMP.

Regular inspection schedules and procedures will be identified in the OMP for dam structures such as spillways, seepage pond dams, piping and the tailings pipelines. These include monitoring the dam crests for settlement or displacement and inspection of the dam faces for signs of erosion or settlement. Action plans for deficiencies will be identified.

Although the TMF structures have been situated to be outside major avalanche routes, and the TMF beaches provide freeboard to resist the maximum probable avalanche, the OMP will also includes procedures for monitoring of avalanche potential and for the control of avalanches to restrict formation of snow sources by triggering small avalanches before larger avalanches can form. Avalanche control at the TMF will be part of site wide avalanche control measures at the KSM site which will include conventional avalanche bombing, triggering systems at key locations and passive avalanche control such as berms and the installation of snow retention fences.

The OMP will include emergency preparedness plans (EMP) for notification of downstream land users in the event of an emergency and procedures for dealing with emergency issues.

The EMP will be prepared in accordance with the Canadian Dam Safety Guidelines and provincial regulatory requirements, and it will cover all potential inundation areas from the TMF to Gincolx. Should the TMF design change by the time the Emergency Preparedness Plan is prepared, the dam break and inundation study should be revisited and potential impacts re-assessed.

Numerous uncertainties are inherent in dam break and inundation modeling and the flood inundation limits produced from such modeling should be regarded as approximate. This limitation should be kept in mind in the development and execution of emergency planning procedures.

2.4 Downstream Drainage Network

The area downstream of the North Dam consists of the following drainage to the Pacific Ocean:

- approximately 12 km north along Teigen Creek, which discharges into Snowbank Creek;
- approximately 5 km east along Snowbank Creek, which discharges into the Bell Irving River;
- approximately 81 km southeast along the Bell Irving River, which discharges into the Nass River; and,
- approximately 200 km along the Nass River, which discharges into Portland Inlet on the Pacific Ocean. The lower 18 km of the Nass River is very wide, ranging in width from 1.5 km to about 2.5 km.

The area downstream of the Southeast Dam consists of the following drainage to the Pacific Ocean:

- approximately 2 km along a local stream which discharges into Treaty Creek;
- approximately 18 km along Treaty Creek , which discharges into the Bell Irving River;
- approximately 60 km along the Bell Irving River, which discharges into the Nass River; and,

- treaty Creek , which discharges into the Bell Irving River. Approximately 200 km along the Nass River, which discharges into Portland Inlet on the Pacific Ocean.

The naturally occurring flows in the creeks and rivers downstream of the dams were estimated based on streamflow records from Bell Irving River, Nass River and other nearby streams. Flows for various return periods were estimated in a regional analysis conducted by Rescan and are summarized in Table 2.1. Probable Maximum Flows (PMF) presented in the table were estimated based on the study conducted by the Agriculture and Agri-Foods Canada: "Probable Maximum Flood Estimator for British Columbia" (AAFC, 2010). The equation for British Columbia Coastal Region was used for this study.

Table 2.1 Estimated Magnitudes of Naturally Occurring Flows in the Rivers

WSC Station No.	Stream Gauging Station Name/Location	Catchment Area (km^2)	MAF	Return Period (years)					PMF
				2	10	50	100	200	
			Flow (m^3/s)						
-	Snowbank Creek at Bell Irving	325	30	156	294	424	481	540	2,200
-	Treaty Creek at Bell Irving	375	35	175	327	470	533	598	2,400
-	Bell Irving at Snowbank Creek	1,210	70	444	772	1,091	1,235	1,384	6,100
-	Bell Irving at Treaty Creek	1,810	100	612	1,038	1,457	1,648	1,847	8,300
08DA010	Bell Irving River below Bowser River	5,160	290	1,412	2,239	3,094	3,491	3,912	18,800
-	Bell Irving at Nass River	5,330	300	1,449	2,293	3,167	3,573	4,003	19,300
-	Nass River below Bell Irving River	11,300	480	2,638	3,981	5,436	6,122	6,858	34,700
08DB001	Nass River above Shumal Creek	18,400	780	3,891	5,695	7,718	8,681	9,725	50,800

Notes: WSC: Water Survey of Canada
PMF: Probable Maximum Flood. Values were estimated from the BC PMF Estimator (AAFC, 2010)
MAF: Mean Annual Flow

cbeasy
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Major Highways
Provincial/State Boundary
International Boundary

1. Projection and datum : BC Environmental Albers with modified central meridian, NAD83
2. Most base map data from Esri
3. Highways from National Road Network

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TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCT 5, 2012

0 125 km

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
PROJECT LOCATION MAP

PROJECT No.
M09480A04

FIG No.
2.1

cbeasy
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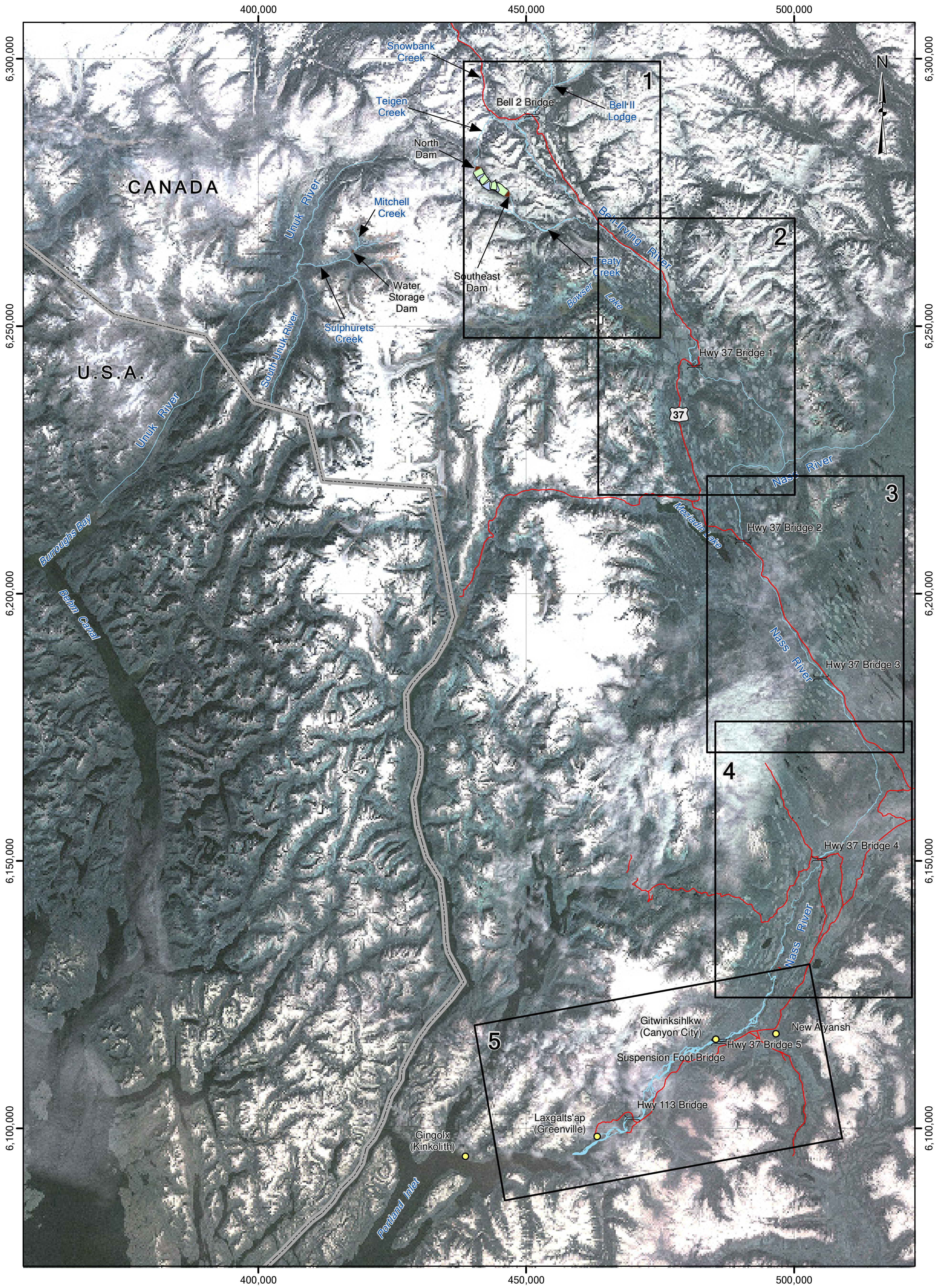


⟗	Bridges	🟫	Dams
—	Roads	🟩	Tailings Ponds
		🟦	CIL Residue Pond
		▭	Figure Tile Extents

1. Landsat imagery downloaded with Global Mapper.
2. Roads and most waterbodies from NTS (1:250,000).
3. UTM Zone 9N, NAD83

NOT FOR CONSTRUCTION

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCT 5, 2012

0 25 km

CLIENT
SEABRIDGE GOLD

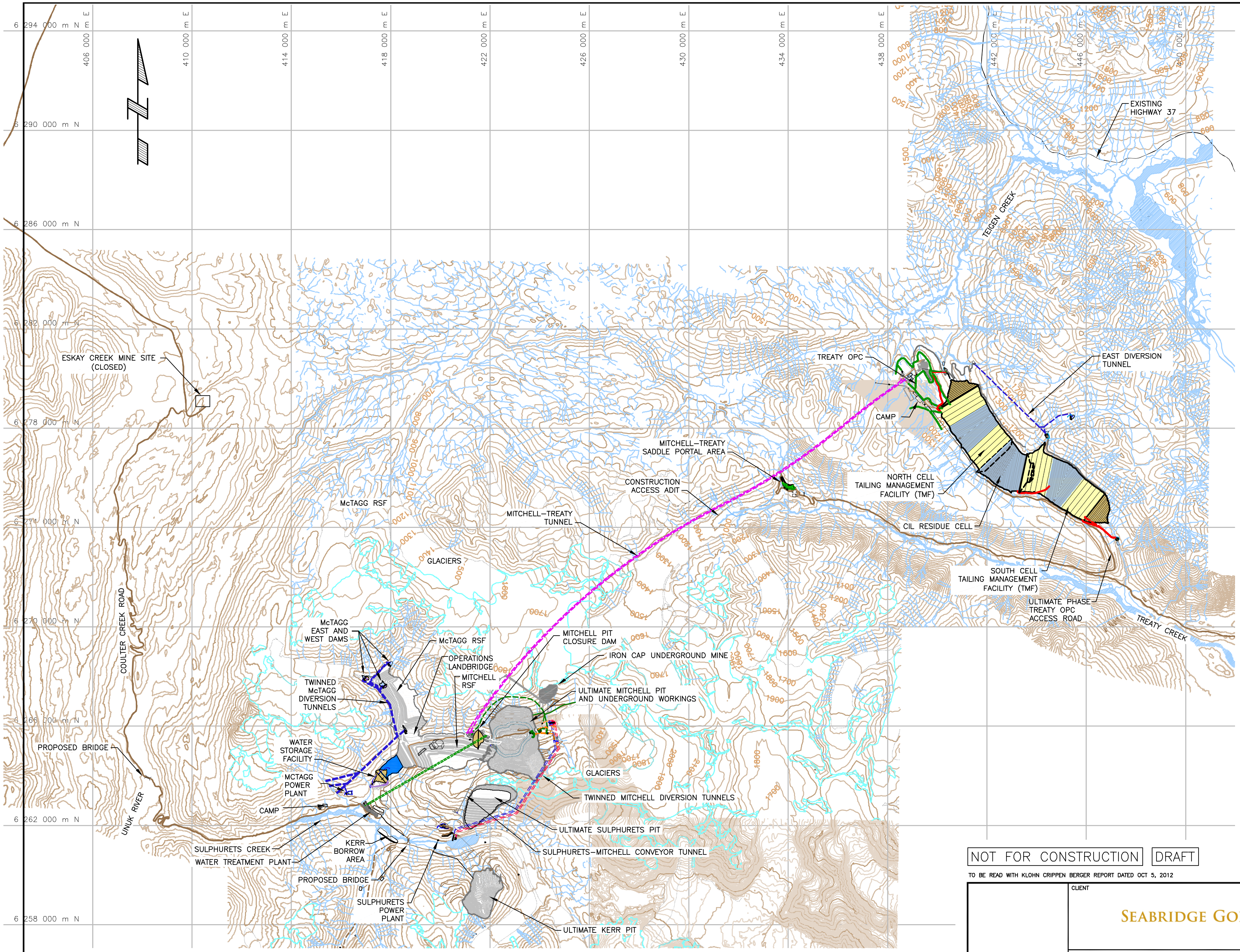
Klohn Crippen Berger

PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
STUDY AREA MAP

PROJECT No.
M09480A04

FIG No.
2.2



LEGEND

- DIVERSION TUNNEL/PORTAL
- TWIN ORE HAULAGE/SERVICE TUNNELS FROM MITCHELL TO TREATY OPC
- OPEN PIT
- ROCK STORAGE FACILITY

GENERAL NOTES

- DATUM NAD 83
- PROJECTION UTM ZONE 9
- ALL UNITS IN METERS UNLESS SPECIFIED
- 100m CONTOURS, FROM BC TRIM DATA (1:20,000 ACCURACY)
- 50m CONTOURS, FROM LIDAR SURVEY
- 10m CONTOURS(McTAGG GLACIER), FROM LIDAR SURVEY(McELHANNEY), AUG. 9, 2010.
- 10m CONTOURS(MITCHELL GLACIER), FROM LIDAR SURVEY(McELHANNEY), SEPT. 28, 2010.
- MINE AREA:
  FROM BOSCHE VENTURES: ORE PROCESS COMPLEX RECEIVED ON APR 3, 2012, SULPHURETS MITCHELL TUNNEL CONVEYOR AND PORTAL TRANSFER CONVEYOR RECEIVED ON APRIL 9, 2012. ACCESS ROAD NEAR TED MORRIS CREEKS RECEIVED ON MAR 23, 2011.

  FROM MOOSE MOUNTAIN: MCTAGG RSF & MITCHELL ROCK STORAGE FACILITY, LANDBRIDGE AND PITS RECEIVED APR 19, 2012, AND MITCHELL NORTH PIONEERING ROAD ON MAR 2, 2012. MINE AREA ROADS, TRUCK SHOP, BORROW AREAS, AND SPILLWAY NEAR WSF RECEIVED MAR. 30, 2012, SLUDGE STORAGE FACILITIES RECEIVED ON APR 3, 2012. CAMP RECEIVED APRIL 24, 2012.

  FROM GOLDER: UNDERGROUND–IRONCAP/MITCHELL RECEIVED ON FEB 01, 2012.
- TAILING MANAGEMENT FACILITY (TMF):
  FROM BOSCHE VENTURES: TMF ORE PROCESSING COMPLEX AND CAMP RECEIVED ON MAY 11, 2012.
  FROM McELHANNEY: TREATY AND NORTH TREATY ROADS RECEIVED ON MAR 15, 2012.

REFERENCE:

ALL DRAWINGS REFER TO D–4001 FOR GENERAL NOTES

NOT FOR CONSTRUCTION | DRAFT

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCT 5, 2012

SCALE: 0 4000 m

CLIENT	SEABRIDGE GOLD
	Klohn Crippen Berger
PROJECT	KSM PROJECT DAM BREAK AND INUNDATION STUDY
TITLE	PROPOSED PROJECT AREA SITE PLAN
PROJECT No.	M09480A04
FIG. No.	2.3

Time: 15:43:13
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Scale: 1:2.5849(PS)
Drawing File: Z:\M\VCR\M09480A04 – KSM 2012 PFS\400 Drawings\DAM_BREAK_AND_INUDATION_STUDY\revB\FIG2.3_rB.dwg (afischer)

Except for the development at Bell 2 Lodge, the area downstream of the North Dam, up to the Nass River, is relatively undeveloped. Seabridge is proposing to construct an access road to the TMF from Highway 37. The road will follow Treaty Creek as shown in Figure 2.1. Highway 37 follows Snowbank Creek and the Bell Irving River to a point just downstream of Bowser River, as shown in Figure 2.2. The highway crosses the Bell Irving River at two locations within this reach: the first crossing is at Bell 2 Lodge and the second crossing is below Bowser River. Bell 2 Lodge is located on the south bank of the Bell Irving River, about 3.4 km upstream of the Snow Bank Creek/Bell Irving River confluence. Services provided at the lodge include a gas station, a restaurant, chalet style accommodation, RV hook-ups and camping, a gift shop, and helicopter landing and fuel. The lodge is visited by tourists during the summer and it is used for heli-skiing in the winter.

The area downstream of the Southeast dam, as far as the Nass River, is also relatively undeveloped. Treaty Creek enters the Bell Irving River approximately 20 km downstream of the dam. The Bell Irving River flows into the Nass River about 60 km downstream of Treaty Creek. Highway 37 follows the Bell Irving River as described above.

Most of the area along the Nass River downstream of the Bell Irving River is relatively undeveloped and sparsely populated. There is a gravel pit and an airstrip on the west bank of the Nass River about 26 km downstream of the Bell Irving/Nass River confluence. There is also an airstrip, a gravel pit, and a large number of industrial buildings and trailer homes on the east bank of the river 3 km further to the south, referred to as the Vandyke Camp. The largest population centers downstream of the Bell Irving/Nass River confluence are New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville) and Gingolx (Kincolith). New Aiyansh is located on the east bank of the Nass River about 133 km downstream of the Bell Irving River. Gitwinksihlkw, Laxgalts'ap and Gingolx are located on the west bank of the Nass River approximately 6.5 km, 38.5 km and 65 km downstream of New Aiyansh, respectively. Population estimates for these communities were published by BC Stats in 2011 and are as follows:

New Aiyansh	758
Gitwinksihlkw (Canyon City)	184
Laxgalts'ap (Greenville)	378
Gingolx (Kincolith)	408

There are two road bridges across the Bell-Irving River, located approximately 3 km upstream and 62 km downstream of the Snowbank Creek/Bell Irving River confluence.

