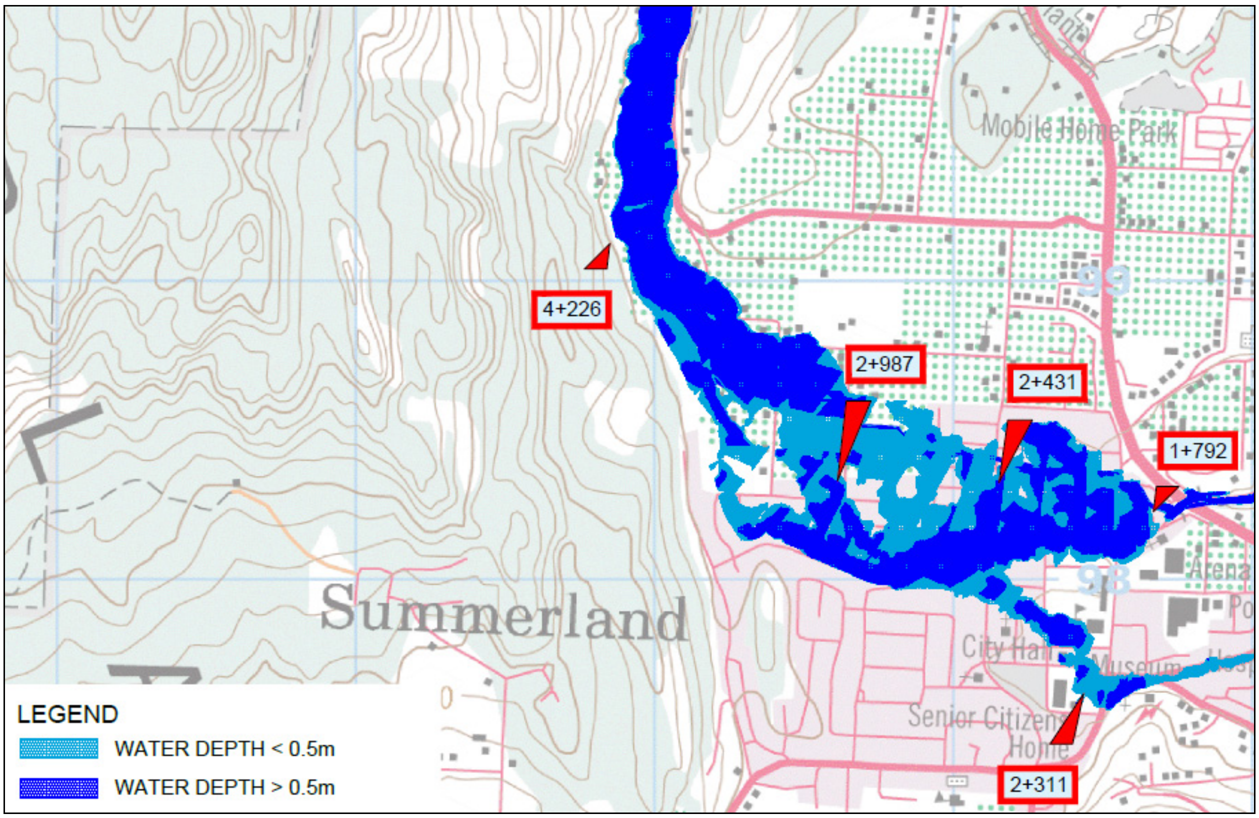

GARNETT RESERVOIR
FLOOD INUNDATION REPORT

District of Summerland
April, 2013

Agua Consulting Inc.
"Engineered Water Solutions"
3660 Anderson Road, Kelowna, BC, V1X 7V8
Phone (250) 212-3266

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(FOR DOUBLE SIDED PRINTING)

Agua Consulting Inc.
"Engineered Water Solutions"

April 19, 2013

District of Summerland
9215 Cedar Avenue
Box 159
Summerland, BC
V0H 1Z0

Attention: Don Darling, Director of Engineering and Public Works

Re: Garnett Reservoir Flood Inundation Report

Dear Don:

Please find enclosed the Garnett Reservoir Flood Inundation Report. This report summarizes the impacts of varying types of potential failures of Garnett Dam, displays the extent of the flood inundation areas, and provides estimates the potential for loss of human life and damage to property. Measures such as additional monitoring, early warning systems, and integration with Emergency Response Plans are included in the report recommendations.

Included in this report is our analysis for the Probable Maximum Flood (PMF) for Aeneas Creek above Garnett Reservoir. Details of this analysis are provided within Appendix C.

We trust that the content of this report is sufficient to meet your expectations and the requirements of the Province. We thank you for the opportunity to be of service.

Yours truly,

Robert Hrasko

Bob Hrasko, P.Eng.
Agua Consulting Inc.

RJH/rh

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DISTRICT OF SUMMERLAND

GARNETT RESERVOIR
FLOOD INUNDATION REPORT

Prepared for:

District of Summerland
9215 Cedar Avenue,
Box 159
Summerland, BC
V0H 1Z0

Prepared by:

Agua Consulting Inc.
"Engineered Water Solutions"
3660 Anderson Road
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April, 2013

Project No. 023-012

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ACKNOWLEDGEMENTS

This report was prepared by R.J. (Bob) Hrasko, P.Eng. of Agua Consulting Inc., Aaron Hahn, EIT, AScT of Hahn Engineering Consulting, and with the assistance of Scott Lee and Shawn Hughes of the District of Summerland who were particularly helpful in collecting as-constructed and operational details for the District's utilities. Their efforts and contributions to this report are noted and appreciated.

TABLE OF CONTENTS

1. INTRODUCTION ... 3
1.1 GENERAL ... 3
1.2 BACKGROUND ... 3
1.3 PROJECT OBJECTIVES ... 6
1.4 SCOPE OF REPORT ... 7
1.5 RELATED REPORTS & REFERENCES ... 8

2. DESIGN APPROACH ... 9
2.1 DAM SAFETY REQUIREMENTS AND CONSEQUENCE OF FAILURE ... 9
2.2 SOFTWARE EMPLOYED ... 10
2.3 GARNETT INFLOW AND FAILURE MODE ... 10

3. HEC-RAS MODEL ... 11
3.1 HEC-RAS ... 11
3.2 CREEK BASE FLOW INPUT ... 11
3.3 GEOGRAPHICAL INPUT AND ACCURACY ... 11
3.4 MODEL BOUNDARIES ... 13
3.5 PIPING BREACH PARAMETERS ... 15

4. DAM BREACH AND HYDRAULIC ROUTING ANALYSIS ... 17
4.1 PIPING FAILURE BREACH RESULTS ... 17
4.2 INUNDATION MAPPING ... 19
4.3 IMPACT OF DAM FAILURE TO LIFE AND PERSONAL PROPERTY ... 19
4.4 HYDROLOGICAL CONSIDERATIONS ... 21
4.5 IMPACT OF DAM FAILURE TO ROADS AND OTHER PUBLIC INFRASTRUCTURE ... 22

5. CONCLUSIONS AND RECOMMENDATIONS ... 23
5.1 CONCLUSIONS ... 23
5.2 RECOMMENDATIONS ... 24

APPENDIX A INUNDATION MAPS
APPENDIX A HEC-RAS FLOW-DEPTH-DURATION GRAPHS
APPENDIX C PROBABLE MAXIMUM FLOOD ANALYSIS
APPENDIX D OPERATING MEMORANDUM FOR GARNETT RELEASES

ABBREVIATIONS

BC DSR	British Columbia Dam Safety Regulation
CAD	Computer Assisted Drafting
CDA	Canadian Dam Association
cms	Cubic Metres Per Second
DOS	District of Summerland
EPP	Emergency Preparedness Plan
HEC-RAS	Hydrologic Engineering Centers River Analysis System
km	Kilometres
km/h	Kilometres per Hour
m	Metres
MAD	Mean Annual Discharge
ML	Mega-litres (1,000 cubic metres)
MoE	Ministry of Environment
MPE	Maximum Probable Earthquake
PMF	Probable Maximum Flood

1. INTRODUCTION

1.1 GENERAL

This report sets out our estimate of flood inundation in the event of a failure of Garnett Dam. Garnett Dam impounds Garnett Reservoir which provides domestic and irrigation water to Garnett Valley within the District of Summerland.

Garnett Dam is an earthfill dam located approximately 10 kilometres north of the Summerland downtown urban core. If the stability of Garnett Dam is compromised, the stored water could breach the dam and form a massive wave of water that would flood Garnet valley and move swiftly south towards town.

This report assesses the impacts associated with this flood wave by predicting resulting flood zones, wave travel times, depth of water flow, structures at risk, and infrastructure at risk. This report confirms the classification of Garnett Dam to be one of EXTREME CONSEQUENCE.

1.2 BACKGROUND

The Garnett Reservoir is located 10 km north from the District of Summerland up the Aeneas Creek valley.. The reservoir natural inflows is from the watershed via Aeneas Creek and from groundwater from the valley to the west. The reservoir outflow is conveyed by lower Aeneas Creek to Okanagan Lake. Garnett Dam was originally constructed across Aeneas Creek in the 1920's. After being raised three times, the dam was fully reconstructed in 1976-1978 at a location 125 metres downstream of the original location by the District of Summerland. The old dam was breached with most of the earth structure still existing underwater and upstream of the new dam.

Figure 1.1 – Garnett Reservoir Location

The headwaters to the Garnett Reservoir are located in Aeneas Provincial Park approximately 18 kilometres upstream of the north end of Garnett Reservoir. There are several creeks and diversions that influence the flows into Garnett Reservoir including Aeneas Creek, Lapsley Creek, and Findlay Creek, which also supplies Darke Creek and Darke Lake.

The water used by the District of Summerland is collected in Garnett Reservoir and is chlorinated once it leaves the Reservoir. It is then conveyed via a transmission main from where it is distributed to the residents of Summerland. The runoff from the Aeneas watershed that is not conveyed in the transmission main is directly released to Aeneas Creek through the Garnett Dam outlet structure or occasionally over the dam spillway. The released water flows along a 15 kilometre water course through rural and urban landscapes of Summerland before it discharges to Okanagan Lake.