There are five road bridges and one suspension foot bridge across the Nass River, located approximately 25 km, 57 km, 100 km, 144, 145 km and 170 km downstream of the Bell Irving/Nass River confluence. Highway 37 follows the Nass River for about 46 km south of the first bridge, and then the highway veers to the southeast and the Nass River veers to the southwest from this point. The bridge at 170 km is on Highway 113. Locations of bridges are provided in Table 2.2.

Table 2.2 Locations of Bridges along the Bell-Irving and Nass Rivers

Bridge	Easting	Northing	Water Course
Bell 2 Bridge	451053	6289480	Bell Irving
Hwy 37 Bridge 1	481432	6242540	Bell Irving
Hwy 37 Bridge 2	490457	6209850	Nass
Hwy 37 Bridge 3	505051	6184240	Nass
Hwy 37 Bridge 4	504762	6150390	Nass
Hwy 37 Bridge 5	486636	6116540	Nass
Suspension Foot Bridge	485934	6116110	Nass
Hwy 113 Bridge	469824	6101930	Nass

Note: Easting and Northing are UTM 9N NAD 83.

The Nisga'a Nation Knowledge Network (http://nnkn.ca/node/15996) reports that the villages of Laxgalts'ap and the site of the original village of Aiyansh have historically been subject to flooding from the Nass River. The flooding has occurred during spring runoff, as well as during the fall due to heavy rains or rain-on-snow events. Flooding in Laxgalts'ap has been reported since 1917. The village of Aiyansh was partially destroyed by the flood in 1917. Between 1960 and 1980 it was moved to its present site at New Aiyansh where the risk of flooding is greatly reduced.

3 DAM SAFETY STANDARDS AND DESIGN CRITERIA

The TMF dams have been designed in accordance with the 2007 Canadian Dam Association Dam Safety Guidelines (CDA, 2007), which provide criteria for the design of dams based on the downstream consequence classification of the structure. The various dam consequence categories and their established thresholds are shown in Table 3.1.

Table 3.1 2007 CDA Dam Safety Guidelines - Dam Classification Categories

Dam Class	Population at Risk (Note 1)	Incremental Losses		
		Potential for Loss of Life (Note 2)	Environmental and Cultural Values	Infrastructure and Economics
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).
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).
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat. Restoration of compensation in kind highly possible.	High economic losses affecting infrastructure, public transportation, and commercial facilities.
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.
Low	None	0	Minimal short-term loss No long-term loss.	Low economic losses; area contains limited infrastructure or services.

Note 1: Definition 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 consequences classes (high, very high, extreme) are proposed to allow for more detailed estimated of potential loss of life (to 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.

The CDA Dam Safety Guidelines indicate that the term "consequence" refers to the incremental damage above and beyond the damage that would have occurred in the same event or conditions had the dam not failed. These may also be called incremental consequences of failure.

Given their size and storage capacity, the North, Saddle and Southeast TMF dams were assigned the "Extreme" consequence classification (KCB, 2012) as is typical of large tailings or water dams. The

Splitter Dam was assigned the “Significant” consequence classification as there is no environmental discharge or loss of life foreseen in its failure. The Extreme classification is the highest classification provided in the CDA Dam Safety Guidelines, and the seismic and flood design criteria for the TMF dams were developed accordingly, as shown in Table 3.2.

Table 3.2 North, Saddle, and Southeast Dams – Seismic and Flood Design Criteria

Design Parameter	Selected Design Criteria
Maximum Design Earthquake	10,000 return period or Maximum Credible Earthquake
Inflow Design Flood - Operation	Store 30 day PMF or 30 day 100-year snowmelt without discharge
Inflow Design Flood - Closure	Spillway sized to handle the PMF

Notes:

1. The seismic and flood design criteria are based on “Extreme” consequence classification as specified in the CDA dam Safety Guidelines.
2. PMF = Probable Maximum Flood.

4 OVERTOPPING AND PIPING FAILURE DAM BREAK METHODOLOGY AND ASSUMPTIONS

This section outlines the methodology and assumptions for the overtopping and piping failure dam break and inundation analyses.

4.1 Topographic Data

The following digital topographic data was used for the study:

- LIDAR data for the site;
- BC TRIM data for off-site areas; and,
- Digital Elevation Data and Airphoto compilation maps of Laxgalts'ap (Greenville) and Gitwinksihlkw (Canyon City).

The LIDAR topography is based on 2 m (6.6 ft) gridded Digital Elevation Model (DEM) and the BC TRIM topography is from 1:20,000 scale DEM (break-lines and DEM points). The maps produced by Eagle Mapping consist of 1:3,000 scale datasets compiled from 2001 BC Government black and white aerial photography. The Greenville and Canyon City maps produced by Eagle Mapping were adjusted vertically +1.1 m and +1.7 m, respectively, to provide a better alignment with the TRIM DEM used for the HEC-RAS model.

The wide range of resolution between the various topographic data used is not unusual for such large scale dam break and inundation analyses, and it is normal practice to use publicly available topographic mapping. As a result, the accuracy of modeled inundation areas varies throughout the study area.

Some of the features mentioned in this report have been illustrated using Google™ Earth software and satellite imagery. Other sources of satellite imagery used include RapidEye, Landsat 7 and Spot 5 imagery.

4.2 Dam Failure Modes and Conditions

Both the "rainy-day" failure and the "sunny-day" failure were considered for the analysis of the dams at the TMF.

- Condition 1: Flood-induced dam failure:
  - Flood-induced dam failure is often referred to as a "rainy-day" failure. A rainy-day or overtopping type failure typically occurs during large flood inflow conditions where the pond water level rises high enough to breach or overtop the dam.
- Condition 2: Sunny-day dam failure (piping, earthquake):
  - Sunny-day failures are normally assumed to occur when the pond is at its normal operating level. Examples of sunny day failures include the slope failure (slumping) of the

dam due to static or earthquake loading, or the failure of the dam caused by piping (internal erosion).

The dam heights and dam failure scenarios considered for the rainy-day and sunny-day failures are presented in Section 4.3.

4.3 Dam Break and Inundation Modeling

4.3.1 The HEC-RAS Model

The HEC-RAS computer model was used for the dam break and inundation analyses. This computer model is frequently used in Dam Break assessments conducted in Canada and the USA. HEC-RAS is a one-dimensional hydraulic model developed by the US Army Corps of Engineers (USACE). It is capable of steady and unsteady flow simulations in river channels. The unsteady component of the model includes calculation of outflows resulting from a dam breach as well as routing of these flows along the channel downstream of the dam.

The HEC-GeoRAS software extension to HEC-RAS, available from the USACE was used for pre- and post-processing of the HEC-RAS data. HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). The interface allows the preparation of geometric data such as inundation levels for import into HEC-RAS and it processes simulation results exported from HEC-RAS. HEC-GeoRAS was used to prepare the geometric data, such as river cross-sections and profiles, for input to the HEC-RAS model. Upon completion of the HEC-RAS runs, the HEC-RAS output was exported to HEC-GeoRAS for processing and delineation of flood limits.

Three separate HEC-RAS hydraulic models were developed as follows:

- Model 1: Failure of the TMF North Dam.
- Model 2: Cascading failures of the Saddle and Splitter Dams.
- Model 3: Failure of the TMF Southeast Dam.

Model 1 started at the North Dam, and followed Teigen Creek, Snowbank Creek, the Bell Irving River, and subsequently the Nass River as far as the river mouth. Model 2 started at the Splitter Dam, and followed Treaty Creek, the Bell Irving River, and the Nass River up to its mouth. Model 3 started at the Southeast Dam, and followed Treaty Creek, the Bell Irving River, and the Nass River up to its mouth.

Both the “rainy-day” failure and the “sunny-failure” failure, as discussed in Section 4.2, were considered for the analysis of the dam failure in the three models. The following dam failure scenarios were considered in the dam break and inundation analysis:

- North Dam end-of-life overtopping failure;

- North Dam end-of-life piping failure;
- Cascading Splitter/Saddle Dams mid-life overtopping failure;
- Cascading Splitter/Saddle Dams mid-life piping failure;
- Southeast Dam end-of-life overtopping failure; and,
- Southeast Dam end-of-life piping failure.

There are seven bridges along the flood route downstream of the North Dam (Figure 2.2). Piers or other aspects of these structures would have negligible impact on the flood flows, and they have not been included in the HEC-RAS model.

4.3.2 Concurrent Flows

The Dam Safety Guidelines indicate that downstream tributary flow conditions used in the assessment should be those most probable to occur coincident with the breach event. For flood inundation analysis of a piping failure, the concurrent flow in the receiving streams and rivers downstream of the dam was assumed to be the Mean Annual Flow (MAF). For inundation analysis of an overtopping failure, the concurrent flow in the receiving streams and rivers downstream of the dam was assumed to be the Probable Maximum Flood (PMF).Flow values are available in Table 2.1.

4.3.3 Model Input Parameters

Input parameters for simulating an overtopping dam failure in HEC-RAS include final breach bottom width, final breach bottom elevation, breach side slopes, and breach formation time. Input parameters for simulating a piping failure include the parameters listed for an overtopping failure plus the initial piping elevation and the piping coefficient. The breaching process implemented in HEC-RAS is not physically based but its dynamics are controlled by the above-mentioned parameters. Therefore, the breach parameters have to be estimated outside the HEC-RAS program, based on a literature review of scientific publications on dam failure. Defined methods for estimating these parameters do not exist; however several researchers have developed empirical regression equations and/or charts based on historical dam breach information. The breach parameters for this study were estimated using the regression equations and charts for the base case dam breach runs to represent the most likely failure scenario for the dam. Sensitivity runs were also completed to test the sensitivity of some of these parameters. A summary of the selected breach parameters is presented in Table 4.1.

Table 4.1 Dam Breach Parameters

Dam	Failure Scenario	Dam Crest Elev. (m)	Dam Foundation Elev. (m)	Dam Height (m)	Dam Crest Width (m)	Dam Side Slope U/S (H:1V)	Dam Side Slope D/S (H:1V)	Flood Water Level (m)	Solids Elevation (m)	Operating Pond Water Level (m)	Volume of Tailings (Mm^3)	Volume of Free Water (Mm^3)	Total Volume (Mm^3)	Total Runout Volume (Tailings + Water) based on a 65% Solids by Weight (Mm^3)	Base Case Breach Formation Time (hrs)	Base Case Breach Depth (m)	Base Case Breach Bottom Elev. (m)	Base Case Breach Bottom Width (m)	Base Case breach Side Slopes (H:1V)	Initial Piping Elev. (m)
North Dam - ultimate	overtopping	1068	850	218	20	[1]	3	1068.3[2]	1062	1062	526	42	568	151	5	218	850	235	1	-
North Dam - ultimate	piping	1068	850	218	20	[1]	3	1062	1062	1062	526	13	539	38	5	218	850	235	1	952
Southeast Dam - ultimate	overtopping	1068	830	238	20	[1]	3	1068.3[2]	1058	1058	595	64	659	227	6	238	830	215	1	-
Southeast Dam - ultimate	piping	1068	830	238	20	[1]	3	1058	1058	1058	595	13	608	38	6	238	830	215	1	943
Splitter-Saddle Dam - mid-life	overtopping	1006	890	116	20	[1]	3	1006.3[2]	994	994	617[3]	73[3]	690[3]	209[3]	5	116	890	215	1	-
Splitter-Saddle Dam - mid-life	piping	1006	890	116	20	[1]	3	994	994	994	617[3]	31[3]	648[3]	107[3]	5	116	890	215	1	935

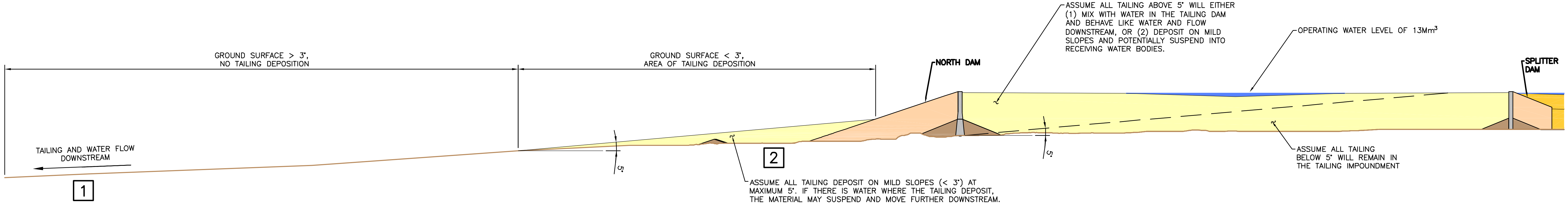
Notes:
1. Upstream face of tailings dams consists of cycloned sand.
2. For initiation of overtopping failure, water level is assumed to be 0.3 m above the dam crest.
3. Volume computed from the cascading failure of Splitter and Saddle Dams
4. Base Case Breach Depth and Width based on the following assumptions:
   Breach depth = dam height
   Breach width = valley width

One of the key variables for routing the flood through the streams and rivers downstream of a dam is Manning's roughness coefficient (n). A value of 0.10 was selected for the base cases to reflect the dense vegetation in the floodplains.

Tailings stored in tailings ponds have higher viscosity than water and, in most dam failures, not all the tailings are released from the pond. Our review of databases of historical tailings dam failure data, taken from USCOLD (1995) and www.tailings.info, indicates that the release proportion varied according to dam site and impoundment geometry, dam height, tailings storage volume, water pond volume and other factors. This database of historical data indicates that, on average, 25% of the tailings contained by a dam were released by failure of that dam, while Azam and Li (2010), concluded that tailings released generally amount to one-fifth of the tailings contained within the facilities based on a sample of 167 dam failures.

Analysis of potential releases of tailings from the proposed KSM impoundment was carried out by taking into consideration the height of the dams, the height of the tailings in the impoundment, the configuration of the impoundment behind the dam and the angle of repose for the tailings. The volume of tailings released was estimated by assuming an angle of repose of 5°, and all tailings above the breach bottom above this angle of repose was assumed to be released from the impoundment. This angle of repose was based on a tailings dam failure flow study by Lucia (1981), which listed final angles for various types of tailings inside and outside tailings impoundments. Based on these values, in the event of a dam breach the tailings at the KSM TMF are assumed to come to rest at approximately 5°.

To estimate the amount of tailings which would subsequently be deposited downstream of the dam and the potential for tailings to be deposited or re-suspended into the receiving water courses, the ground slope and the amount of water available in the impoundment and the river downstream of the dam were considered. It was assumed that no tailings would deposit on ground slopes greater than 3°. The amount of tailings that continues to flow downstream was estimated by back calculating the tailings volume based on a 65% solids content (by weight) for the tailings after combining the solids with the total amount of available water. Released tailings were assumed to behave (i.e., flow velocities) like water. This is a conservative assumption since the tailings would be more viscous than water and would not flow as easily. Generally, tailings slurries with solids content greater than 65% do not flow well. The portion of tailings that would deposit in the immediate area downstream of the tailings dam was calculated as all of the tailings released from the impoundment, less the volume of tailings that behaves like water and flows further downstream. Figure 4.1 depicts the methodology of tailings release and deposition used for the TMF dam break analyses. Total released volumes are presented in Table 4.1.



LEGEND

▨ TILL
▨ CYCLONE SAND
▨ COMPACTED RANDOM FILL
▨ FLOTATION (ROUGHER) TAILING
▨ CIL RESIDUE (CLEANER) TAILING

NOT FOR CONSTRUCTION

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCT 5, 2012

SCALE 0 500 m

CLIENT
SEABRIDGE GOLD
Klohn Crippen Berger

PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
ILLUSTRATION OF TAILING RELEASE AREA AND DEPOSITION ZONES

PROJECT No. M09480A04
FIG. No. 4.1

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Scale: 1:2.5849(PS)
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KCB-R-MD

4.3.4 Sensitivity Analyses

There are numerous uncertainties inherent in tailings dam break modelling and routing of extreme floods caused by a dam break. Some of these are:

- Dam breach parameters - In HEC-RAS, the dam breaching process is not physically based (explicit entrainment of dam material). Instead, gradual breaching of the dam is parameterized by final breach dimensions and shape, and the breach formation time. All these parameters must be set prior to running the model. The value of these parameters is set based on historical data, and requires a fair amount of judgment.
- Tailings dam vs. earthfill dams - Most methodologies were developed based on a sample of breached water-retaining dams for which structural characteristics could be reasonably estimated. Tailings dams, however, often exhibit a poorly defined upstream face with uncertain impoundment structural characteristics.
- Lack of model calibration –Measured water level versus discharge data from a streamflow station is required to calibrate a model. Such data is often not available and, even if it is available, the data would cover only the range of flows recorded during the life of the station and not the extreme flood flows expected due to a dam break. Therefore, the model cannot be calibrated for extreme flood flows.
- Roughness coefficient – Since the model cannot be calibrated, channel and overbank roughness values cannot be determined with certainty.

Analyses were conducted to test the sensitivity of model results to model parameters such as Manning's roughness coefficient (n) and breach formation time.