Figure 1.2 – Garnett Dam (looking east)

The Garnett Reservoir full-pool water elevation is approximately 632.76 metres with a total water surface area of 38.3 ha. Garnett Reservoir is annually filled by a sub-catchment area of approximately 9,100 ha (91 km^2). With a total live storage volume of 2,360 ML, Garnett Reservoir comprises about 14% of the total District of Summerland reservoir storage capacity.

The Garnett Dam is an earthfill dam having a crest length of approximately 100 metres, a height of 13 metres, and a top crest width of 5 metres. It has an upstream side-slope of 3H:1V and a downstream side-slope of 2H:1V.

Figure 1.3 – Garnett Outlet Control Structure

Figure 1.4 – Garnett Outlet Gate Control Structure

Figure 1.5 – Garnett Reservoir's Spillway and Location

1.3 PROJECT OBJECTIVES

The primary objectives of this report are as follows:

- To develop a hydraulic model capable of characterizing the flows impacts along various cross-sections throughout the Aeneas Creek water course, resulting from a breach of Garnett Dam;

- To create flood inundation maps detailing probable flood zones complete with depths of flooding water;

- To determine the degree of potential impact to life, personal property, environment, and key infrastructure assets in the flood inundated areas; and,

- To supply supporting documentation for the Garnett Reservoir's Emergency Preparedness Plan (EPP) as per the Canadian Dam Association's (CDA) Dam Safety Guidelines.

1.4 SCOPE OF REPORT

This report was prepared by completing the following list of tasks:

- Assemble all available information required to characterize an Garnett Dam breach including: the size and geometry of Garnett Reservoir, the construction of the Garnett Dam, the topography of the Aeneas Creek water course, the location of sensitive areas, and other related physical information;
- Construct a viable computer model able to simulate the breach of Garnett Dam;
- Provide flood inundation mapping indicating the areas at risk;
- Provide graphs and tables detailing the breach wave characteristics along several locations of the water course (includes peak flows, time to wave, time to peak flow, duration of elevated waters, maximum increase in water elevation, and maximum average flow velocity);
- Identify the approximate population and infrastructure that may be affected including road crossings, water infrastructure, residential property, etc.

In addition to the initial scope of work, this report also includes the Probable Maximum Flood analysis which is summarized in Appendix C.

1.5 RELATED REPORTS & REFERENCES

The following references were used in the preparation, review, and writing of this document.

ASCE Fall Convention	Limitations of Dam-Breach Flood Routing Models	October 1981
British Columbia Dam Safety Regulation	Water Act	September 2011
Canadian Dam Association	Dam Safety Guidelines	July 2007
District of Summerland Engineering and Public Works – Agua Consulting Inc	District of Summerland Engineering and Public Works	November 2008
District of Summerland Engineering and Public Works – EarthTech Canada Inc	Watershed Risk Assessment	June 2002
Journal of Hydraulic Engineering	Breaching Characteristics of Dam Failures	May 1984
Maryland Dam Safety	Dam Break Analysis & Hazard Classifications	October 1996
Ministry of Environment	Consequence of Failure Classification: A Guide for Initial Assessment	June 2011
Ministry of Environment – Assessment and Planning Division	Proposed Solutions to the Taste and Odour Problems in Garnett Reservoir	July 1981
Ministry of Forests, Lands and Natural Resource Operations British Columbia	Dam Failure Consequence Classification Conversion Guideline for Dams in British Columbia	August 2011
Natural Resources Canada: Earth Sciences Centre	Geogratis	August 2011
Office of Hydrology and National Weather Service	NWS-Dam Break Flood Forecasting Model	April 1988
United States Bureau of Reclamation	Flood Hazard Charts	April 1988
US Army Corps of Engineers	HEC-RAS: User manual & Release Notes Version 4.1	January 2010
Water Resources Service of British Columbia – Thurber Consultants Ltd	Aeneas Creek Flood Control Study	January 1974

2. DESIGN APPROACH

2.1 DAM SAFETY REQUIREMENTS AND CONSEQUENCE OF FAILURE

The Ministry of Environment (MoE) and the Canadian Dam Association (CDA) assess the dams throughout BC in accordance with consequence of failure classification. The classifications criteria taking precedence for the Garnett Dam is the British Columbia Dam Safety Regulation (BC DSR). The classification rating guidelines are listed in Table 2.1.

According to this criterion, the existing classification for the Garnett Dam is listed as HIGH. As a response to the findings detailed in this report, it is the opinion of this consultant that the classification be either in the VERY HIGH or EXTREME category. The reasons are the population at risk, the critical services that would be affected, and the high value of property in close proximity downstream of the dam.

Table 2.1 – BC Dam Failure Consequences Classification Table (BC DSR, 2011)

Consequence Classification NEW BC Dam Safety Regulation 108/2011	Population at Risk	Loss of Life		Environment and Cultural Values[2]		Infrastructure & Economics[2]		Consequence Classification OLD BC Dam Safety Regulation 44/2000
	BC Reg. 108/2011 Only	BC Reg. 108/2011	BC Reg. 44/2000[3]	BC Reg. 108/2011	BC Reg. 44/2000	BC Reg 108/2011	BC Reg. 44/2000	
Low	None	No possibility of loss of life	Minimal	Minimal short-term and no long-term loss or deterioration	No significant loss of habitat or sites	Minimal economic losses mostly limited to dam owner's property	< $100K Minimal	Very Low
Significant	Temporary Only	Low potential for multiple loss of life[6]	Some Possible	No significant loss or deterioration incl. Important habitat Restoration or compensation possible	Loss or deterioration of regionally important habitat & sites – High chance for restoration or compensation	Low economic losses to buildings, services, public transportation, infrastructure, etc.	< $1M Limited Infrastructure, Public, Commercial	Low
High	Permanent Residents	< 10	< 10[4]	Significant loss or deterioration incl. Important habitat Restoration or compensation possible	Same as below	High economic losses to buildings, services, public transportation, commerce, infrastructure, etc.	< $10M[4] Same as below	High (Low[4])
Very High	Permanent Residents	< 100	< 100	Significant loss or deterioration incl. critical habitat Restoration or compensation impractical	Loss or deterioration of Nationally & Provincially important habitat & sites – High chance for restoration or compensation	Very high economic losses to **important** buildings, services, transportation, infrastructure, commerce etc. **Or** severe damage to residential areas	< $100M Substantial Infrastructure, Public, Commercial	High (High[4])
Extreme	Permanent Residents	>100	>100	Major loss or deterioration incl. critical habitat Restoration or compensation impossible	Loss or deterioration of Nationally & Provincially important habitat & sites – Low chance for restoration or compensation	Extremely high economic losses to **critical** buildings, services, transportation, infrastructure, commerce etc. **Or** destruction or severe damage to residential areas	>$100M Very High Infrastructure, Public, Commercial, Residential	Very High

[1] This table contains abridged descriptions of the dam failure consequences. Attachment 1 contains the full descriptions from BC Regulation 108/2011. In all cases the Regulation takes precedence over information contained in this table.
[2] Names for these categories in BC Reg. 44/2000 are "Environmental and Cultural Losses" and "Economic and Social Losses" respectively.
[3] Conservative estimate of loss of life amongst population affected by the flood waters (may equal Population at Risk).
[4] Sub-classifications of "High (Low)" and "High (High)" and associated thresholds were established by policy in 1998 for use in the BC Dam Safety Program risk-based assessment.
[5] A temporary population (e.g. in recreational areas) could be quite large and a "sunny-day" failure could result in multiple fatalities.

Since the classification given to the Garnett Dam is considered to be HIGH or of a greater consequence class an Emergency Preparedness Plan (EPP) is required as part of the requirements as set out by the CDA. This report has been conducted in accordance with these requirements and shall form as part of the EPP.

2.2 SOFTWARE EMPLOYED

In order to create a viable simulation of a Garnett Dam breach, a computer was required to complete the numerous calculations. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1.0 was selected. This software package is state-of-the-art and widely used in the civil engineering industry. It was selected due to its ability to model various types of dam breaches and it is capable of importing geometric data from computer assisted drafting (CAD) software. In addition, CAD software called Carlson Civil Suite and AutoCAD was used to create the model's input geometry and inundation maps.

2.3 GARNETT INFLOW AND FAILURE MODE

There are predominantly two types of dam failure modes – overtopping and piping.

(1) An overtopping failure is one that occurs when the water flows over the crest of the dam. The velocities of the water will begin to displace material forming a trough. This trough will quickly grow in size and ultimately release most of the water from the reservoir.

(2) A piping failure is one that is formed by a leak within the dam. Similar to an overtopping failure, the velocity of the water through the leak will displace embankment material causing the opening to enlarge. Although this type of failure can occur anywhere in the dam's structure, it is most likely to fail at the dam's outlet piping.

Due to the overwhelming similarities between the overtopping and piping failure flow hydrographs and breach durations, only the piping failure hydrographs for 1.0-hour and 2.5-hour breaches have been utilized in this analysis.

3. HEC-RAS MODEL

3.1 HEC-RAS

The Hydrologic Engineering Centers River Analysis System (HEC-RAS) is a simulation software developed by the US Army Corps of Engineers and has been developed to manage rivers, harbours, and other public works under their jurisdiction. The HEC-RAS software has found wide acceptance among hydraulic engineers and researchers due to its robust channel flow analysis capabilities and its ability to determine floodplain areas. Furthermore, HEC-RAS uses steady and unsteady state modeling routines and dam breach modules – thus making the software ideal for dam breach modeling. Due to its extensive capabilities, cost, and compatibility with CAD software packages, HEC-RAS was chosen to simulate the Garnett Dam breach.

The following sections of this report are largely based on the two modeling routines employed by HEC-RAS – (1) the Froelich equations for dam breach hydrograph determination and (2) the use of the implicit finite difference method coupled with the Saint-Venant equations for unsteady flow determination. Due to the complexity of the solving routines, it is necessary to thoroughly review the output solutions for stability and correctness. The solution found by HEC-RAS has been compared to similar historical dam breaches, hand calculations and water volume checks. All comparisons and checks indicate that the solution found by HEC-RAS is stable and reasonable for this situation.

3.2 CREEK BASE FLOW INPUT

Initially a creek base flow input parameter is entered. According to a 1974 report by Thurber Consultants Ltd, the recurrence intervals for peak flows of 1.4, 2.0, and 2.5 m^3/s along Aeneas Creek is estimated to have a recurrence interval of 25, 30, and 40 years respectively. Since the HEC-RAS unsteady-state breach simulation becomes unstable with base flows less than 5 m^3/s, a base flow of 5 m^3/s was selected for this exercise. Although 5 m^3/s base flow is considered very high for the Aeneas water course, this high base flow is negligible when compared to peak flows resulting from a dam breach. The objective of this exercise is to determine the limits of greater flooding.

3.3 GEOGRAPHICAL INPUT AND ACCURACY

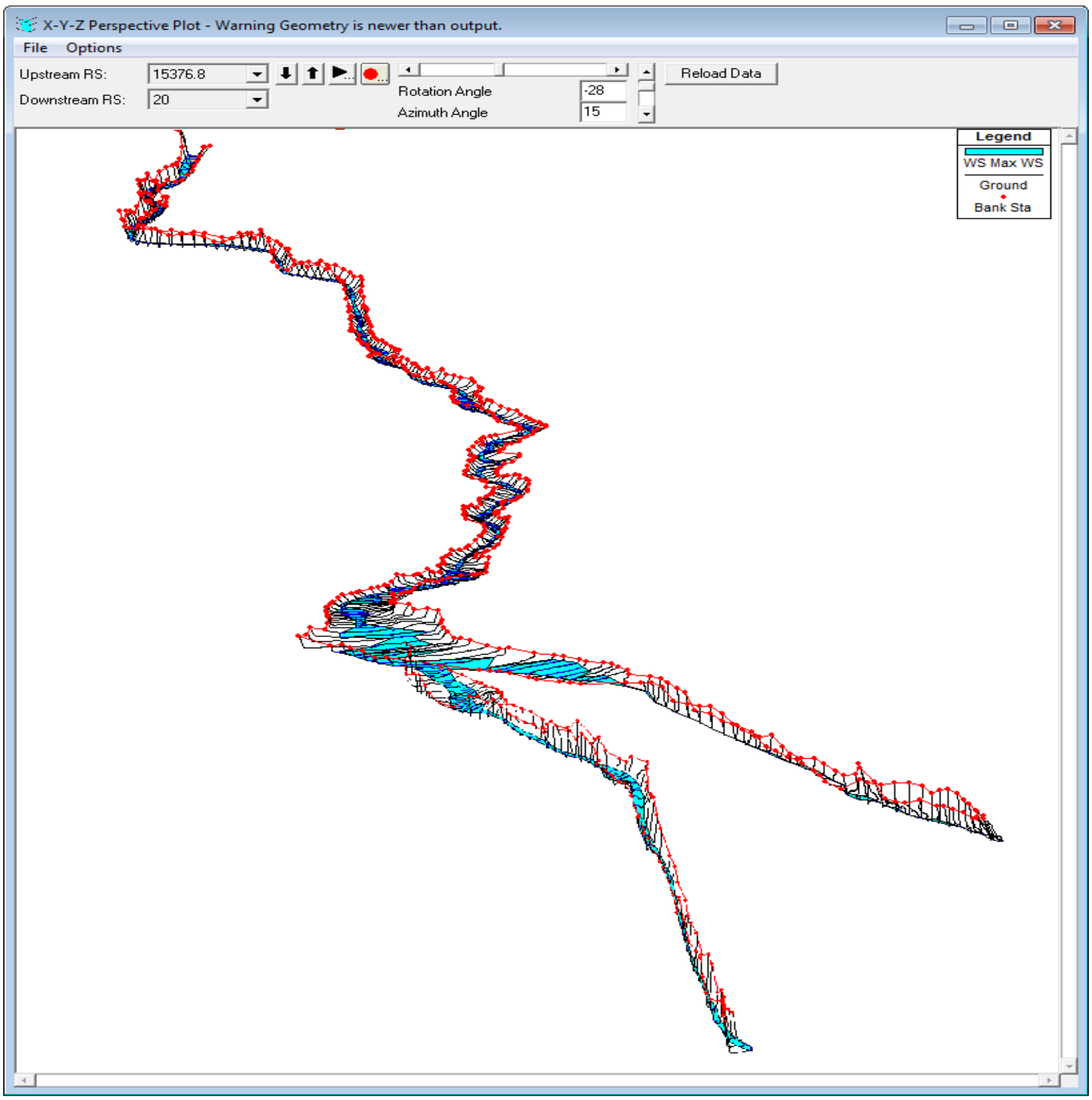
Topographical information characterizing the water course must also be entered in the program. The water course from Garnett Reservoir to Okanagan Lake is approximately 15 kilometres in length. A three-dimensional surface detailing the entire water course was created in CAD using one metre and ten metre (best available) contour data collected from the District of Summerland and the Natural Resources Canada Earth Sciences Centre respectively. Although the data is coarser in the upland and rural areas, it is considered to be sufficient to accurately simulate the attenuation and time delay characteristics of a dam failure breach wave.

The CAD surface of the water course was then divided into 50 metre cross-sections with 10 metre interpolated cross-sections. The cross-sections were exported from the CAD software and imported directly into the HEC-RAS model. Cross-sections were then screened for errors and then either simplified or removed. Finally, parameters including Manning's open-channel flow coefficients, reach lengths, left and right bank stations, levee locations, and other key inputs were entered. A summary of the Manning coefficients are summarized in Table 3.1. A display of the cross-sections set into the HEC-RAS model are displayed in Figure 3.1.

Table 3.1 - HEC-RAS Manning Coefficients

Description	Manning Coef.
Earth channel - stony, cobbles	0.04
Floodplains - pasture, farmland	0.04
Floodplains - light brush	0.05
Floodplains - heavy brush	0.08
Floodplains - trees	0.15

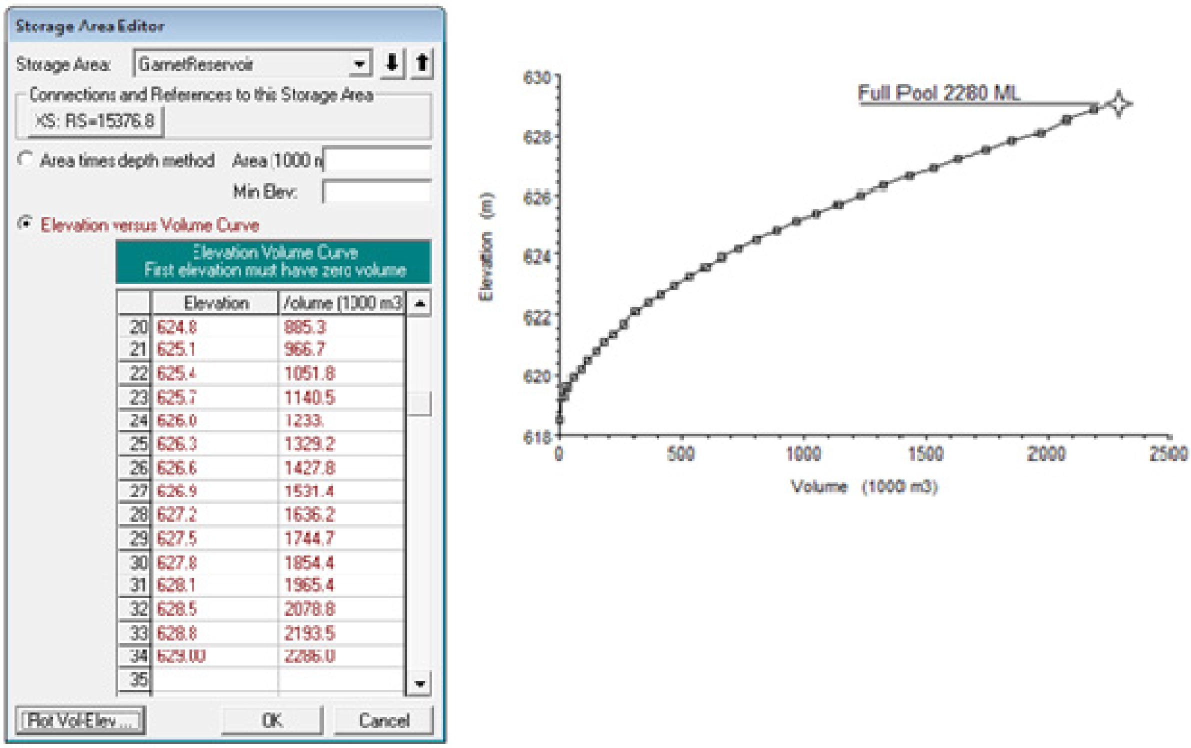
Figure 3.1 - HEC-RAS Inundation Area Model Cross Sections



3.4 MODEL BOUNDARIES

As an input boundary, the relationship for Garnett Reservoir water levels and storage volumes was required for the model. Figure 3.2 illustrates the stage volume relationship of Garnett Dam.

Figure 3.2 - Garnett Reservoir Stage-Volume Table



As an output boundary, a rating curve was needed to describe the hydraulic capacity between the two outlet routes to Okanagan Lake. In the lower part of Aeneas Creek, two routes exist to the lake for high flows, the main Aeneas Creek channel and, when water levels rise to higher levels, a side channel north of Aeneas Creek.

This was derived by using the newly created HEC-RAS model and simulating a variety of flow rates using the steady state routine.

The resulting boundary condition found in Figures 3.3 and 3.4 were derived using a high water level (HWL) of 343.0 m for Okanagan Lake. Figure 3.3 sets out the boundary conditions of the main channel. Figure 3.4 sets out the boundary conditions of the north side channel.