5 OVERTOPPING AND PIPING DAM BREAK ANALYSES AND RESULTS

5.1 Dam Description and General Assumptions

A general arrangement of the proposed TMF is shown in Drawing D-4101 in Appendix I, and design sections of the TMF and the associated dams are presented in Drawings D-4105, D4106 and D-4107 in Appendix I. The North and Southeast Dams will be compacted cyclone sand dams constructed by the centreline method with a crest width of 20 m, and downstream slope of 3H:1V. The ultimate heights of the North and Southeast Dams will be approximately 215 m and 239 m, respectively. A vertical till core, with a minimum width of 20 m, is provided in each dam to restrict seepage.

The North Dam will be founded on bedrock, and relatively shallow glacial till. The glacial till is relatively erosion resistant and the presence of bedrock and the till in the dam abutments and at the dam foundation is expected to limit the size of the dam breach. Therefore, as indicated in Table 4.1, the maximum breach depth and breach bottom width for the dam break analyses have been assumed to be 218 m and 235 m, respectively.

The Saddle Dam is located southeast of the Splitter Dam, near the midpoint of the valley. Its left abutment is founded on till while it's right abutment is founded on shallow colluvium underlain by bedrock. The valley bottom beneath the dam contains roughly 20 m of alluvial deposits underlain by till. The till is irregularly distributed but has a maximum thickness of over 60 m in the deepest part of a buried bedrock channel beneath the center of the dam. The till thins rapidly as it climbs the west side of the valley and is less than 5 m thick at El. 950 m. Bog deposits (compressible peat and silt) are locally present atop the alluvium along the valley bottom. Bog deposits and alluvium will be removed where required. The maximum breach depth and breach bottom width for the dam break analyses have been assumed to be 116 m and 215 m, respectively.

The abutments of the Southeast Dam have a thin veneer of glacial till, with the bedrock located at relatively shallow depth. The dam foundation has shallow alluvial deposits underlain by glacial till and bedrock below the till. The glacial till is relatively erosion resistant and the presence of bedrock and the till in the dam abutments and at the dam foundation is expected to limit the size of the dam breach. Therefore, as indicated in Table 4.1, the maximum breach depth and breach width for the dam break analyses have been assumed to be 239 m and 215 m, respectively.

Figure 5.1 to Figure 5.4 present flow and water level hydrographs resulting from piping and overtopping failure base cases for the North, Splitter/Saddle and Southeast Dams. These figures illustrate the incremental consequence of a dam failure compared to expected naturally occurring flows and water levels.

In the following three sections, detailed analyses resulting from the hypothetical failure of the Ultimate North Dam, Midlife Splitter/Saddle and Ultimate Southeast Dam are presented.