Figure 3.3 – Aeneas Creek to Okanagan Lake: Rating Curve

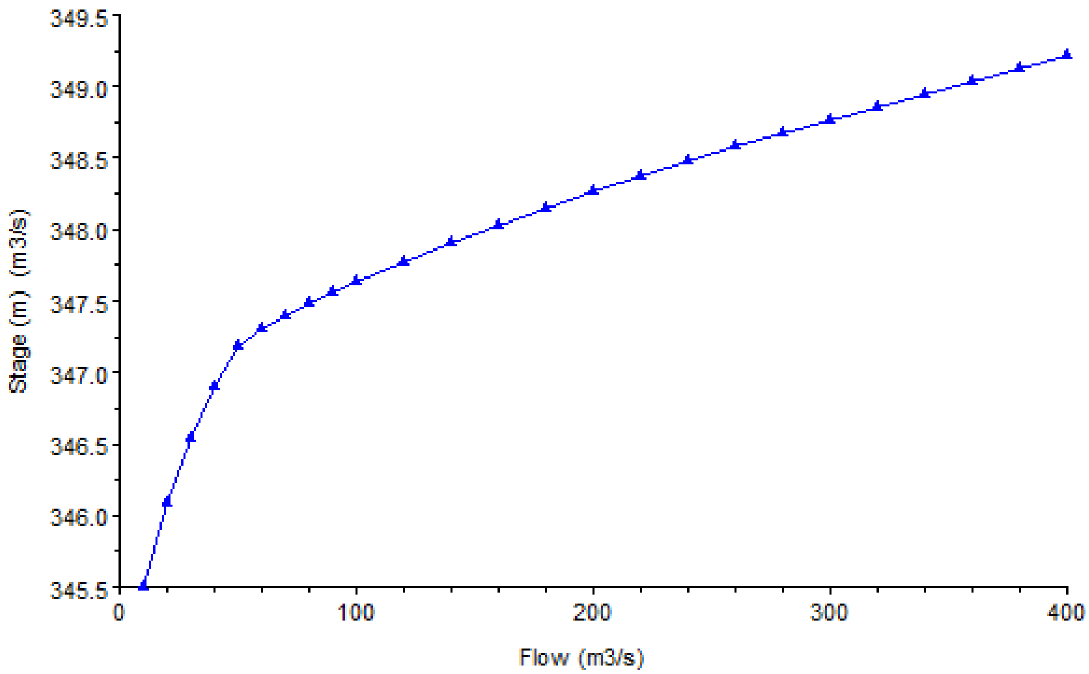
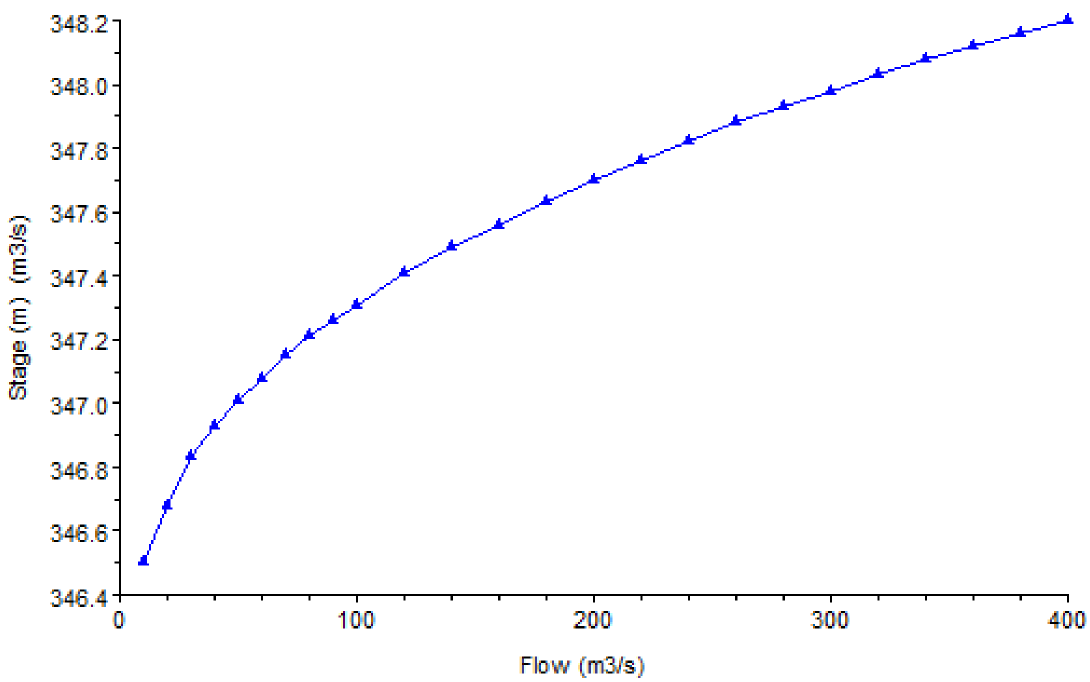


Figure 3.4 – Breakaway flow to Okanagan Lake: Rating Curve



3.5 PIPING BREACH PARAMETERS

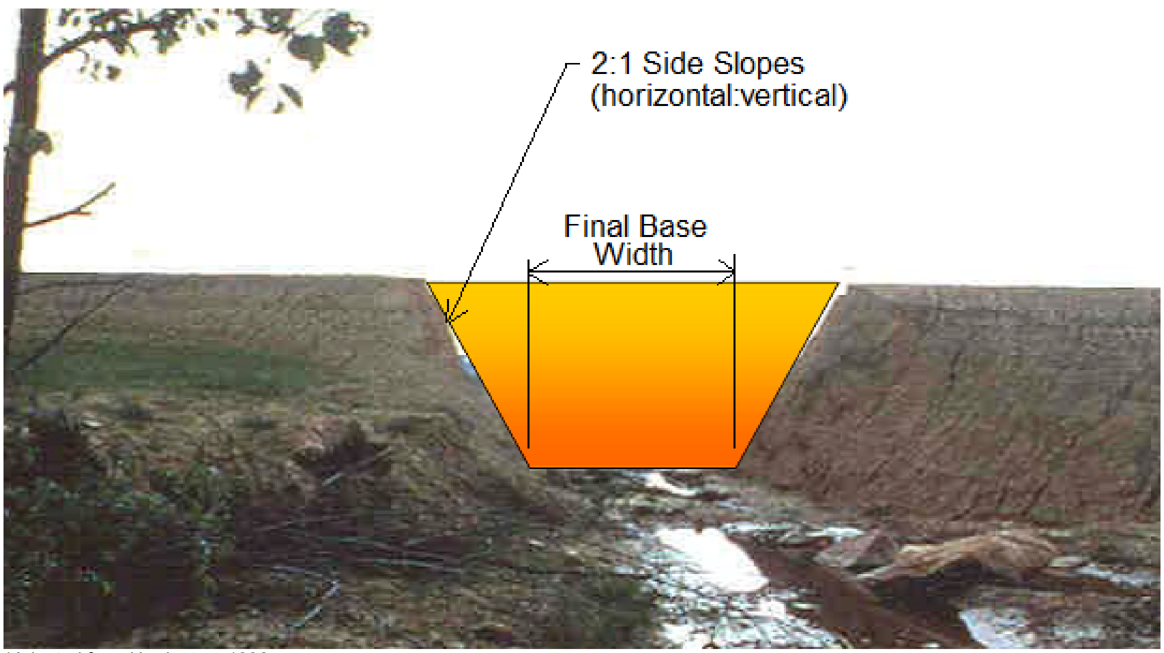
Key inputs dictating the characteristics of the breach wave were entered for a piping failure. Based on research from several reports and papers, it was concluded that a piping breach of the Garnett Dam would transpire over a period of between 1 and 2.5 hours. Furthermore, due to the type of dam material, size, surface area of the reservoir at full-pool, the volume of storage water and the geographic boundaries around the dam, the breach channel geometry was assumed have 1.5H:1V side slopes and a 7 metre final bottom width. The parameters used to characterize the piping failure are detailed in Table 3.2 and illustrated in Figure 3.5 and Figure 3.6.

Table 3.2 – HEC-RAS Piping Failure Parameters

Description	Value
Final Bottom Width (m)	7
Final Bottom Elevation (m)	623.5
Left Side Slope (x H:1 V)	1.5
Right Side Slope (x H:1 V)	1.5
Full Formation Time (hr)	1 & 2.5*
Orifice Piping Coefficient	0.5
Initial Piping Elevation	623.5

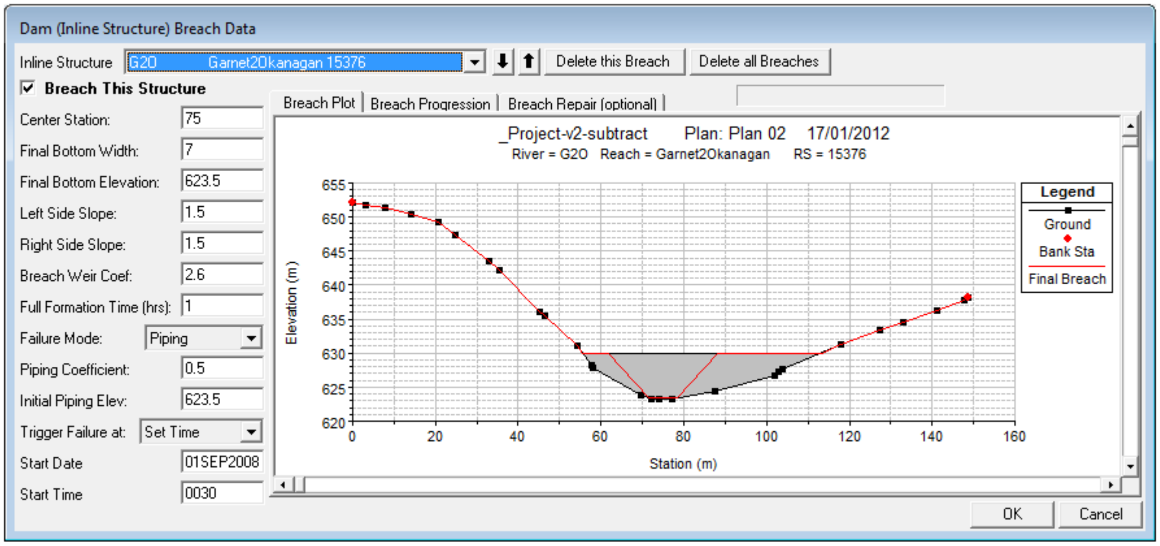
*Two simulations conducted (1.0 hrs and 2.5 hrs)

Figure 3.5 –Assumed Piping Breach Geometry*



*Adapted from Harrington, 1996

Figure 3.6 –Assumed Piping Breach Geometry



4. DAM BREACH AND HYDRAULIC ROUTING ANALYSIS

4.1 PIPING FAILURE BREACH RESULTS

The HEC-RAS model was used to simulate 1.0 and 2.5 hour-long piping breach failures. A total of 12 cross-sections describing varying topography, population density, and surface type were selected along the water course at known landmarks. The 12 cross-sections locations are shown in Figure 4.1 and Figure 4.2. The simulation results for the cross-sections' wave characteristics are detailed in Table 4.1 for the 1.0 and 2.5 hour breaches. Detailed sections and mapping is provided in Appendix A.

Figure 4.1 – All Selected Cross-Sections

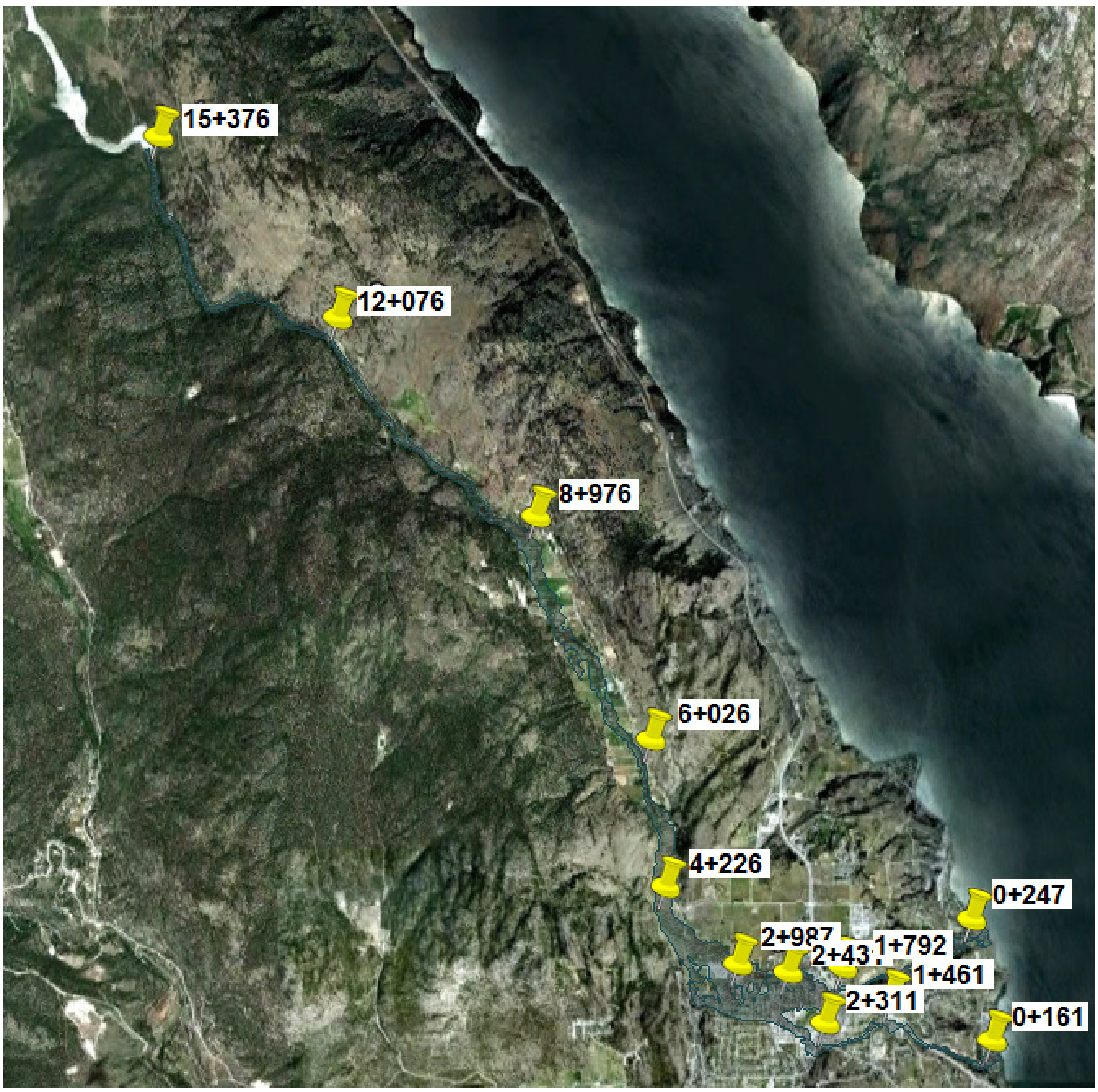


Figure 4.2 – Downtown Summerland Cross-Section Stations

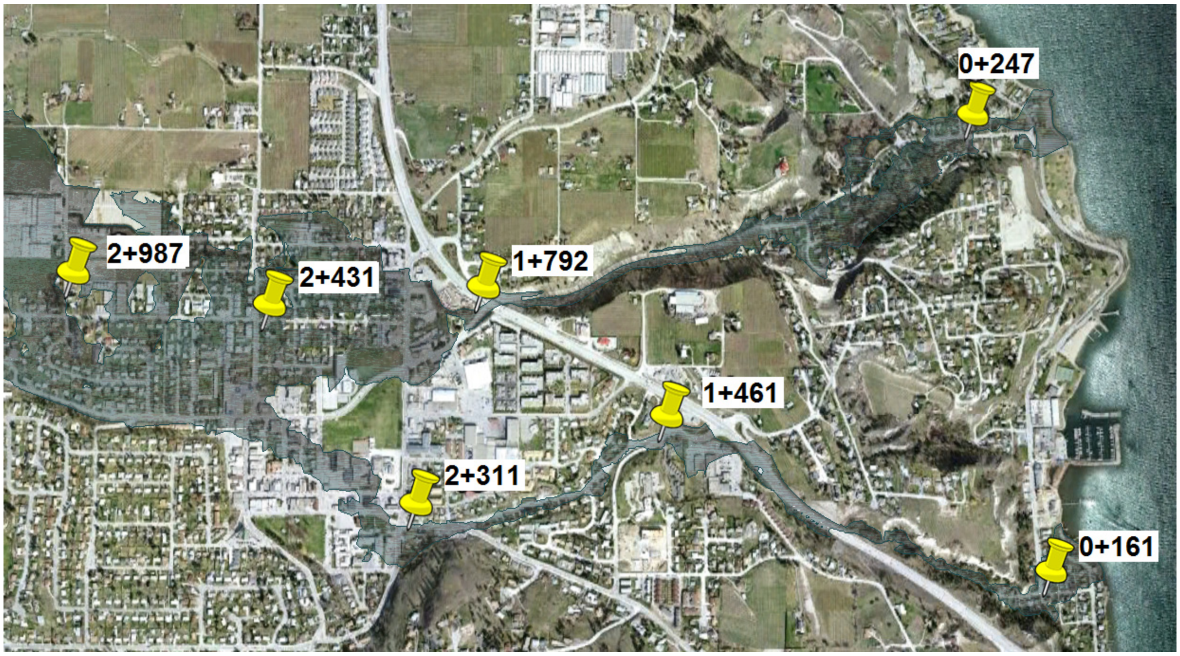


Table 4.1 - 1.0 Hour and 2.5 Hour Dam Breach Results*

	15+376 100m Below Dam	12+076 1st Residence Downsteam	8+976 Wildhorse Rd & Garnet Valley Rd	6+026 19402 Garnet Valley Rd	4+226 Jones Rd & Garnet Valley Rd	2+987 Washington Rd & Dunsdon Crt	2+431 Victoria Rd	1+792 Hwy 97 Crossing	0+247 Charles Ave & Peach Orchard Rd	2+311 Wharton St & Prairie Valley Rd	1+461 Atkinson Rd & Prairie Valley Rd	0+161 Shaughnessy Ave
	1.0 hr Dam Breach Duration											
Peak Discharge [cms]	384	306	280	234	227	220	210	134	134	70	69	65
Time to Wave Arrival [hr]	0.2	1.0	1.5	2.1	2.6	3.0	3.3	3.4	3.6	3.5	3.6	3.8
Time to Peak Flow [hr]	0.9	1.3	1.8	2.4	2.8	3.2	3.4	3.6	3.7	3.7	3.8	4.0
Duration of Elevated Water Level [hr]*	8.0	9.8	8.9	8.0	7.8	9.5	7.2	7.6	9.3	2.8	3.4	2.6
Maximum Increase in Water Elevation [m]	2.85	3.08	2.69	1.89	1.52	1.23	0.91	1.55	1.05	0.67	1.04	0.55
Maximum Average Flow Velocity [m/s]	4.05	3.00	1.44	1.46	1.07	0.66	0.87	2.85	1.64	0.70	1.64	1.79
	2.5 hr Dam Breach Duration											
Peak Discharge [cms]	277	255	246	223	219	214	206	132	132	68	68	66
Time to Wave Arrival [hr]	0.7	1.5	2.4	3.0	3.7	4.1	4.3	4.5	4.7	4.5	4.7	4.9
Time to Peak Flow [hr]	2.2	2.6	2.9	3.5	4.0	4.3	4.5	4.7	4.8	4.7	4.9	5.1
Duration of Elevated Water Level [hr]*	7.6	9.9	8.9	8.3	7.8	9.4	6.9	7.6	9.2	2.8	3.4	2.6
Maximum Increase in Water Elevation [m]	2.33	2.82	2.52	1.85	1.50	1.22	0.90	1.54	1.04	0.66	1.03	0.55
Maximum Average Flow Velocity [m/s]	3.74	2.84	1.37	1.45	1.06	0.65	0.86	2.83	1.64	0.70	1.64	1.79

*Stations are measured in metres from the Aeneas Creek mouth to Garnett Reservoir (the flow path that breaks away from Aeneas Creek has a separate stationing - it is measured in metres from where it meets Okanagan Lake). Recorded times are in hours and are recorded from the beginning of the breach. Duration of water level is considered to be of depths greater than 150mm (see Figure A.2 for more details).