Figure 5.1 Overtopping Failures with Probable Maximum Flood, Water Depth

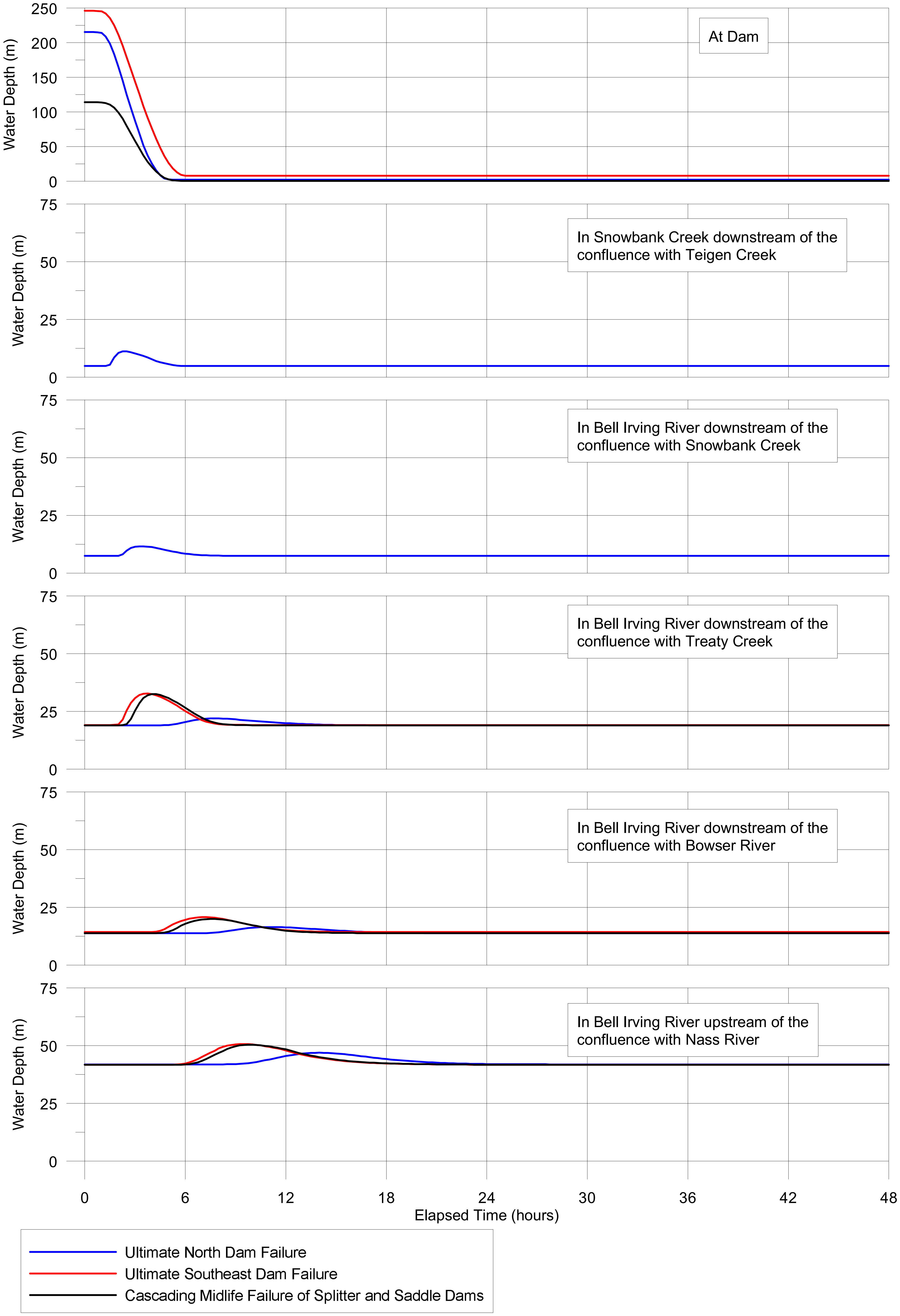


Figure 5.1 Overtopping Failures with Probable Maximum Flood, Water Depth

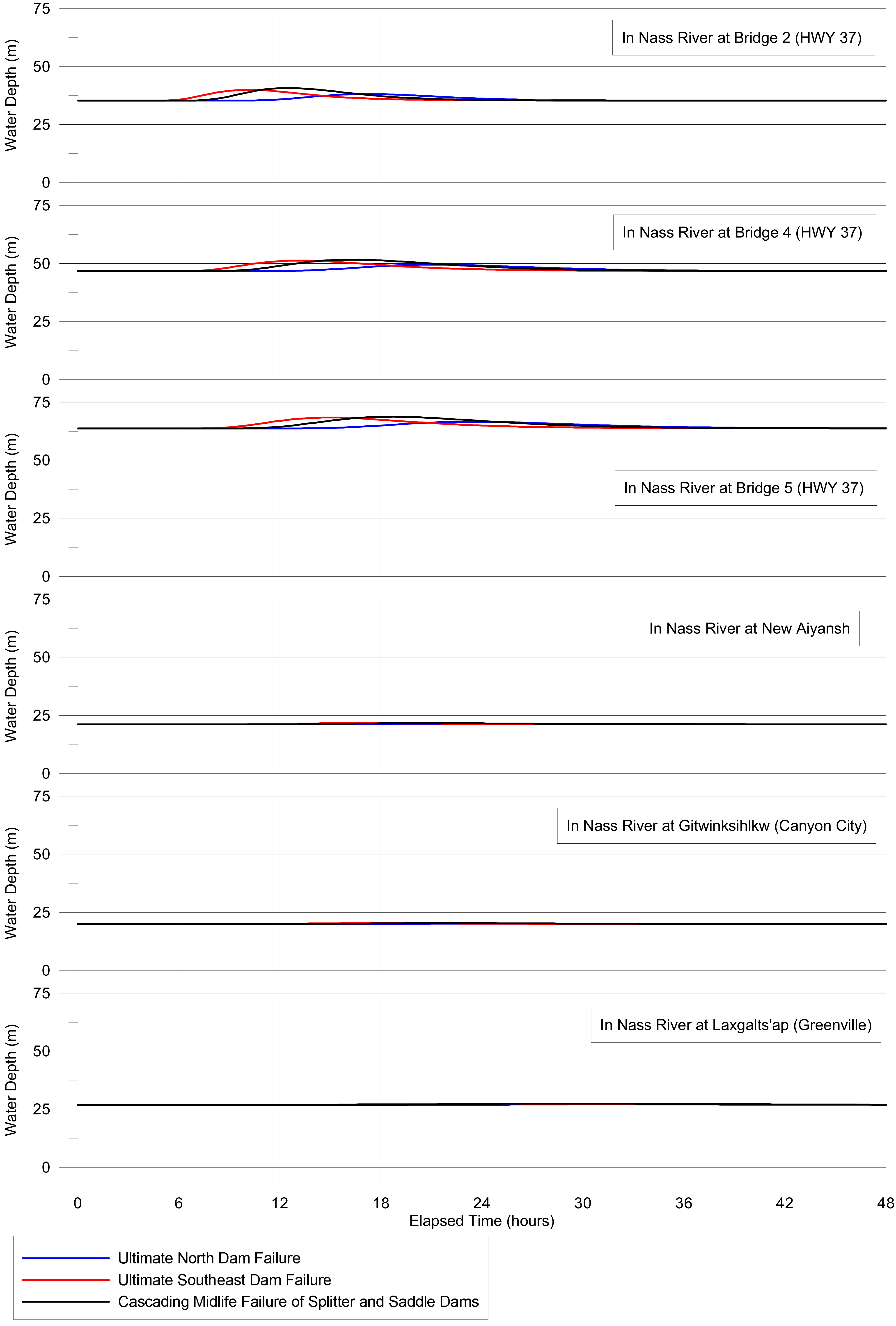


Figure 5.2 Overtopping Failures with Probable Maximum Flood, Discharge

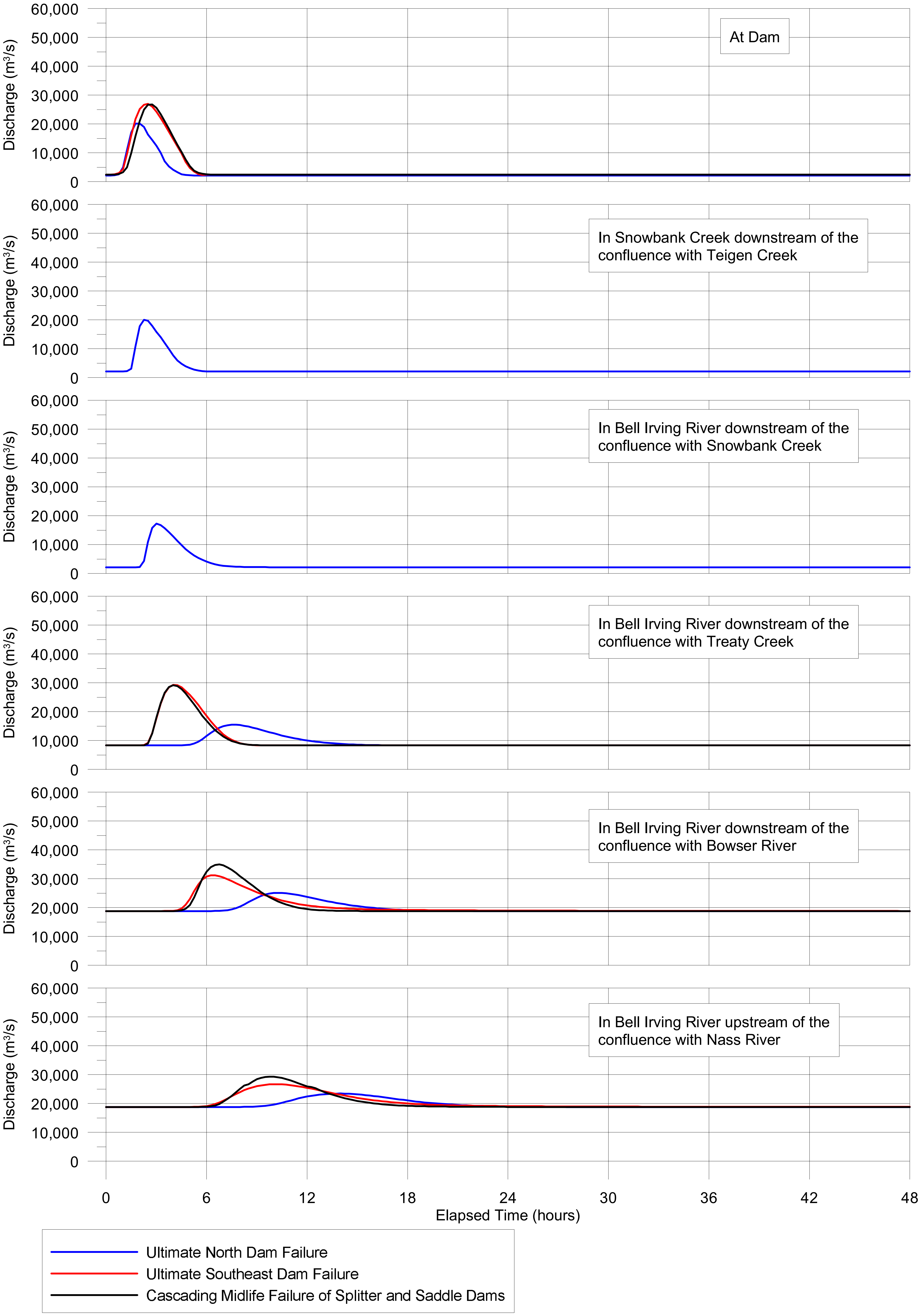


Figure 5.2 Overtopping Failures with Probable Maximum Flood, Discharge

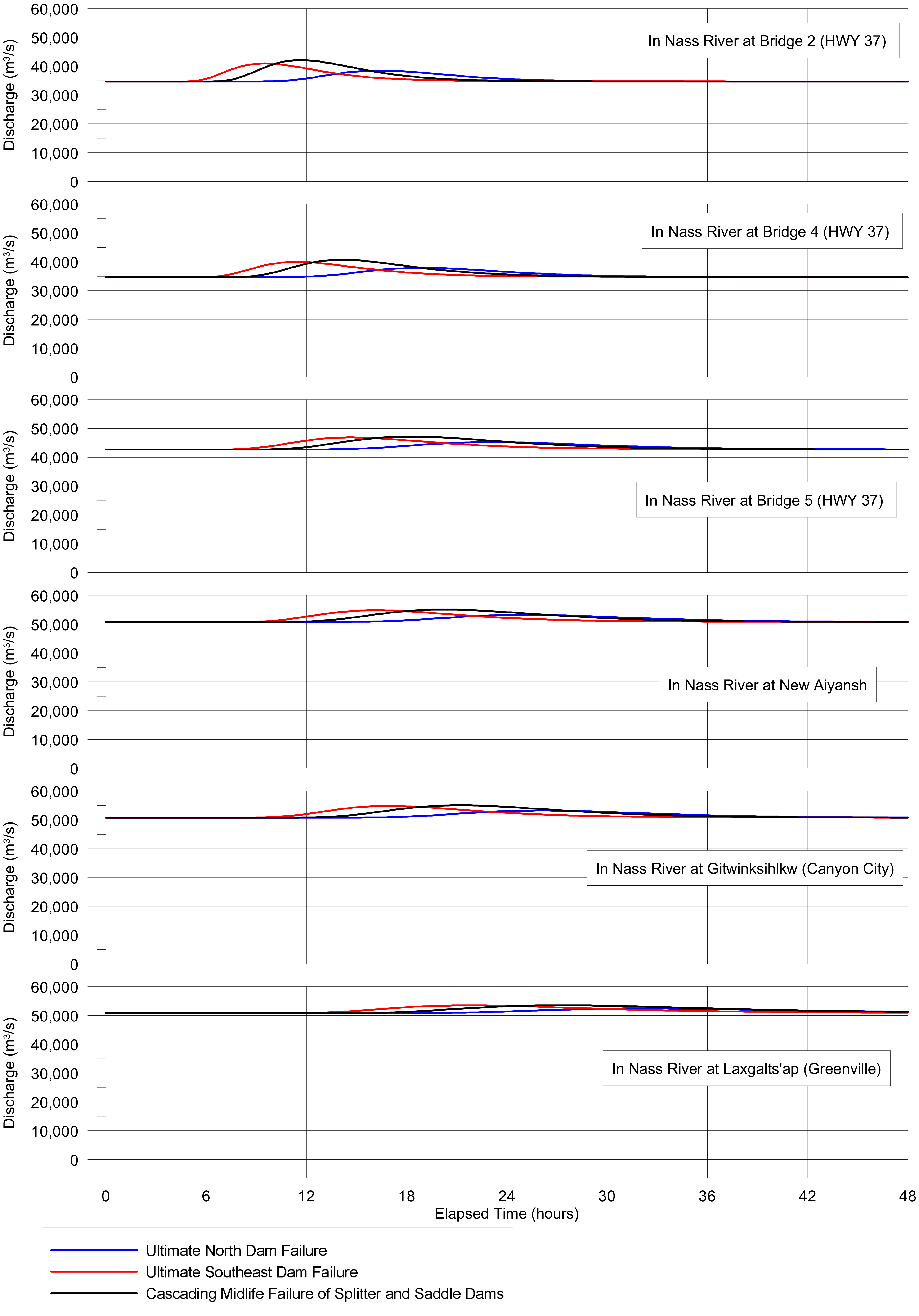


Figure 5.3 Piping Failures with Mean Annual Flows, Water Depth

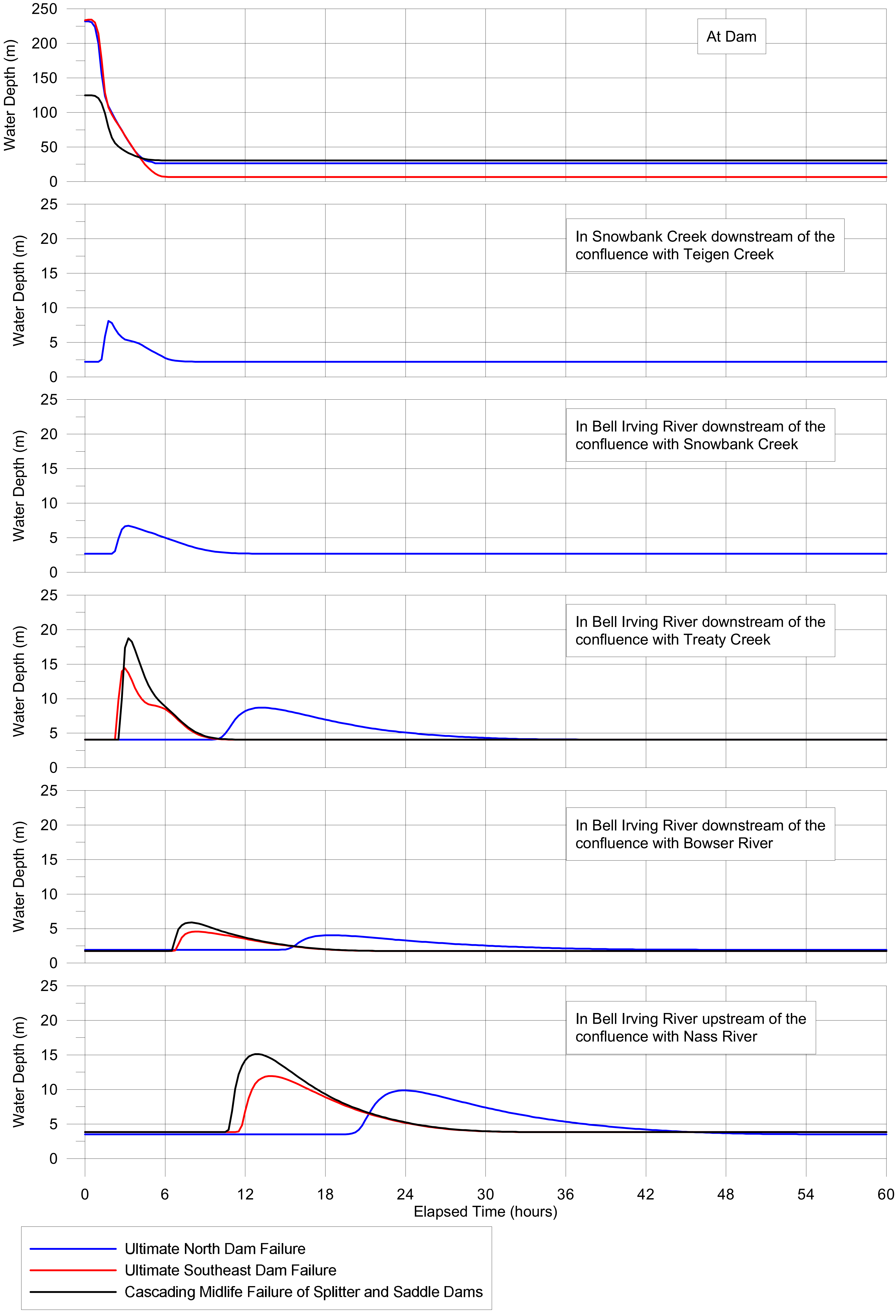


Figure 5.3 Piping Failures with Mean Annual Flows, Water Depth

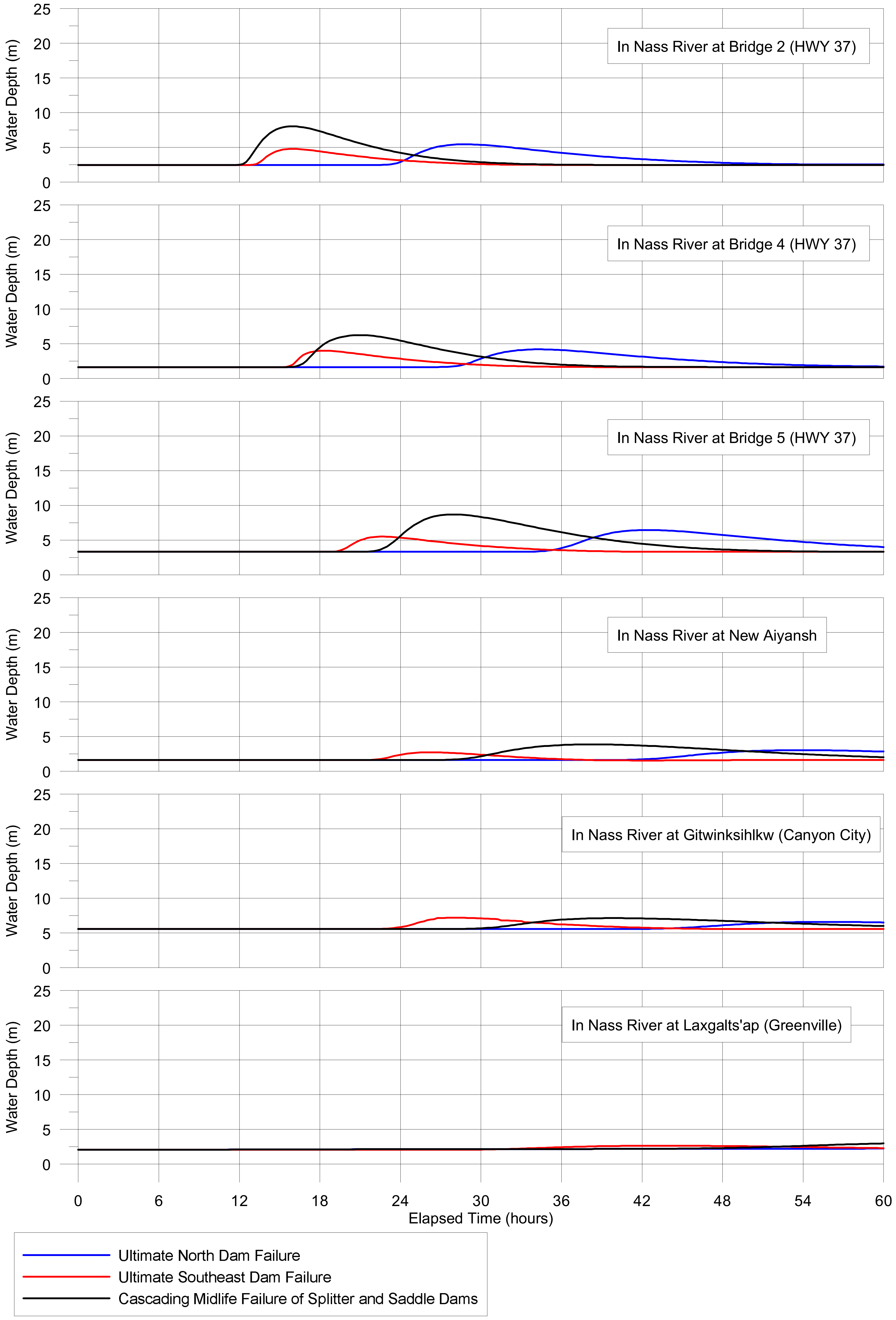


Figure 5.4 Piping Failures with Mean Annual Flows, Discharge

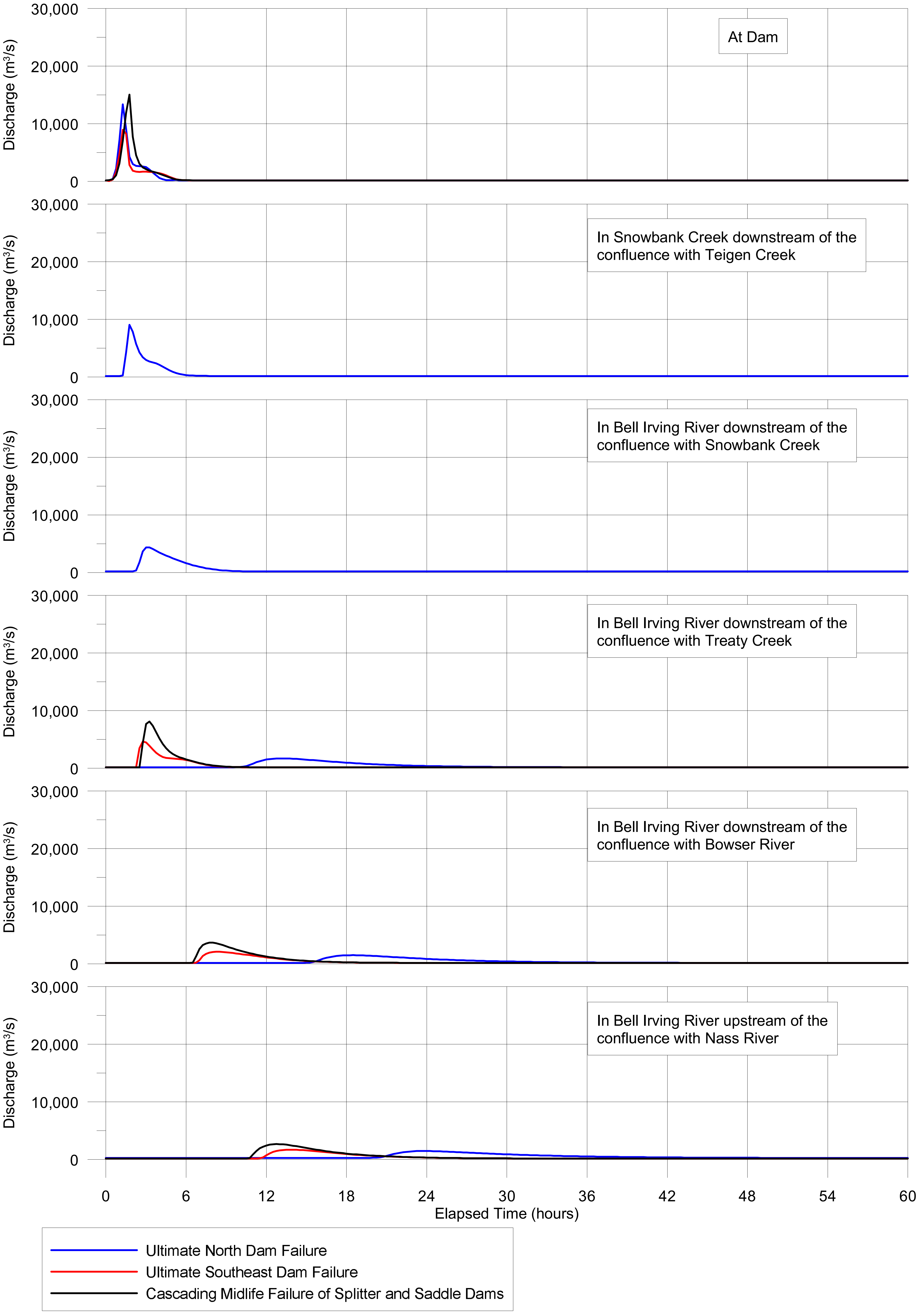
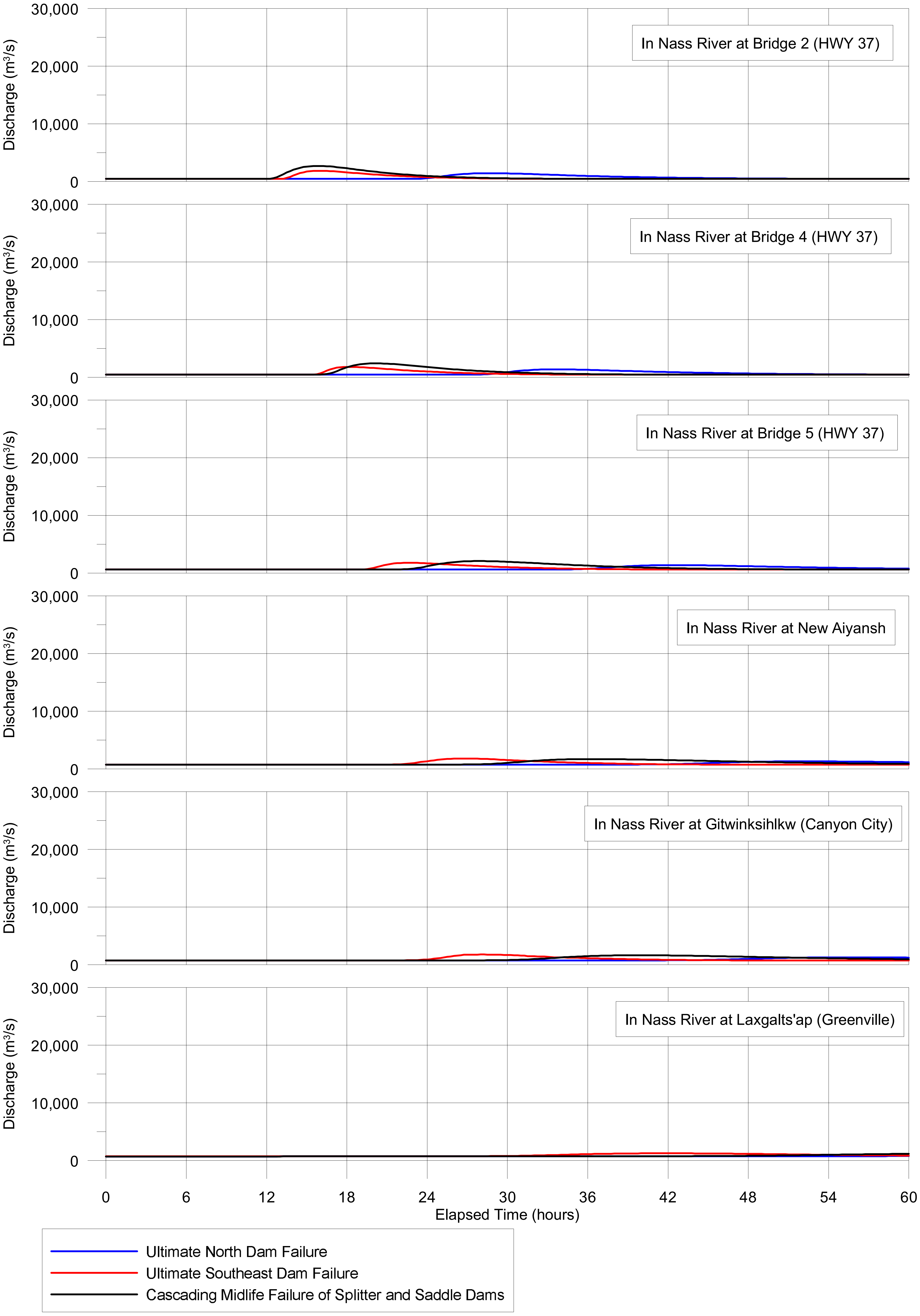


Figure 5.4 Piping Failures with Mean Annual Flows, Discharge



5.2 Ultimate North Dam

Results of the dam failure analysis for the Ultimate North Dam, including discharges, flood depths and flood travel times at selected locations, are summarized in Table 5.2 to Table 5.4, and Figure 5.1 to Figure 5.4. The Ultimate stage has been identified as the most critical case in terms of hypothetical dam failure; therefore intermediate stages are not investigated in this study.

Table 5.2 to Table 5.4 show peak flows, peak water levels and timing of the flood wave at various locations of interest downstream of the dam, and for the piping and overtopping failure base case scenarios.

For the overtopping failure scenario, results indicate that it would take approximately 2 hours and 8.25 hours after the initiation of the breach for the flood to reach the Bell Irving River and the Nass River, respectively. Modeled water levels peak 3.25, 14, 27, and 34 hours after the initiation of the breach at the Bell Irving River, the Nass River, Gitwinksihlkw, and Lxgalts'ap, respectively.

For the piping failure scenario, results indicate that it would take approximately 2 hours and 19.5 hours after the initiation of the breach for the flood to reach the Bell Irving River and the Nass River, respectively. Modeled water levels peak at 3.25, 24, 56, and 84 hours after the initiation of the breach at the Bell Irving River, the Nass River, Gitwinksihlkw, and Lxgalts'ap, respectively.

Higher naturally occurring flows (PMF) during the hypothetical overtopping dam failure, as opposed to piping failure with concurrent Mean Annual Flows increase flood wave celerity and decrease flood wave travel time.

The modeled inundation lines resulting from hypothetical overtopping and piping failures of the Ultimate North Dam are shown in Figure 5.5. They are compared to inundation lines resulting from naturally occurring PMF conditions.

Table 5.1 summarizes locations that would potentially be inundated by the various flow conditions.