As listed in Table 4.1, the 1.0-hour breach travels significantly faster than the 2.5-hour breach. With a travel times from Garnett Reservoir to Okanagan Lake ranging from 3.6 and 3.8 hours, the 1.0-hour breach wave is larger, more intense, and travels at an average velocity approximately 30% faster than the 2.5 hour wave. The water elevations along the route are also greater for the 1.0-hour breach; however, the duration of elevated flood water levels is significantly longer for the 2.5-hour breach. The levels of elevated water and maximum flows at each station are described in the following sections.

4.2 INUNDATION MAPPING

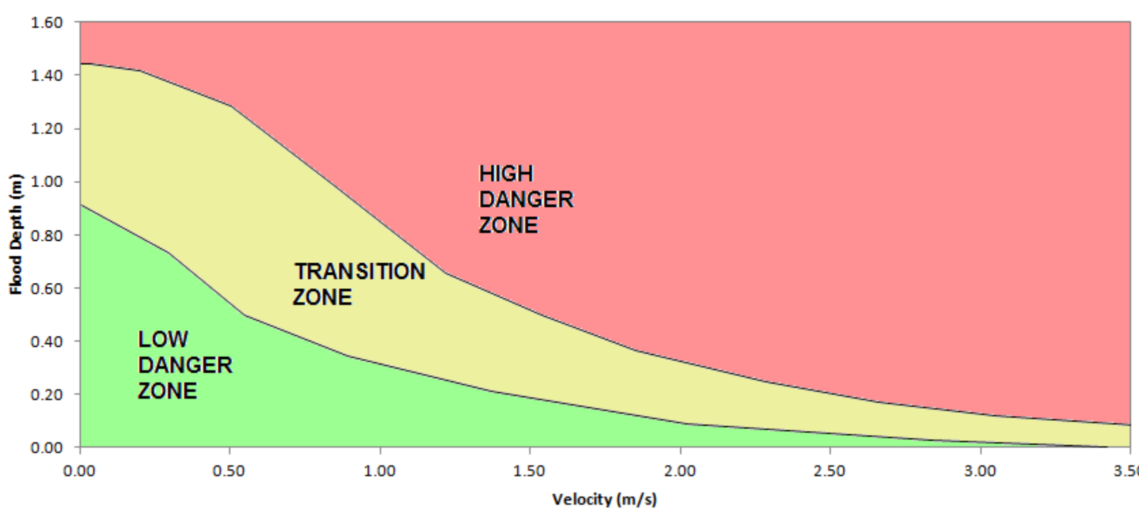
The maximum resulting water surface profiles for every 50-metre interval were obtained from the 1.0-hour piping breach simulation and exported back to CAD for inundation plotting. There are two plots detailing the inundated areas and potential flood depths, **Figure 4.6** and **Figure 4.7** at the end of Section 4. The first plot displays the rural upland area and the second displays the two corridors through the central areas of the District of Summerland.

Since only maximum water elevations are shown in the inundation mapping, it is important to note that damage would be created by not only the depth of flooding, but also the higher velocities. Table 4.1 in the previous section describes average velocities of the channel of up to approximately 4 m/s (14.4 km/h). The max velocities experienced at any station would be significantly higher. Where narrower flood sections are shown in the inundation plots, there is greater potential for higher flows and increased damage. The following report section describes the hazard levels associated with various flow velocities and water depths.

4.3 IMPACT OF DAM FAILURE TO LIFE AND PERSONAL PROPERTY

A failure of the Garnett Dam carries an EXTREME potential for loss of life and damage to personal property. Although the extent of damage cannot be determined exactly, the hazard level for all areas inundated by flood waters can be estimated for adults, cars, and houses by flood depth and velocity as shown in Figures 4.3, 4.4 and 4.5 respectively.

Figure 4.3 – Estimated Hazard Level for Adults (USBR, 1988)



As the depth of water increases, so do the velocity and the ability of the flowing water to sweep away persons and/or building structures.

Figure 4.4 – Estimated Hazard Level for Cars (USBR, 1988)

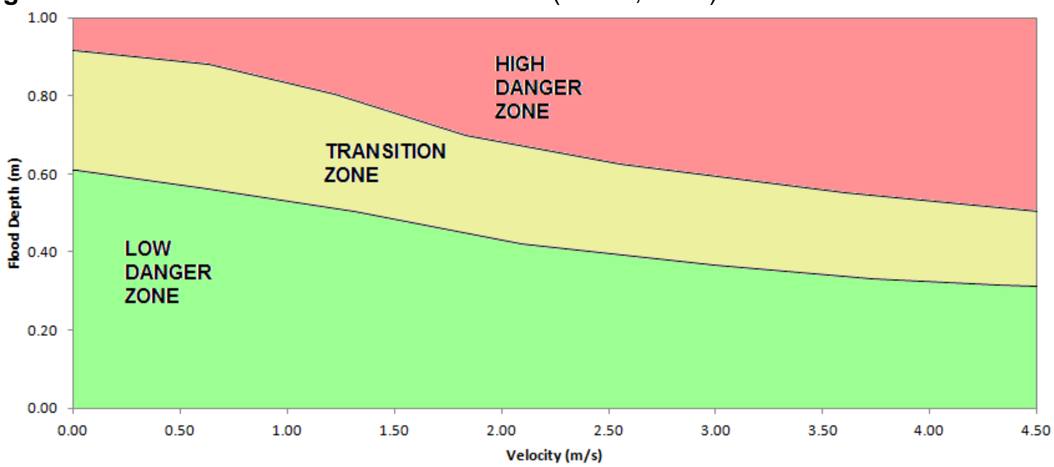
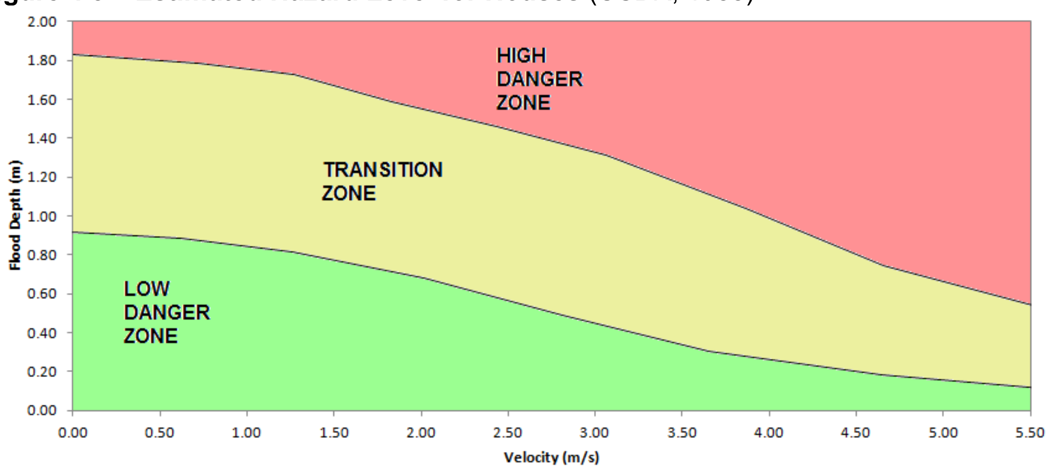


Figure 4.5 – Estimated Hazard Level for Houses (USBR, 1988)



A total of 742 building structures are located within the flood inundated areas, of which 681 are houses with hazard levels of some High Danger Zone. The structures residing in the upland areas at low elevations along Aeneas Creek nearest to Garnett Dam would likely be destroyed. Due to the short routing times, deep water depths and higher velocities, the residents in these homes would be at the greatest danger levels.

In terms of overall population, assuming approximately 3 residents per structure, there would be approximately 2,000 persons at risk if a dam breach were to occur. Approximately 15% of these persons (300 persons) are located in the upstream areas at highest risk.

4.4 HYDROLOGICAL CONSIDERATIONS

There are several hydrological operating conditions that the District of Summerland faces in the operation of Garnett Dam. These include:

1. **Low Runoff Events:** The downstream channel in Aeneas Creek is very limited due to urbanization and infilling in the area north of downtown. The channel is subject to icing in the winter season resulting in reduced channel capacity between Victoria Avenue and Rosedale Road. A letter report was developed for Summerland by Agua Consulting Inc. setting out channel capacity and options for channel capacity upgrades. The letter dated August 31, 2012 can be provided upon request. The summer capacity of the channel is only 1.10 m^3/s with a reduced winter capacity due to ice build-up of only 0.30 m^3/s;
2. **Spring Runoff:** Every year, Summerland staff operate Garnett Dam releases based on withholding sufficient water in the reservoir for domestic and irrigation supplies. The limited capacity of the downstream channel results has resulted in the District staff taking more precautions to minimize the use of the Garnett Dam Spillway. The reservoir filling target for spring every year is now 15% below high water level. The Memorandum, included in Appendix D of this report sets out the operating levels, volumes and back ground for this operating guideline;
3. **Probable Maximum Flood** A probable maximum flood assessment was carried out. The PMF assessment reviewed the buffering capacity of the reservoir and the conveyance capacity of the Garnett Dam spillway. The results are provided in Appendix C.
4. **Dam Failure:** High flow created by a dam failure is developed within this report. Inundation maps are included. The peak flow estimate at the dam during the failure is 384 cms, which is attenuated by land forms and structures to 65 cms by the time the flow reaches Okanagan Lake. There are two routes to the lake, the primary route down Peach Orchard Drive, and a secondary route that could flow down Prairie Valley Road.