Table 5.1 Ultimate North Dam Failure - Modelled Inundated Locations

Location	Upstream Flood Entry Point Easting (m)	Upstream flood entry point Northing (m)	Length of the Inundated Segment (km)	Inundated by PMF + overtopping failure	Inundated by PMF + no breach	Inundated by MAF + piping failure
Bell2 lodge	451,050	6,289,500	-	Yes	Yes	No
HWY 37	444,500	6,289,000	0.5	**Yes**	**Yes**	**Yes**
HWY 37	446,500	6,288,800	1	Yes	Yes	No
HWY 37	470,500	6,263,500	4	Yes	Yes	No
HWY 37	476,100	6,258,000	0.5	Yes	Yes	No
HWY 37	476,300	6,255,800	9	Yes	Yes	No
HWY 37	481,800	6,243,600	2	Yes	Yes	No
HWY 37	491,500	6,209,000	9	Yes	Yes	No
HWY 37	496,890	6,200,300	2	Yes	Yes	No
HWY 37	498,500	6,195,000	1.4	Yes	Yes	No
HWY 37	500,600	6,197,000	1.7	Yes	Yes	No
HWY 37	502,800	6,189,100	16	Yes	Yes	No
HWY 113	493,600	6,118,300	From Gitwinksihlkw to Portland Inlet	Yes	Yes	No

Results shows that Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville), 12 highway sections, as well as existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will be inundated by an overtopping failure of the Ultimate North Dam. However, these locations would also be flooded under naturally occurring flows (PMF), therefore the incremental consequence of an Ultimate North Dam overtopping failure is negligible.

Results shows that Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City) and Laxgalts'ap (Greenville), will not be inundated by a piping failure of the Ultimate North Dam. One section of highway 37 in the vicinity of the dam, as well as existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will likely be inundated by a piping failure of the Ultimate North Dam, while they are not inundated under Mean Annual Flows conditions. Therefore, the incremental consequence of an Ultimate North Dam piping failure is significant.

Table 5.2 Ultimate North Dam Failure – Discharge

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Flow (m^3/s)											
Concurrent River Flow (PMF)				2,200	2,200	6,100	8,300	18,800	19,300	34,700	34,700	42,750	50,800	50,800	50,800
Concurrent River Flow (Mean Annual Flow)				30	30	70	100	290	300	480	480	480	782	782	782
Overtopping	1068.3	PMF	151	20,100	20,000	17,200	15,500	25,200	23,500	38,500	37,900	45,300	53,300	53,300	52,400
Piping	1062	MAF	38	13,400	9,100	4,400	1,700	1,500	1,500	1,500	1,400	1,400	1,300	1,300	1,000

Notes:
Flows shown include concurrent flow in rivers.
Flows are rounded to the nearest 100 m3/s.

Table 5.3 Ultimate North Dam Failure – Water Depth

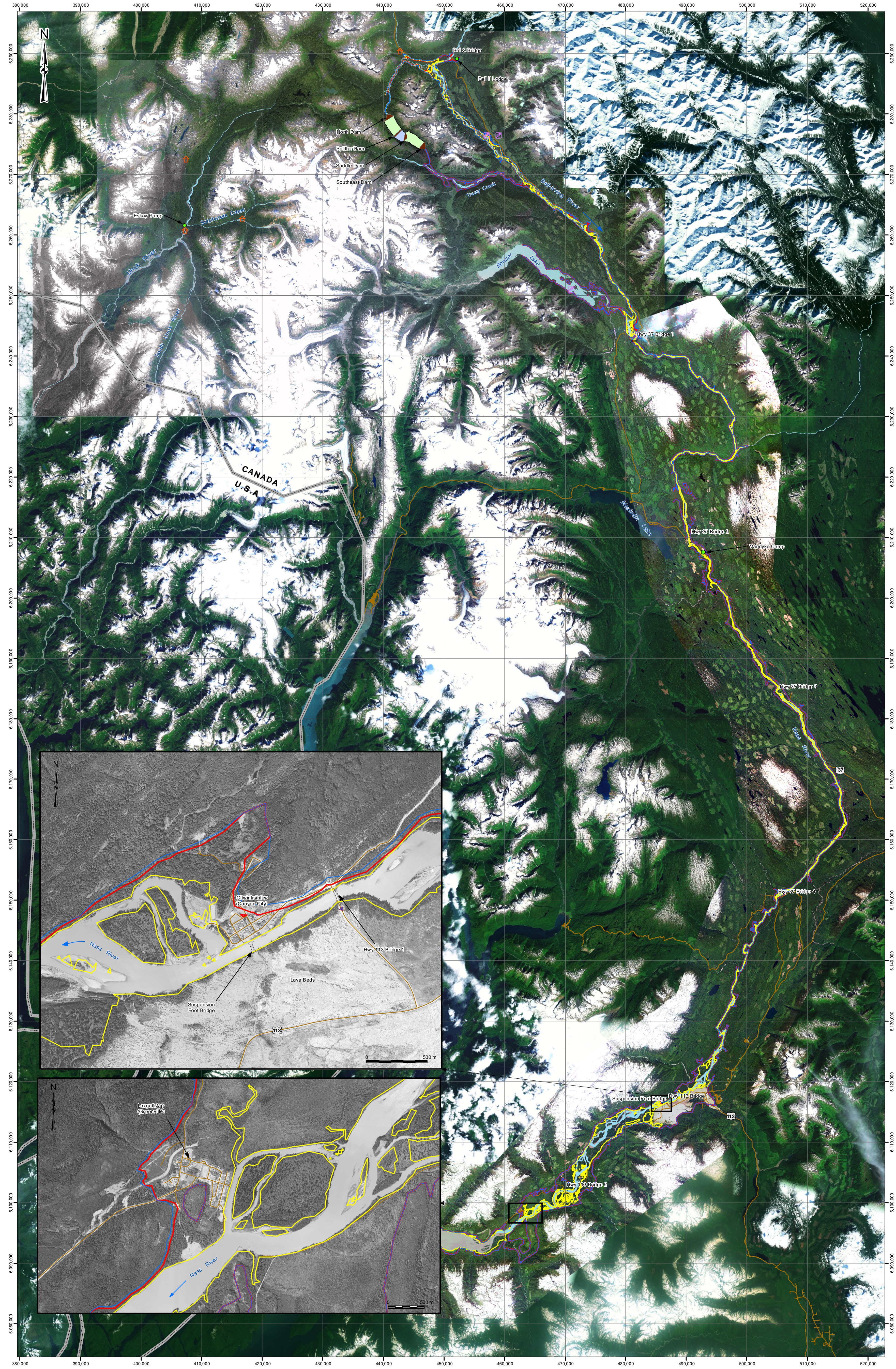
Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Water Depth (m)											
Concurrent River water Depth (PMF)				-	4.9	7.5	19.0	13.9	42.0	35.3	46.7	63.7	21.1	19.9	26.8
Concurrent River Water Depth (Mean Annual Flow)				-	2.2	2.7	4.1	1.9	3.5	2.5	1.7	3.3	1.6	5.6	2.1
Overtopping Failure -Increase above Base Flow (PMF)	1068.3	PMF	151	-	6.4	4.1	3.0	2.7	5.0	2.8	2.8	2.9	0.3	0.2	1
Piping Failure - Increase above Base Flow (MAF)	1062	MAF	38	-	5.9	4.0	4.6	2.1	6.4	3.0	2.6	3.2	1.4	1.0	1

Notes:
Water depths are rounded to the nearest 0.1 m.

Table 5.4 Ultimate North Dam Failure - Flood Arrival Times and Durations

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)		At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
					Flood timing (hr)											
Overtopping	1068.3	PMF	151	Arrival time (hr)	-	1.25	2	4.5	6.75	8.25	9.5	9.75	11.75	14.75	16.75	19.5
Overtopping	1068.3	PMF	151	Time to Peak (hr)	-	2.25	3.25	7.75	11	14	17	21	23.5	25.5	26.5	33.5
Overtopping	1068.3	PMF	151	Duration of Flooding (hr)	5.25	4.5	5.5	10.5	12.75	15.75	20	29	28	28.5	28	29
Piping	1062	MAF	38	Arrival time (hr)	-	1.25	2	9.5	14.45	19.5	22.5	27	33	39.75	41.25	59.75
Piping	1062	MAF	38	Time to Peak (hr)	-	1.75	3.25	13.25	18.5	23.75	28.75	34.25	42.25	53.75	55.75	83.75
Piping	1062	MAF	38	Duration of Flooding (hr)	5.5	5.5	8.5	22	22.55	28.75	29.25	30	37.25	43.5	43.25	44.25

Notes:
Times are rounded to the nearest 15 min.
Arrival time is defined as the time a 0.03 m increase above background level is predicted.
Time to peak is the time of maximum water level.
Duration of flooding is the difference between the time at which the flood wave returns to 0.1 m above background level and the flood arrival time.



Bridge

Remote Hunting Cabin

Cultural Site

Potential Inundation Area
(Overtopping Failure with Probable Maximum Flood)

Potential Inundation Area
(Piping Failure with Average Annual Flow)

Potential Inundatioin Area
(Probable Maximum Flood without dam breach)

Road/Highway

Tailings Dam

CIL Residue Pond

Tailings Pond

Study Area Waterbody

Notes:
1. Not all existing facilities are shown. Some facilities may have been missed and/or are unknown
2. UTM Zone 9N, NAD83
3. ESRI Online, RapidEye and aerial imagery
4. Roads from NRN and most waterbodies from NTS (1:250,000)
5. Cultural and remote hunting cabin sites provided by RESCAN
6. Flows concurrent with a hypothetical piping failure are Mean Annual Flows. They are confined within the main river channel and are not shown on this figure

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SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
TMF INUNDATION AREA
ULTIMATE NORTH DAM FAILURE

PROJECT No. M09480A04

FIG No. 5.5

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5.3 Splitter and Saddle Dams

The Splitter Dam is a compacted cyclone sand internal structure that separates flotation tailings from CIL tailings. The Saddle Dam is a compacted cyclone sand dam designed to retain CIL tailings until the South Cell is constructed at which point it will be contained/buttressed by the flotation tailings of the south cell. This section presents the results of a Midlife hypothetical cascading failure of both Splitter and Saddle Dams, before the Saddle Dam is buttressed by the flotation tailings of the South Cell.

Results of the analysis of the midlife Splitter/Saddle Dam cascading failures including discharges, flood depths and flood travel times at selected locations, are summarized in Table 5.6 to Table 5.8, and Figure 5.1 to Figure 5.4.

Table 5.6 to Table 5.8 show peak flows, peak water levels and timing of the flood wave at various locations of interest downstream of the dam and for the piping and overtopping failure base case scenarios.

For the overtopping failure scenario, results indicate that it would take approximately 5.5, 13 and 14 hours after the initiation of the breach for the flood to reach the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts'ap, respectively. Modeled water levels peak 10, 22, and 29 hours after the initiation of the breach at the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts'ap, respectively.

For the piping failure scenario, results indicate that it would take approximately 10.5, 28 and 39 hours after the initiation of the breach for the flood to reach the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts'ap, respectively. Modeled water levels peak 13, 40, and 70 hours after the initiation of the breach at the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts'ap, respectively.

Higher naturally occurring flows (PMF) during the hypothetical overtopping dam failure, as opposed to piping failure with concurrent Mean Annual Flows increase flood wave celerity and decrease flood wave travel time.

The modeled inundation lines resulting from hypothetical overtopping and piping failures of the Midlife Splitter and Saddle Dams are shown in Figure 5.6. They are compared to inundation lines resulting from naturally occurring PMF conditions.

Table 5.5 summarizes locations that would potentially be inundated by the various flow conditions.

Table 5.5 Midlife Splitter and Saddle Dams Failure - Modelled Inundated Locations

Location	Upstream Flood Entry Point Easting (m)	Upstream flood entry point Northing (m)	Length of the Inundated Segment (km)	Inundated by PMF + overtopping failure	Inundated by PMF + no breach	Inundated by MAF + piping failure
Bell2 lodge	451,050	6,289,500	-	Yes	Yes	No
HWY 37	468,300	6,265,000	0.3	**Yes**	**No**	**No**
HWY 37	470,500	6,263,500	6	**Yes**	**No**	**No**
HWY 37	476,300	6,255,800	9.5	**Yes**	**No**	**No**
HWY 37	481,800	6,243,600	2	Yes	Yes	No

Location	Upstream Flood Entry Point Easting (m)	Upstream flood entry point Northing (m)	Length of the Inundated Segment (km)	Inundated by PMF + overtopping failure	Inundated by PMF + no breach	Inundated by MAF + piping failure
HWY 37	491,500	6,209,000	9	Yes	Yes	No
HWY 37	496,890	6,200,300	2	Yes	Yes	No
HWY 37	498,500	6,195,000	1.4	Yes	Yes	No
HWY 37	500,600	6,197,000	1.7	Yes	Yes	No
HWY 37	502,800	6,189,100	16	Yes	Yes	No
HWY 113	493,600	6,118,300	From Gitwinksihlkw to Portland Inlet	Yes	Yes	No

Results shows that Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville), 10 highway sections as well as existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will be inundated by an overtopping failure of the Midlife Splitter and Saddle Dams. However, most of these locations would also be flooded under naturally occurring flows (PMF), therefore the incremental consequence of a Midlife Splitter and Saddle Dams overtopping failure is small.

Results show that neither Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City) and Laxgalts'ap (Greenville) nor any section of Highway 37 and Highway 113 will be inundated by a piping failure of the Midlife Splitter and Saddle Dam. However, existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will likely be inundated by a piping failure of the Midlife Splitter and Saddle Dams while they are not inundated under concurrent Mean Annual Flows. Therefore, the incremental consequence of a Midlife Splitter and Saddle Dams piping failure is significant.

Table 5.6 Midlife Splitter/Saddle Dam Failure – Discharge

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Flow (m^3/s)											
Concurrent River Flow (PMF)				2,200	2,200	6,100	8,300	18,800	19,300	34,700	34,700	42,750	50,800	50,800	50,800
Concurrent River Flow (Mean Annual Flow)				30	30	70	100	290	300	480	480	480	782	782	782
Overtopping	1006.3	PMF	227	26,700	-	-	29,300	34,900	29,300	42,100	40,700	47,200	55,100	55,100	53,600
Piping	994	MAF	38	15,100	-	-	8,100	3,700	2,700	2,700	2,400	2,100	1,700	1,700	1,300

Notes:
Flows shown include concurrent flow in rivers.
Flows are rounded to the nearest 100 m3/s.

Table 5.7 Midlife Splitter/Saddle Dam Failure – Water Depths

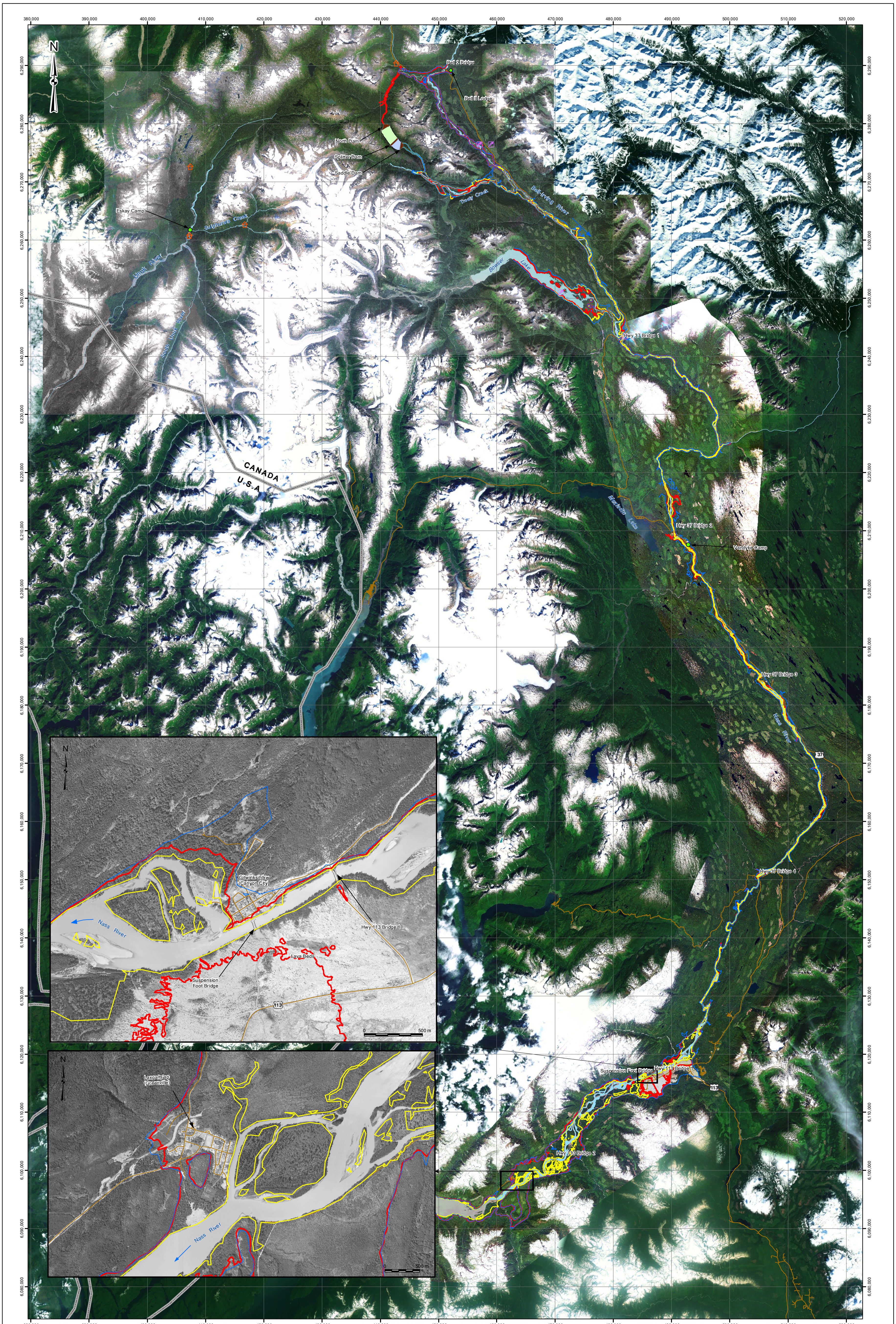
Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Water Depth (m)											
Concurrent River water Depth (PMF)				-	-	-	19.1	13.9	41.8	35.3	46.7	63.7	21.1	19.9	26.8
Concurrent River Water Depth (Mean Annual Flow)				-	-	-	4.1	1.7	3.8	2.5	1.7	3.3	1.6	5.6	2.1
Overtopping Failure -Increase above Base Flow (PMF)	-	PMF	227	-	-	-	13.5	6.2	8.6	5.4	4.9	5.0	0.5	0.4	0.6
Piping Failure - Increase above Base Flow (MAF)	-	MAF	38	-	-	-	14.7	4.1	11.3	5.6	4.6	5.4	2.3	1.6	1.2

Notes:
Water depths are rounded to the nearest 0.1 m.