4.5 IMPACT OF DAM FAILURE TO ROADS AND OTHER PUBLIC INFRASTRUCTURE

The failure of Garnett Dam would be considered a catastrophic event. There may be loss of life, but there would definitely be loss of private structures and community infrastructure. Public infrastructure at risk includes the following:

- **Municipal Roads:** District of Summerland owned and operated roads would be at risk. All roads in the centre of the flood path would not be expected to survive. The roads along Garnett Valley are for the most part relatively high and above the flood path, however there are areas along the routing where the roads may be submerged. The locations are illustrated in the detailed inundation maps in Appendix A. Access to Garnett Dam and Reservoir will be cut off in the event of a dam failure;
- **Bridges and Culverts:** All road sections where the velocities are expected to be high are expected to wash out. The bridge abutments may get undermined and the culverts would likely be displaced;
- **Provincial Highways:** Highway 97 would be at risk at two locations. At Peach Orchard Drive, there is a large underpass that will convey a great deal of water. The peak flow projected at this location is 132 cms of which the majority of water may pass under the highway. At this location the flow is perpendicular to the highway. Damage would be localized. At the second location, the flow would routed down Prairie Valley Road to Highway 97 from where it would flow over and along the highway through the silt bluff area. The peak flow is projected to be 70cms. The stability of soils in this area is expected to be poor and significant erosion would be expected along the Highway. Closure of the highway would be recommended;
- **Police Services:** The Summerland RCMP detachment located at 9101 Pineo Road is very close to the flooding and access to the station could be cut off in the event of a dam failure if both the main and channels are flooded;
- **Hospital:** The Summmerland Health Centre is situated on a sufficiently high site and access to the site will still exist from the south end of town via Giants Head Road, Tomlin Street and Atkinson Road. Access from the north may not be possible;
- **Electrical Service:** Overhead and buried transmission mains would be expected to be damaged or undermined during a dam break event all along the flood route. The deeper the water, the higher the chance of pole displacement. Service lines to all homes in the upper Garnett Valley would be at severe risk;
- **Fire Station:** Emergency services are typically coordinated out of the Fire Station, which is located at 10115 Jubilee Road. The main fire hall station is in the path of the south reach of the flood wave. An alternate base for emergency services should be identified.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The failure of the Garnett Dam will produce a large and fast traveling flood wave. It would cause extreme damage to the environment, roadways, bridges, private property, and public infrastructure as well as pose an extreme safety risk to local residents.

The following is a summary of the conclusions of this report:

C-1 In the event of a dam failure, projected areas of inundation are illustrated on the maps at the end of Section 4. More detailed maps are provided in Appendix A;

C-2 The estimated time to full formation of the flood wave for a piping or overtopping breach failure is estimated to be between 1.0 and 2.5 hours;

C-3 The maximum flood wave is predicted to have a peak discharge 384 cms at the dam. This flow rate would attenuate through delays from the ground surfaces to be reduced to approximately 210 cms near the Victoria Road cross section (STN 2+431). It then splits into two corridors and attenuates again to 134 cms in the Aeneas Creek corridor and 65 cms in the break-off corridor to Prairie Valley Road;

C-4 The estimated travel time for the maximum predicted flood wave is approximately 3.0 hours from time of breach initiation until the wave reaches the high density areas of Summerland (Station 2+987 – Washington Rd & Dunsdon Crt). It takes approximately 3.8 hours to reach Okanagan Lake via the Aeneas Creek corridor and 4.9 hours to reach the lake via the break off corridor down Prairie Valley Road;

C-5 A total of 742 structures are located in areas of flooding. Of these, 681 structures are residences. The residences immediately beneath the Garnett Dam located along Garnett Valley Road are at extreme risk of being destroyed suddenly in the event of a breach;

C-6 Access to critical services will be affected by a major Dam Break. Police, fire department and hospital access will be affected as will regional transportation at Highway 97;

C-7 If Garnett Dam fails, an estimated 2000 residents will be affected by the flood water. Approximately 15% of these residents or 300 persons reside in upland rural areas in Garnett Valley;

C-8 The Garnett Dam spillway channel has a current capacity of 38 cms, however this can be increased to 43 cms with downstream bank stabilization improvements. The calculated numbers allow for a 0.25 freeboard across the crest of the dam;

C-9 The PMF inflow to Garnett Reservoir is estimated to be 58 cms. This flow is attenuated by Garnett Reservoir to flow out of the spillway at a rate of 43 cms, assuming improvements on the lower spillway channel are carried out.

5.2 RECOMMENDATIONS

In consideration of the conclusions, the following recommendations are presented:

R-1 In review of the CDA guidelines, based on persons at risk and based on value of property damaged, it is recommended that the Province should review the failure classification of this dam. It is currently rated as VERY HIGH and it may be EXTREME;

R-2 It is recommended that the DoS take every precaution to implement all preventative requirements as set out by the MoE and CDA for dams having an EXTREME consequence of failure classification. These precautions and guidelines should be carried out or followed as soon as possible. Typical measures include alarmed remote monitoring, on-line monitoring of seepage, and stress and strain gauges within the dam structure;

R-3 On-line seepage monitoring would be able to detect sudden increases of flow below the Garnett Reservoir. A weir or similar measuring infrastructure should be installed immediately and located at the base of the earth dam and should be maintained and monitored on-line by operations staff. Furthermore, means of communicating the alarm to the appropriate EPP authorities should be put in place;

R-4 It is recommended that the inundation maps and property addresses generated from this report be incorporated into the District of Summerland Emergency Response Plan. Furthermore, the District of Summerland staff and emergency service personnel should be made aware of these documents and their whereabouts;

R-5 The Emergency Planning staff should be made aware of the location of the Summerland Fire Hall and Police station and the risks associated with dam failure on those structures. The emergency plan should have the means to relocate to higher ground and still be functional in the event of a dam failure;

R-6 The District of Summerland should consider means in which to extend the remote monitoring equipment to be installed for seepage so that it also records on-line dam water levels and spillway flows;

R-7 Spillway channel improvements are required on the lower channel to contain flows on the side slopes and increase the capacity from 38 cms up to 43 cms. This is a critical improvement to the spillway structure;

R-8 This report should be used as a supplementary document to the Comprehensive District of Summerland Dam Safety Review.

APPENDIX A - INUNDATION MAPS

Ten maps are included in Appendix A.

Figure A.1	Key Map
Figure A.2	Main Reach - Garnett Valley 1 of 6
Figure A.3	Main Reach - Garnett Valley 2 of 6
Figure A.4	Main Reach - Garnett Valley 3 of 6
Figure A.5	Main Reach - Garnett Valley 4 of 6
Figure A.6	Main Reach - Garnett Valley 5 of 6
Figure A.7	Main Reach - Garnet Valley 6 of 6
Figure A.8	North Reach - North Urban Area
Figure A.9	North Reach - Peach Orchard Drive
Figure A.10	South Reach - Prairie Valley Road to along Highway 97 silt bluffs

APPENDIX B - HEC-RAS FLOW-DEPTH-DURATION GRAPHS

Table B.1 - Output Data 1.0hr and 2.5hr Dam Breaches

	STN [m]	Q [cms]	W.S.Elev [m]	E.G.Elev. [m]	Vel.Ch. [m/s]	Froude [#]
1.0 HR Breach	15+276	386.72	620.71	624.93	4.05	0.86
	12+077	308.67	588.71	589.17	3.00	0.65
	8+977	280.12	546.02	546.12	1.44	0.32
	6+027	235.02	518.53	518.64	1.46	0.32
	4+227	227.89	498.73	498.79	1.07	0.33
	2+987	220.33	487.91	487.93	0.66	0.23
	2+431	210.26	483.69	483.73	0.87	0.32
	1+793	134.42	474.58	475.00	2.85	0.73
	0+247	134.22	359.27	359.40	1.64	0.66
	2+312	70.15	479.38	479.41	0.70	0.29
	1+462	69.25	455.36	455.50	1.64	0.50
	0+162	65.82	356.65	356.82	1.79	0.81
2.5 HR Breach	15+276	578.61	623.57	624.28	3.74	0.85
	12+077	255.77	588.43	588.85	2.84	0.65
	8+977	246.32	545.85	545.95	1.37	0.32
	6+027	223.73	518.45	518.55	1.45	0.31
	4+227	218.96	498.70	498.76	1.06	0.33
	2+987	213.96	487.89	487.91	0.65	0.23
	2+431	205.97	483.68	483.72	0.86	0.32
	1+793	132.35	474.57	474.97	2.83	0.73
	0+247	132.17	359.26	359.39	1.64	0.66
	2+312	70.15	479.38	479.41	0.70	0.29
	1+462	69.25	455.36	455.50	1.64	0.50
	0+162	65.82	356.65	356.82	1.79	0.81

Figure B.2 - Flow and Water Elevation Graph Example

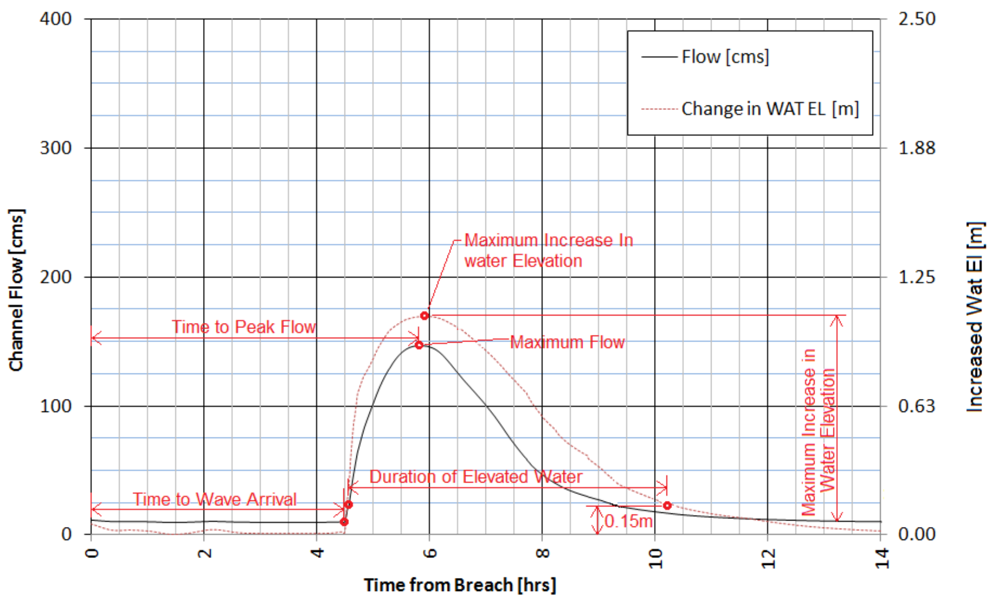


Figure B.3 - Output for Station 15+376 - 1.0 Hour Dam Breach Duration
(XS#1 - 100m downstream of Garnett Dam)