Table 5.8 Midlife Splitter/Saddle Dam Failure – Flood Arrival Times and Durations

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)		At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
					Flood timing (hr)											
Overtopping	1068.3	PMF	151	Arrival time (hr)	-	-	-	2	4.25	5.5	6.5	8	8.5	11.25	12.75	14
Overtopping	1068.3	PMF	151	Time to Peak (hr)	-	-	-	4.25	7.5	9.75	12.5	16.25	18.75	20.5	21.75	28.5
Overtopping	1068.3	PMF	151	Duration of Flooding (hr)	7.25	-	-	7	10.5	15.75	19	28	30.75	32	33.75	34.5
Piping	1062	MAF	38	Arrival time (hr)	-	-	-	2.75	6.5	10.5	12	17.75	21	26.75	28	38.5
Piping	1062	MAF	38	Time to Peak (hr)	-	-	-	3.25	8	12.75	15.75	21	28	38.5	39.75	69.5
Piping	1062	MAF	38	Duration of Flooding (hr)	6.75	-	-	7.25	12.75	19.25	21	21	30.25	40	40	41.5

Notes:
Times are rounded to the nearest 15 min.
Arrival time is defined as the time a 0.03 m increase above background level is predicted.
Time to peak is the time of maximum water level.
Duration of flooding is the difference between the time at which the flood wave returns to 0.1 m above background level and the flood arrival time.



- ⟗ Bridge
- ⌂ Remote Hunting Cabin
- ✎ Cultural Site
- Potential Inundation Area (Overtopping Failure with Probable Maximum Flood)
- Potential Inundation Area (Piping Failure with Average Annual Flow)
- Potential Inundatioin Area (Probable Maximum Flood without dam breach)
- Road/Highway
- 🟫 Tailings Dam
- 🟦 CIL Residue Pond
- 🟩 Tailings Pond
- 🟦 Study Area Waterbody

Notes:
1. Not all existing facilities are shown. Some facilities may have been missed and/or are unknown
2. UTM Zone 9N, NAD83
3. ESRI Online, RapidEye and aerial imagery
4. Roads from NRN and waterbodies from NTS (1:250,000)
5. Cultural and remote hunting cabin sites provided by RESCAN
6. Flows concurrent with a hypothetical piping failure are Mean Annual Flows. They are confined within the main river channel and are not shown on this figure

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SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
TMF INUNDATION AREA
CASCADING MIDLIFE FAILURE OF
SPLITTER AND SADDLE DAMS

PROJECT No. M09480A04

FIG No. 5.6

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5.4 Ultimate Southeast Dam

Results of the dam failure analysis for the Ultimate Southeast Dam, including discharges, flood depths and flood travel times at selected locations, are summarized in Table 5.10 to Table 5.12, and Figure 5.1 to Figure 5.4. The Ultimate stage has been identified as the most critical case in terms of hypothetical dam failure; therefore intermediate stages are not investigated in this study.

Table 5.10 to Table 5.12 show peak flows, peak water levels and timing of the flood wave at various locations of interest downstream of the dam, and for the piping and overtopping failure base case scenarios.

For the overtopping failure scenario, results indicate that it would take approximately 5, 10 and 11 hours after the initiation of the breach for the flood to reach the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts’ap, respectively. Modeled water levels peak 9.5, 17.5, and 23 hours after the initiation of the breach at the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts’ap, respectively.

For the piping failure scenario, results indicate that it would take approximately 11, 22 and 28.5 hours after the initiation of the breach for the flood to reach the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts’ap, respectively. Modeled water levels peak 14, 28, and 43.5 hours after the initiation of the breach at the Bell Irving/Nass confluence, Gitwinksihlkw, and Lxgalts’ap, respectively.

Higher naturally occurring flows (PMF) during the hypothetical overtopping dam failure, as opposed to piping failure with concurrent Mean Annual Flows increase flood wave celerity and decrease flood wave travel time.

The modeled inundation lines resulting from hypothetical overtopping and piping failures of the ultimate North Dam are shown in Figure 5.7. They are compared to inundation lines resulting from naturally occurring PMF conditions.

Table 5.9 summarizes locations that would potentially be inundated by the various flow conditions.

Table 5.9 Ultimate Southeast Dams Failure - Modelled Inundated Locations

Location	Upstream Flood Entry Point Easting (m)	Upstream flood entry point Northing (m)	Length of the Inundated Segment (km)	Inundated by PMF + overtopping failure	Inundated by PMF + no breach	Inundated by MAF + piping failure
Bell2 lodge	451,050	6,289,500	-	Yes	Yes	No
HWY 37	468,300	6,265,000	0.3	**Yes**	**No**	**No**
HWY 37	470,500	6,263,500	6	**Yes**	**No**	**No**
HWY 37	476,300	6,255,800	9.5	**Yes**	**No**	**No**
HWY 37	481,800	6,243,600	2	Yes	Yes	No
HWY 37	491,500	6,209,000	9	Yes	Yes	No
HWY 37	496,890	6,200,300	2	Yes	Yes	No
HWY 37	498,500	6,195,000	1.4	Yes	Yes	No
HWY 37	500,600	6,197,000	1.7	Yes	Yes	No
HWY 37	502,800	6,189,100	16	Yes	Yes	No
HWY 113	493,600	6,118,300	From Gitwinksihlkw to Portland Inlet	Yes	Yes	No

Results shows that Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville), 10 highway sections, as well as existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will likely be inundated by an overtopping failure of the Ultimate Southeast Dam. However, most of these locations would also be flooded under naturally occurring flows (PMF), therefore the incremental consequence of an Ultimate Southeast Dams overtopping failure is small.

Results shows that neither Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City) and Laxgalts'ap (Greenville) nor any section of Highway 37 and Highway 113 will be inundated by a piping failure of the Ultimate Southeast Dam. However, existing cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will likely be inundated by a piping failure of the Ultimate Southeast Dam, while they are inundated under concurrent Mean Annual Flows. Therefore, the incremental consequence of an Ultimate Southeast Dam piping failure is significant.

Table 5.10 Ultimate Southeast Dam Failure – Discharge

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Flow (m^3/s)											
Concurrent River Flow (PMF)				2,200	2,200	6,100	8,300	18,800	19,300	34,700	34,700	42,750	50,800	50,800	50,800
Concurrent River Flow (Mean Annual Flow)				30	30	70	100	290	300	480	480	480	782	782	782
Overtopping	1068.3	PMF	209	27,000	-	-	29,700	30,800	26,900	41,000	40,000	46,900	54,900	54,800	53,500
Piping	1062	MAF	107	9,000	-	-	4,700	2,100	1,700	1,900	1,800	1,800	1,800	1,800	1,300

Notes:
Flows shown include concurrent flow in rivers.
Flows are rounded to the nearest 100 m3/s.

Table 5.11 Ultimate Southeast Dam Failure – Water Depth

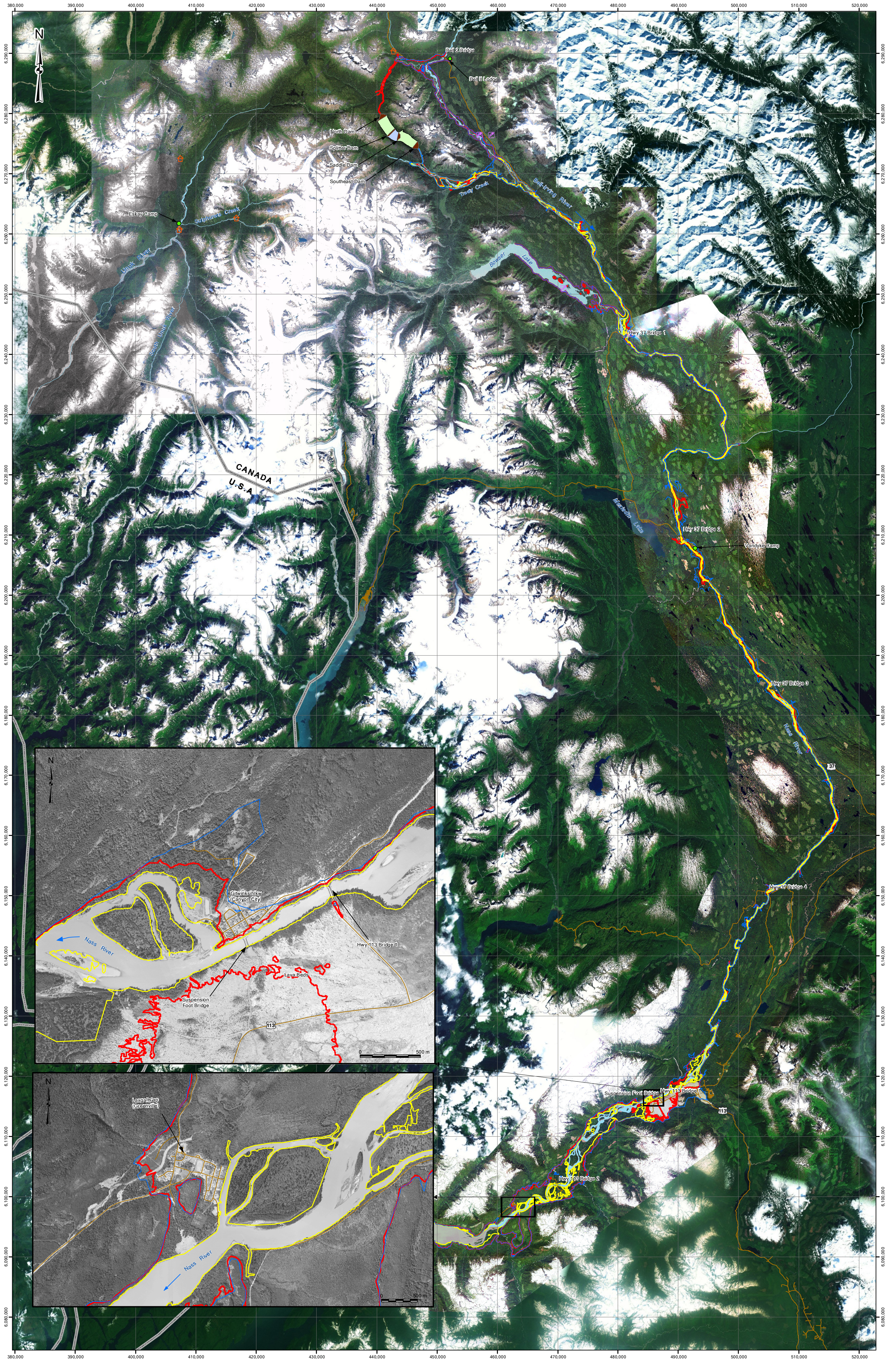
Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
				Water Depth (m)											
Concurrent River water Depth (PMF)				-	-	-	19.1	13.9	41.8	35.3	46.7	63.7	21.1	19.9	26.8
Concurrent River Water Depth (Mean Annual Flow)				-	-	-	4.1	1.7	3.8	2.5	1.7	3.3	1.6	5.6	2.1
Overtopping Failure -Increase above Base Flow (PMF)	1068.3	PMF	209	-	-	-	13.1	6.5	8.6	4.7	4.6	4.3	0.4	0.4	0.6
Piping Failure - Increase above Base Flow (MAF)	1062	MAF	107	-	-	-	10.3	2.8	8.1	2.3	2.4	2.2	1.2	1.6	0.6

Notes:
Water depths are rounded to the nearest 0.1 m.

Table 5.12 Ultimate Southeast Dam Failure - Flood Arrival Times and Durations

Failure Scenario	Reservoir Elevation at Failure (m)	Concurrent Stream Flow	Total Outflow Volume (Mm^3)		At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River downstream of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River	Nass River at Bridge 2	Nass River at Bridge 4	Nass River at Bridge 5	Nass River at New Aiyansh	Nass River at Gitwinksihlkw (Canyon City)	Nass River at Lxgalts'ap (Greenville)
					Flood timing (hr)											
Overtopping	1068.3	PMF	151	Arrival time (hr)	-	-	-	1.75	3.75	5	6	6	7	8.75	9.75	10.75
Overtopping	1068.3	PMF	151	Time to Peak (hr)	-	-	-	3.75	7	9.5	10.25	13.25	15	16.5	17.5	22.75
Overtopping	1068.3	PMF	151	Duration of Flooding (hr)	6.25	-	-	6.75	10.75	15.75	18.5	26.5	28	28.5	29	29.75
Piping	1062	MAF	38	Arrival time (hr)	-	-	-	2.5	6.75	11.25	13	15.75	18.75	21.25	22	28.5
Piping	1062	MAF	38	Time to Peak (hr)	-	-	-	3	8.25	14	16	10.25	22.5	26.25	28.25	43.5
Piping	1062	MAF	38	Duration of Flooding (hr)	6.25	-	-	7	12.25	18	16.5	16.5	19	14.5	20.75	36.5

Notes:
Times are rounded to the nearest 15 min.
Arrival time is defined as the time a 0.03 m increase above background level is predicted.
Time to peak is the time of maximum water level.
Duration of flooding is the difference between the time at which the flood wave returns to 0.1 m above background level and the flood arrival time.



)(	Bridge	―	Potential Inundation Area (Overtopping Failure with Probable Maximum Flood)	🟫	Tailings Dam
⌂	Remote Hunting Cabin	―	Potential Inundation Area (Piping Failure with Average Annual Flow)	🟦	CIL Residue Pond
▨	Cultural Site	―	Potential Inundatioin Area (Probable Maximum Flood without dam breach)	🟩	Tailings Pond
		―	Road/Highway	🟦	Study Area Waterbody

Notes:
1. Not all existing facilities are shown. Some facilities may have been missed and/or are unknown
2. UTM Zone 9N, NAD83
3. ESRI Online, RapidEye and aerial imagery
4. Roads from NRN and waterbodies from NTS (1:250,000)
5. Cultural and remote hunting cabin sites provided by RESCAN
6. Flows concurrent with a hypothetical piping failure are Mean Annual Flows. They are confined within the main river channel and are not shown on this figure

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PROJECT
KSM PROJECT
DAM BREAK AND INUNDATION STUDY

TITLE
TMF INUNDATION AREA
ULTIMATE SOUTHEAST DAM FAILURE

PROJECT No. M09480A04

FIG No. 5.7

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5.5 Sensitivity analysis

Analyses were conducted to test the sensitivity of model results to model parameters such as Manning's roughness coefficient (n) and breach formation time. Sensitivity to Manning's roughness coefficient (n) was assessed through simulations with a Manning's n equal to 0.05, 0.10 and 0.15, and noting relative changes in flows and water levels. Breach formation time is related to dam height but different empirical equations (e.g. MacDonald 1984, BC Hydro 1992, and Von Thun & Gillette 1990) yield different estimates. Sensitivity to breach formation time was assessed through simulations with breach formations times equal to 3, 5, and 7 hours for the Ultimate North Dam and Midlife Splitter/Saddle Dams, and equal to 3.5, 6 and 8 hours for the Ultimate Southeast Dam, and noting relative changes in flows and water levels.

In general, an increased value of the Manning's roughness coefficient (n):

- induces greater water depths overall for a set discharge;
- reduces wave celerity, resulting in a delayed flood wave; and,
- increases the attenuation of the flood wave going downstream, resulting in decreased peak water level, and increased flood duration.

The model sensitivity to a varying Manning's roughness coefficient is insignificant immediately downstream of the dam and becomes increasingly significant as the wave moves downstream.

In general, an increased breach formation time allows for a more gradual release of water and tailings, thus reducing peak flow and peak water level, and increasing the duration of the flood wave. The initial lag due to different values of breach formation time does not vary as the flood wave travels downstream.

Table 5.13 presents a summary of variations in flow rates resulting from variations in input parameters.

Table 5.13 Sensitivity Analysis - Variation in Peak Flow

Failure	Sensitivity to Parameter	Departure From Base Case	At Dam	Snowbank Cr downstream of Teigen Cr	Bell Irving River downstream of Snowbank Cr	Bell Irving River d/s of Treaty Cr	Bell Irving River downstream of Bowser River	Bell Irving River upstream of Nass River
		Departure from base case						
Overtopping North (Ultimate North Dam)	Manning's n	50%	0%	0%	10%	50%	60%	60%
		150%	0%	0%	0%	-30%	-30%	-30%
	Breach Formation Time	60%	70%	70%	50%	0%	0%	0%
		140%	-30%	-30%	-30%	-10%	0%	0%
Piping North (Ultimate North Dam)	Manning's n	50%	0%	10%	30%	50%	60%	60%
		150%	0%	0%	-20%	-30%	-30%	-30%
	Breach Formation Time	60%	50%	30%	30%	0%	0%	0%
		140%	-20%	-20%	-10%	-10%	0%	0%
Overtopping South (Midlife Splitter/Saddle Dam and ultimate Southeast Dam)	Manning's n	50%	0%	0%	20%	40%	50%	50%
		150%	0%	0%	-20%	-20%	-20%	-30%
	Breach Formation Time	60%	70%	50%	20%	0%	0%	0%
		130%	-30%	-20%	-10%	-10%	-10%	0%
Piping South (Midlife Splitter/Saddle Dam and ultimate Southeast Dam)	Manning's n	50%	0%	20%	50%	60%	60%	60%
		150%	0%	-10%	-20%	-30%	-30%	-30%
	Breach Formation Time	60%	70%	20%	10%	0%	0%	0%
		130%	-20%	-10%	-10%	-10%	-10%	0%

5.6 Tailings Runout

A breach of any one of the tailings dam would release tailings and water into the downstream river. Table 4.1 shows the estimated volume of tailings that would be released from the various impoundments. The volumes of tailings which would either be deposited in the river and floodplains downstream of the tailings dam were estimated using a repose angle of 5°. The methodology for these estimates is described in Section 4.3.3.

During an overtopping failure, which is most likely to coincide with a PMF event, a significant amount of water is present within the impoundment and high flows would be present in the receiving water bodies, therefore it is reasonable to assume that no tailings would locally accumulate outside of the tailings impoundment following an overtopping failure. The tailings would mix with the water flows and be transported downstream initially by the dam breach flow and then continue with the flows associated with the PMF until velocities reduce and stream gradients allow deposition.

The volume of tailings that would deposit outside of the impoundment following a piping failure is based on the angle of repose assumed for the tailings. Based on historical data reported in literature for tailings dam failures, it was assumed that tailings would not accumulate or form deposits on slopes greater than 3°.The value of 3° is slightly lower than the residual angle of repose of 5° due to water transport. The tailings may deposit in thin layers on ground slopes greater than 3° but the amount would likely not be significant compared to flatter areas. The results of this order of magnitude estimate of tailings deposition based on river slopes indicate the following:

- For a North Dam piping failure, the tailings are expected to deposit at two locations. The first location would be from the North Dam toe to approximately 1.4 km downstream of the toe, with approximately 20 Mm^3 of flotation tailings deposited at this location. The second location would between 6.3 km and 9.4 km downstream of the North Dam toe, with approximately 220 Mm^3 of flotation tailings deposited at this location. No deposition was assumed between 1.4 km and 6.3 km since the ground slope exceeds 3°.
- For a Southeast Dam piping failure, about 290 Mm^3 of flotation tailings would be deposited between 4 km and 6.6 km from the downstream toe of the Southeast Dam. No tailings deposition is assumed to occur immediately downstream of the dam since the ground slope exceeds 3°.

Figure 5.8 show approximate locations of the tailings deposition for the North and Southeast dams during a hypothetical piping failure.

5.7 Rate of Floor Rise

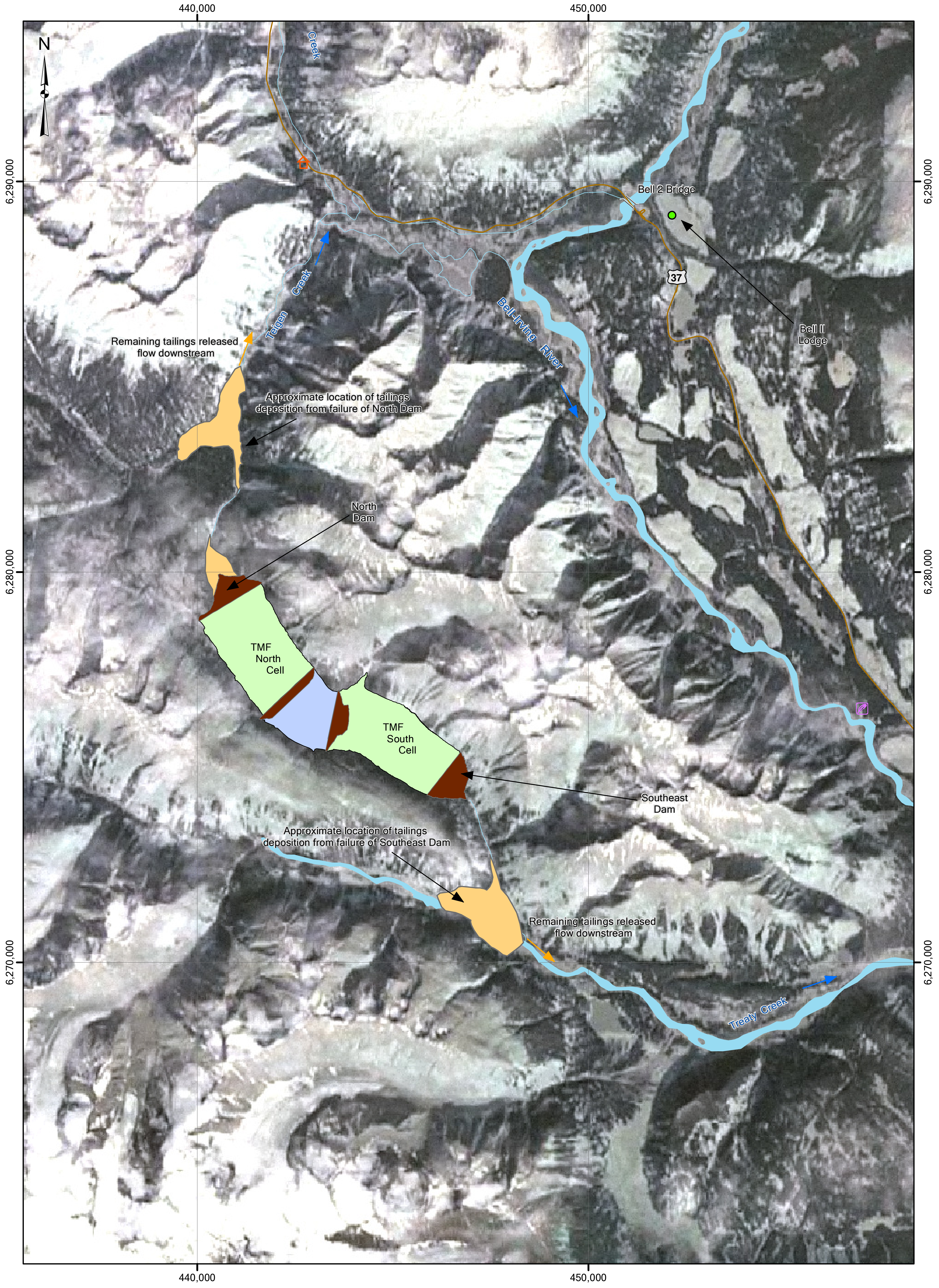
The rate of flood rise during the overtopping and piping failure scenarios are summarized in

Table 5.14 Summary of Rate of Flood Rise

Dam Break Mode	Dam	Rate of Flood Rise (m/hr)	
		Bell Irving / Nass confluence	Nass River at Gitwinksihlkw (Canyon City)
Overtopping Failure	Ultimate North Dam	0.9	0.02
	Midlife Splitter/Saddle Dam	2	0.04
	Ultimate Southeast Dam	1.9	0.1
Piping Failure	Ultimate North Dam	1.5	0.1
	Midlife Splitter/Saddle Dam	5	0.01
	Ultimate Southeast Dam	2.9	0.3

The rate of rise is determined as the change in elevation divided by the time between the initiation of the flood wave and when the peak of the flood wave occurs. The rate of rise for the piping failure mode is typically higher than for the overtopping mode because there is less water in the river during average conditions than during the flood condition so the incremental raise is more pronounced. The rate of rise for the piping failure mode for the Midlife Splitter/Saddle Dam is higher due to the presence of more water (North Cell and CIL Cell), although this condition is temporary as the dams are ultimately buttressed by the South Cell.

afischer
Z:\M\VCR\M09480A04 - KSM 2012 PFS\400 Drawings\GIS\mxd\dam_break\TMF\fig5.8_north&SE_tailings_deposition.mxd



⌯	Bridge	🟧	Tailings Deposition
⌂	Remote Hunting Cabin	🟩	Tailings Pond
✎	Cultural Site	🟦	CIL Residue Pond
—	Road/Highway	🟫	Tailings Dam

1. Landsat imagery downloaded with Global Mapper.
2. Roads from NRN and most waterbodies from NTS (1:250,000).
3. Cultural and remote hunting cabin sites provided by RESCAN.
4. UTM Zone 9N, NAD83.

NOT FOR CONSTRUCTION

0 5 km

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
TMF DAM BREAK AND INUNDATION STUDY

TITLE
NORTH DAM AND SOUTHEAST DAM
PIPING FAILURE
TAILINGS DEPOSITION

PROJECT No. M09480A04
FIG No. 5.8

6 SUMMARY

Flood inundation limits presented herein are based on hypothetical failures of the Ultimate North Dam, Midlife Splitter and Saddle Dams, and Ultimate Southeast under highly unlikely scenarios, particularly the overtopping mode of failure which would have the largest downstream impact. The results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dam.

The dam break analysis utilized the HEC-RAS hydrodynamic computer model, developed by the US Army Corps of Engineers. The model covered the entire reach from the various dams to Portland Inlet. Breach Peak flow at the various dams is sensitive to the assumed breach formation time. The shorter the breach formation time the higher the dam breach peak discharge. The attenuation of the flood as it travels downstream is dependent on assumed Manning’s roughness coefficient (n). The larger the roughness coefficient, the larger the attenuation.

The various dam breaches lead to a flood wave that would move downstream, decreasing in elevation change. The facilities downstream include:

- habitations, towns and villages including Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts’ap (Greenville);
- cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains; and,
- up to 12 sections of Highways 37 and 113.

The modelling consequences of a dam breach are summarized as follows:

- Overtopping failures of the main dams during PMF conditions result in a flood wave that varies from approximately 3 m to 8 m high at the Bell Irving /Nass Confluence to less than 2 m high at Gitwinksihlkw (Canyon City). Other observations include:
  - The extent of the flood wave is similar to that of the naturally occurring PMF levels, especially in the downstream section of the river network, along the Nass River. The incremental consequence of an overtopping failure in terms of life safety and potential damage to property along the Bell Irving and Nass Rivers (as defined in the CDA Dam Safety Guidelines), is considered to be negligible.
  - The rate of rise of the flood wave from the overtopping failure is in the order of 1 m/hr to 2 m/hr near the Bell Irving/Nass confluence, reducing to in the order of 0.02 m/hr to 0.1 m/hr near the Nass River at Gitwinksihlkw (Canyon City).
- Piping failure of the main dams during normal operations results in a flood wave that varies from approximately 6 m to 11 m high at the Bell Irving/Nass Confluence to less than 1.6 m high at Gitwinksihlkw (Canyon City). Additional observations include:

  - Habitations, towns and villages including Bell 2 Lodge, New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville) are not expected to be flooded during a piping failure of any of the various dams. Cabins and outfitter/guide facilities located on riverbanks, floodplains or close to natural floodplains will likely be flooded by a piping failure
  - A piping failure of any of the dams may have more noticeable incremental consequences as it could include flooding above annual average levels and as a result some cabins and outfitter/guide locations could be flooded and there could also be some loss of life.
  - The rate of rise of the flood wave from the piping failure is in the order of 1.5 m/hr to 3 m/hr near the Bell Irving/Nass confluence, reducing to in the order of 0.1 m/hr to 0.3 m/hr near the Nass River at Gitwinksihlkw (Canyon City)
- Overtopping or piping failure of the Midlife Splitter/Saddle Dam results in a higher flood wave due to the cascading water volumes from the North Cell and the CIL Cell. However, this is a temporary condition and this condition is eliminated as the CIL Cell becomes buttressed with the South Cell later in the mine life.

7 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Seabridge Gold Inc. (Client) for the specific application to the KSM 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.

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APPENDIX I

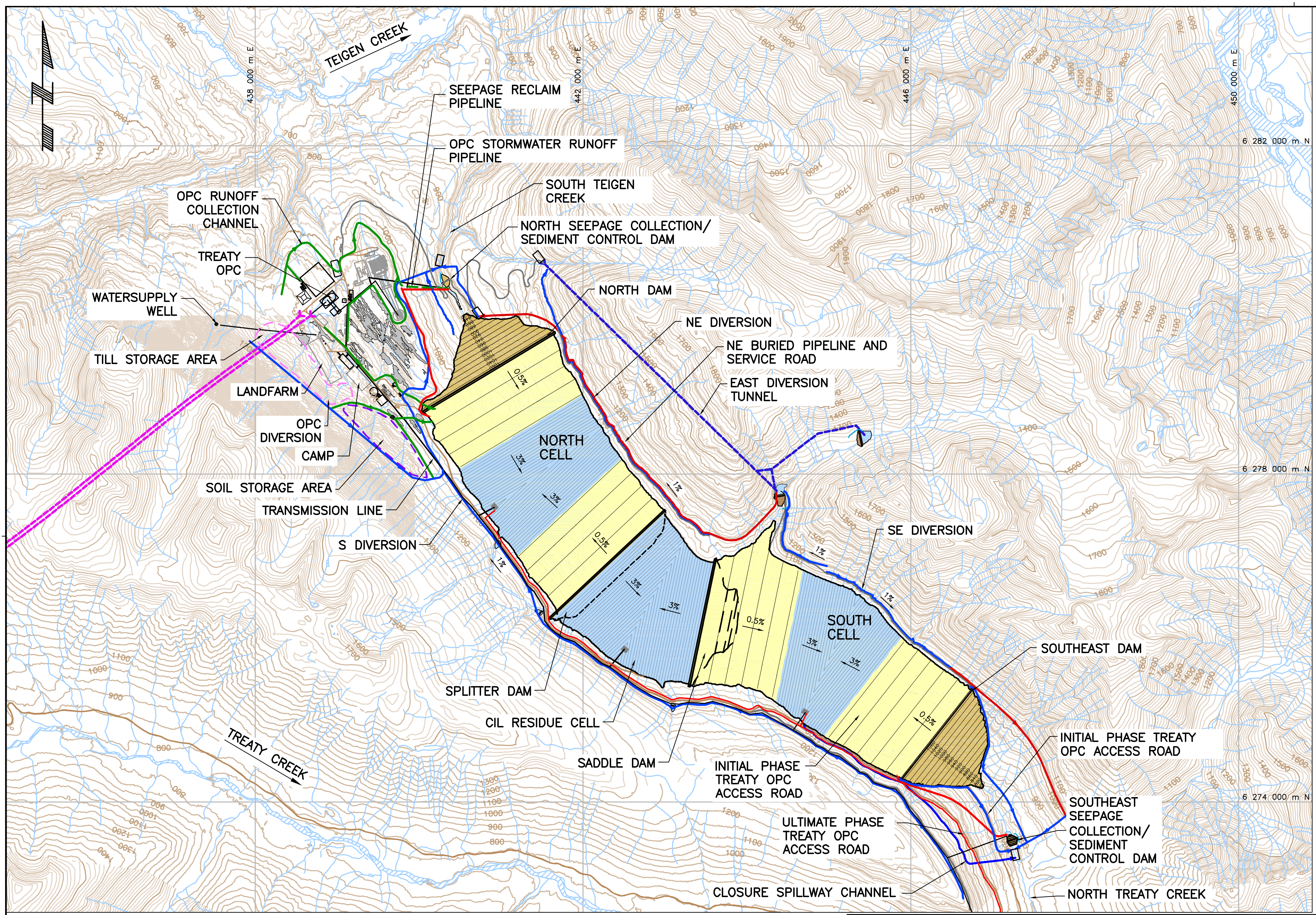
TMF Drawings from TMF Engineering Design Update Report

D-4101 – TMF General Arrangement

D-4105 – North Cell North Dam Design Geological Section

D-4106 – CIL Residue Cell Design Geological Sections

D-4107 – South Cell Design Geologic Sections



LEGEND

―	TRANSMISION LINE
―	SERVICE ROAD
―	PROPOSED ACCESS ROAD
←	CONTACT WATER DIVERSION
←	FRESH WATER DIVERSION
←	PIPELINE
‐ ‐ ‐	DIVERSION TUNNEL
═ ═ ═	TWIN ORE HAULAGE / SERVICE TUNNELS FROM MITCHELL TO TREATY OPC
▨	CYCLONE SAND DAMS
▭	TAILING
▭	TAILING POND
■	RECLAIM BARGE
⬬	WETLAND (FEB 2010)

NOTES

1. BASEMAP 10m INTERVAL CONTOUR LIDAR DATA RECEIVED FROM SEABRIDGE, SEPT, 2008, AND 20m INTERVAL CONTOUR FROM BC TRIM DATA.
2. DATUM: NAD83 UTM ZONE 9.
3. TMF TREATY ORE PROCESSING COMPLEX AND CAMP RECEIVED ON MAY 11, 2012.

NOT FOR CONSTRUCTION

SCALE: 0 1000 m

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B	JULY, 2012	DRAFT – ISSUED FOR CLIENT REVIEW	AW	MB	HP	GP
A	JUNE 8, 2012	DRAFT – ISSUED FOR CLIENT REVIEW	AW	MB	HP	GP

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
2012 TMF ENGINEERING DESIGN

TITLE
TAILING MANAGEMENT FACILITY
GENERAL ARRANGEMENT

SCALE	PROJECT No.	DWG. No.	REV.
AS SHOWN	M09480A04	D-4101	D

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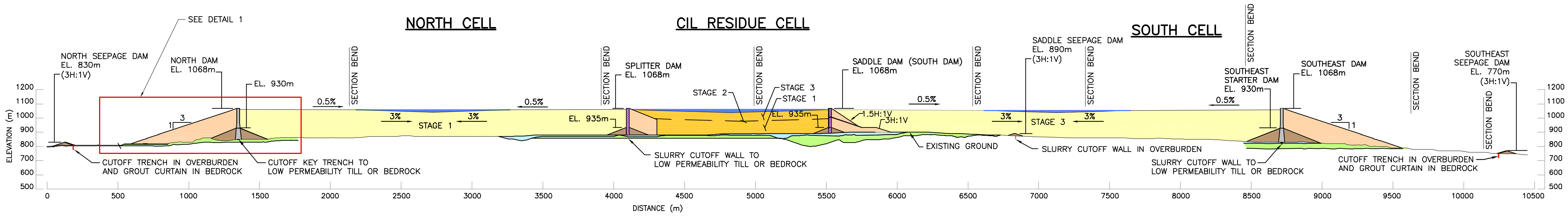

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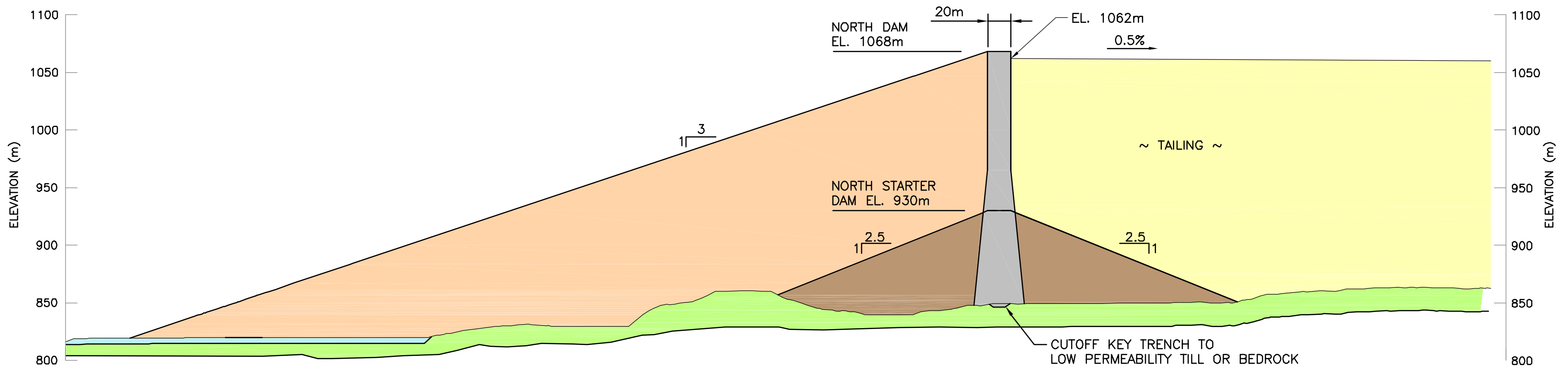
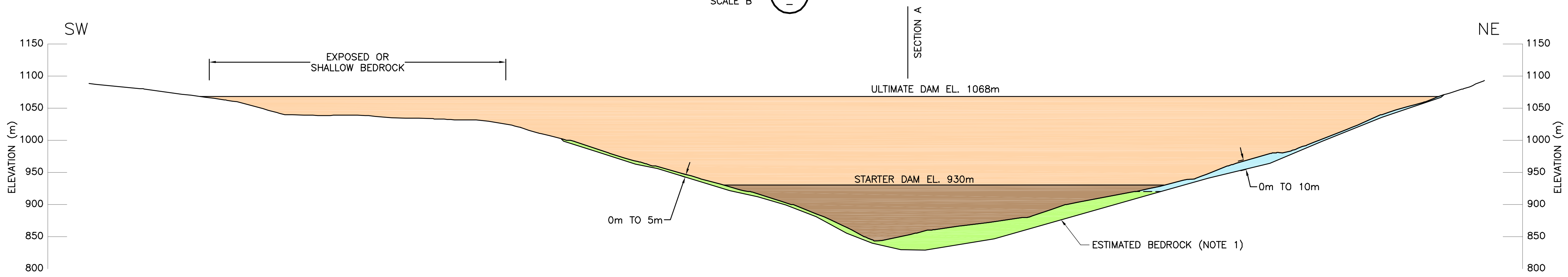


DETAIL (1) – **NORTH DAM**
SCALE B



SECTION (B) 4102 **NORTH DAM CENTERLINE**
SCALE C

LEGEND

🟩	TILL (INCLUDES UP TO 5m ALLUVIUM OR COLLUVIUM)
▨	TILL
▨	CYCLONE SAND
▨	COMPACTED RANDOM FILL
▨	FLOTATION (ROUGHER) TAILING
🟨	CIL RESIDUE (CLEANER) TAILING
▨	COLLUVIUM OR ALLUVIUM >5m
🟦	RECLAIM POND

NOTE

1. ESTIMATED FROM GEOPHYSICAL SEISMIC REFRACTION SURVEYS, DRILLING, AND GEOLOGY MAPPING.

SCALE A: 0 1000 m
SCALE B: 0 200 m
SCALE C: 0 200 m

NOT FOR CONSTRUCTION

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B	JULY, 2012	DRAFT – ISSUED FOR CLIENT REVIEW	AW	MB	HP	GP
A	JUNE 8, 2012	DRAFT – ISSUED FOR CLIENT REVIEW	AW	MB	HP	GP

DRAWING NO.	REFERENCE DRAWING

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
2012 TMF ENGINEERING DESIGN

TITLE
NORTH CELL
DESIGN GEOLOGIC SECTIONS

SCALE: AS SHOWN
PROJECT No.: M09480A04
DWG. No.: D–4105
REV.: C

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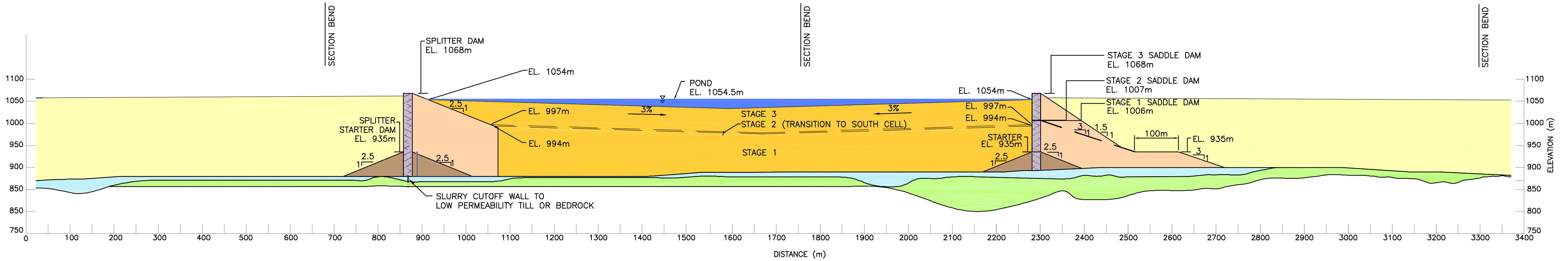

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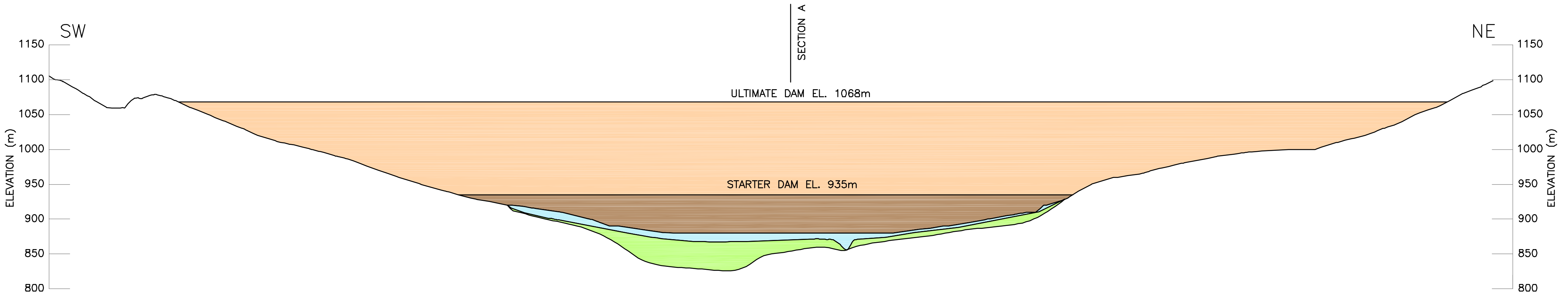

SECTION (C) SPLITTER DAM CENTERLINE

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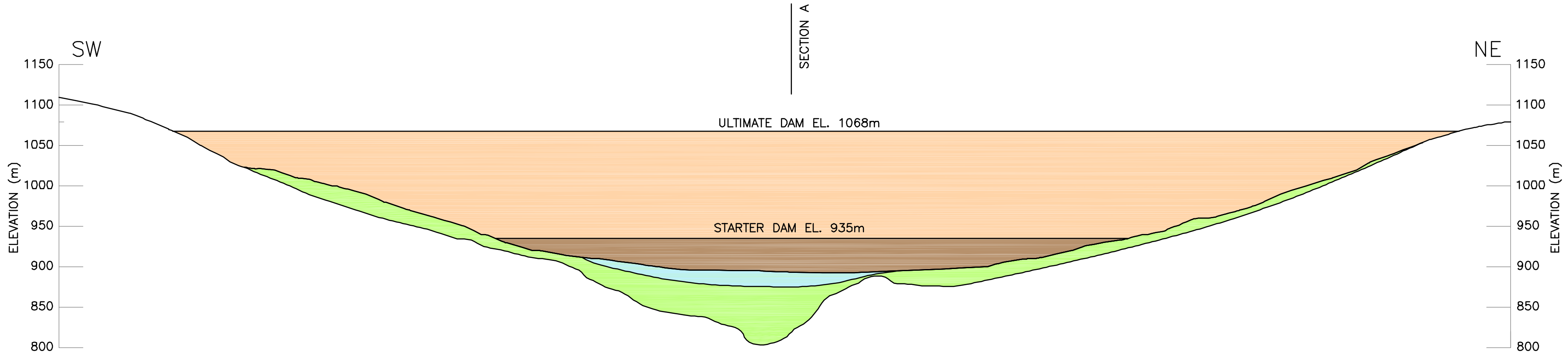

SECTION (D) SADDLE DAM CENTERLINE

SCALE B 4102

LEGEND

🟩	TILL BLANKET OR VENEER
▨	TILL (LINER BEDDING)
▨	CYCLONE SAND
▨	COMPACTED RANDOM FILL
🟨	FLOTATION (ROUGHER) TAILING
🟧	CIL RESIDUE (CLEANER) TAILING
▨	ALLUVIAL OR COLLUVIAL MATERIALS
🟦	RECLAIM POND
– – – –	HDPE LINER

NOTES

1. OVERBURDEN DEPTHS AND MATERIALS FROM GEOPHYSICAL SEISMIC REFRACTION AND RESISTIVITY SURVEYS, AND DRILLING.
2. BEDROCK DEPTH FROM SURFICIAL GEOLOGY MAPPING OF OUT CROP, DRILLING AND GEOPHYSICAL SURVEYS.

SCALE A: 0 250 m

SCALE B: 0 200 m

NOT FOR CONSTRUCTION

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CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
2012 TMF ENGINEERING DESIGN

TITLE
CIL RESIDUE TAILING CELL
DESIGN GEOLOGIC SECTIONS

SCALE: AS SHOWN
PROJECT No.: M09480A04
DWG. No.: D–4106
REV.: C

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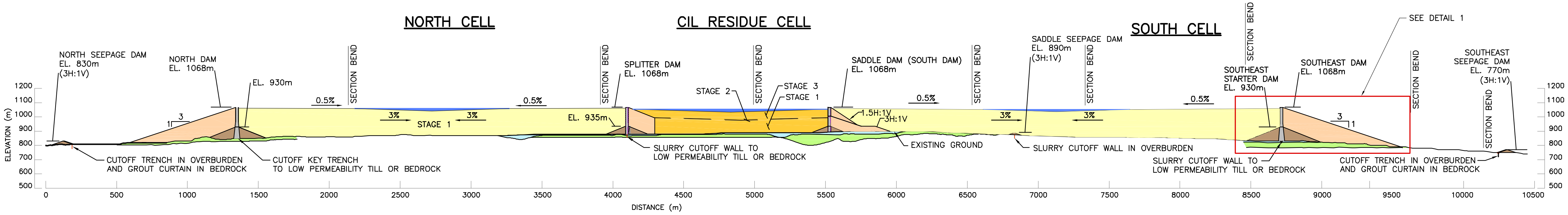

SECTION A DAM AND TAILING CROSS-SECTION FULLY LINED CIL POND

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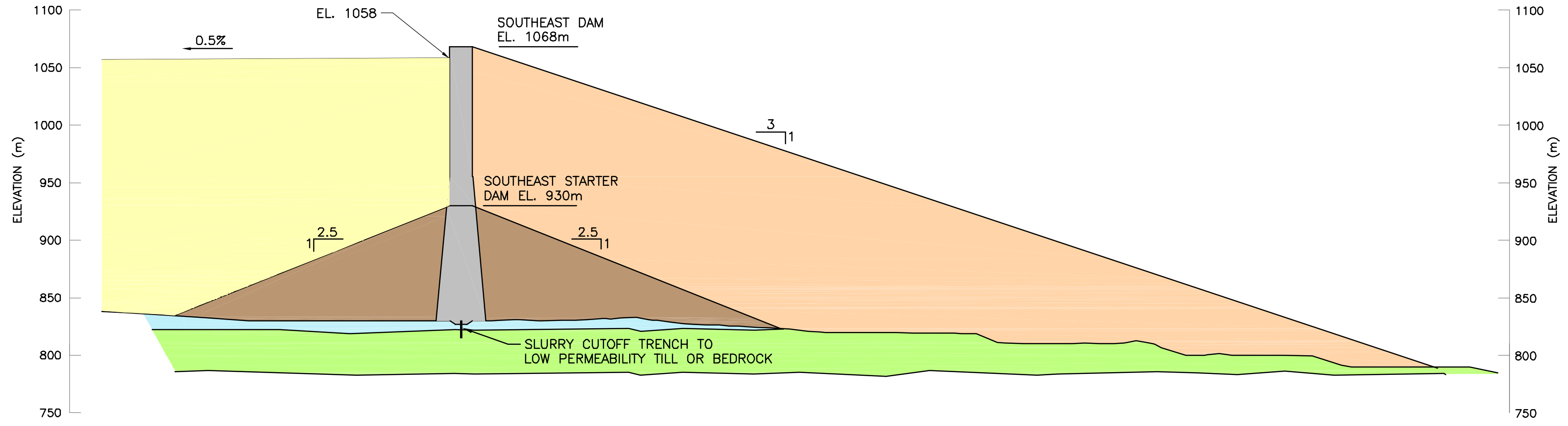
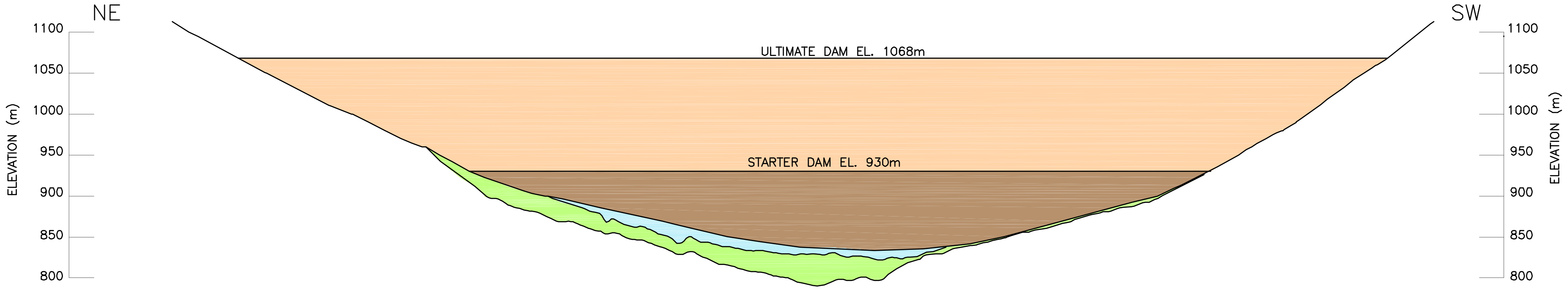


DETAIL 1 SOUTHEAST DAM

SCALE B –



SECTION E SOUTHEAST DAM CENTERLINE

SCALE C 4102

LEGEND

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▨	TILL
▨	CYCLONE SAND
▨	COMPACTED RANDOM FILL
▨	FLOTATION (ROUGHER) TAILING
🟨	CIL RESIDUE (CLEANER) TAILING
▨	COLLUVIUM / ALLUVIUM
🟦	RECLAIM POND

NOTES

1. ESTIMATED FROM GEOPHYSICAL SEISMIC REFRACTION SURVEYS, AND DRILLING.
2. BEDROCK DEPTH ESTIMATED FROM SURFICIAL GEOLOGY MAPPING AND GEOPHYSICAL SURVEYS.

SCALE A: 0 1000 m
SCALE B: 0 200 m
SCALE C: 0 200 m

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DRAWING NO.	REFERENCE DRAWING

CLIENT
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT
KSM PROJECT
2012 TMF ENGINEERING DESIGN

TITLE
SOUTH CELL
DESIGN GEOLOGIC SECTIONS

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