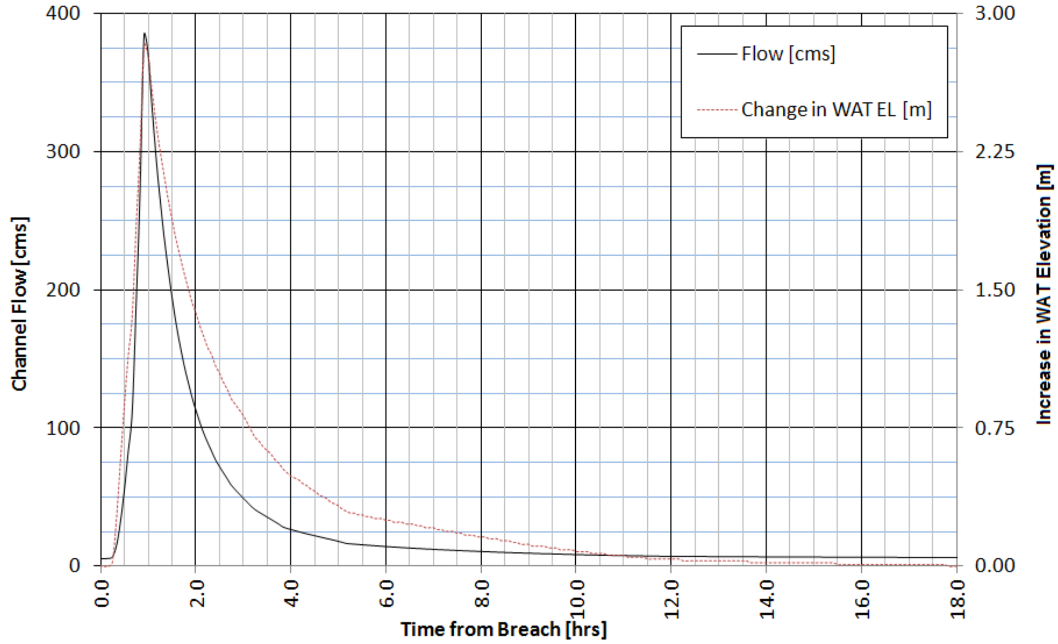


Figure B.4 - Output for Station 15+376 - 2.5 Hour Dam Breach Duration
(XS#1 - 100m downstream of Garnett Dam)

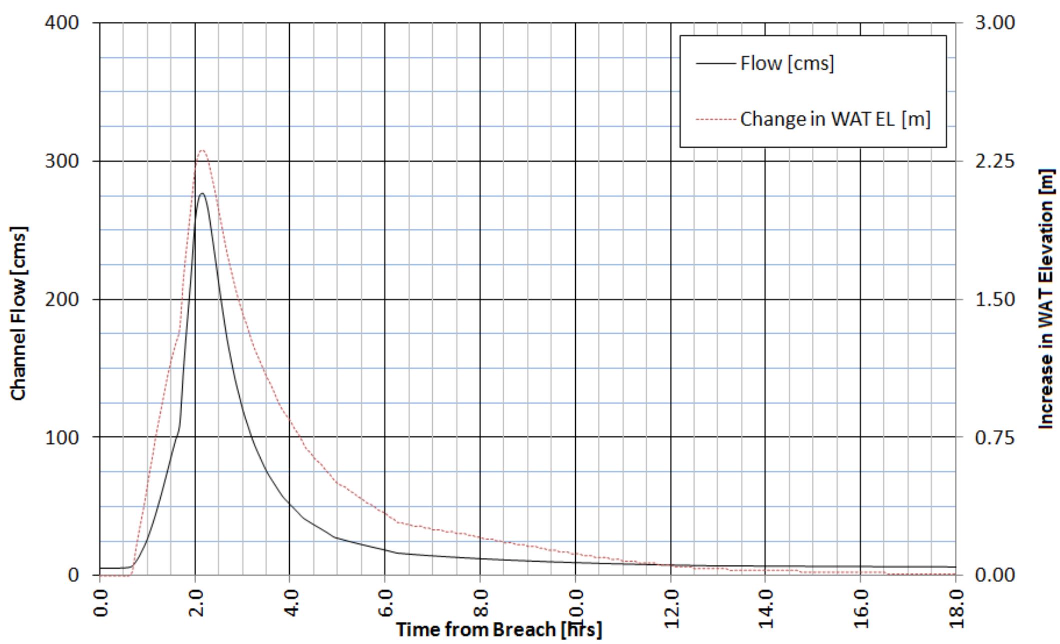


Figure B.5 - Output for Station 12+076 - 1.0 Hour Dam Breach Duration
(XS#2 - 1st Residence Downstream of Garnett Reservoir)

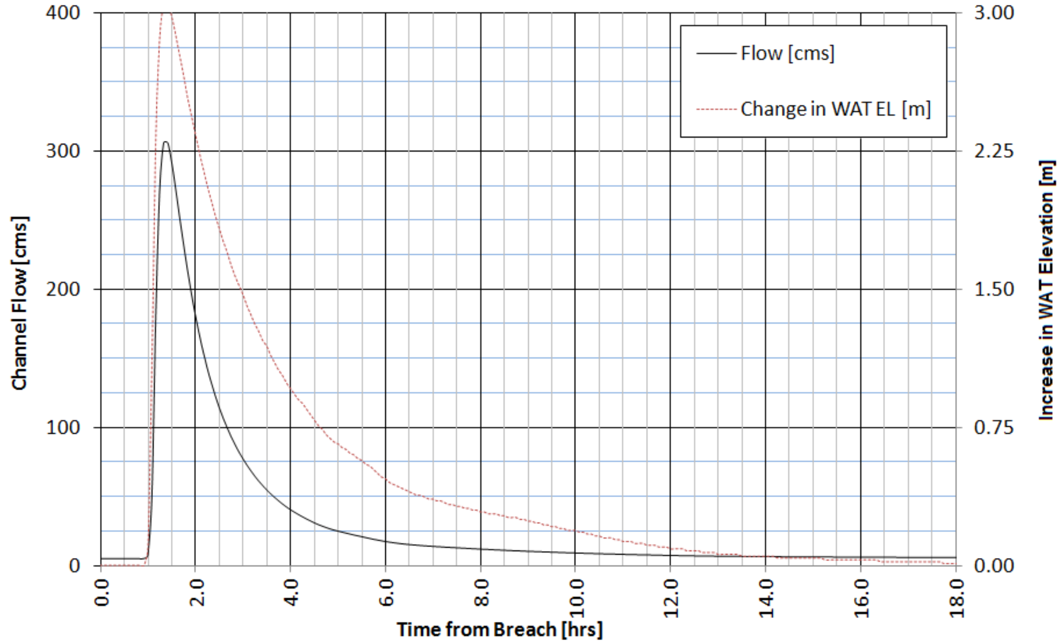


Figure B.6 - Output for Station 12+076 – 2.5 Hour Dam Breach Duration
(XS#2 - 1st Residence Downstream of Garnett Reservoir)

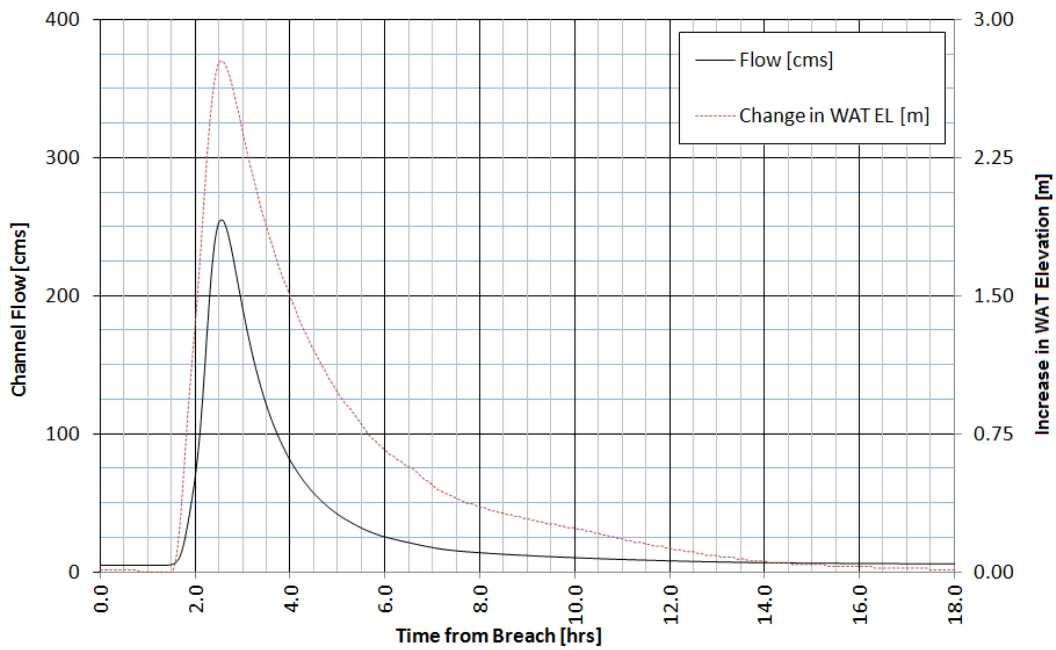


Figure B.7 - Output for Station 8+976 - 1.0 Hour Dam Breach Duration
(XS#3 - Wildhorse Rd & Garnett Valley Rd)

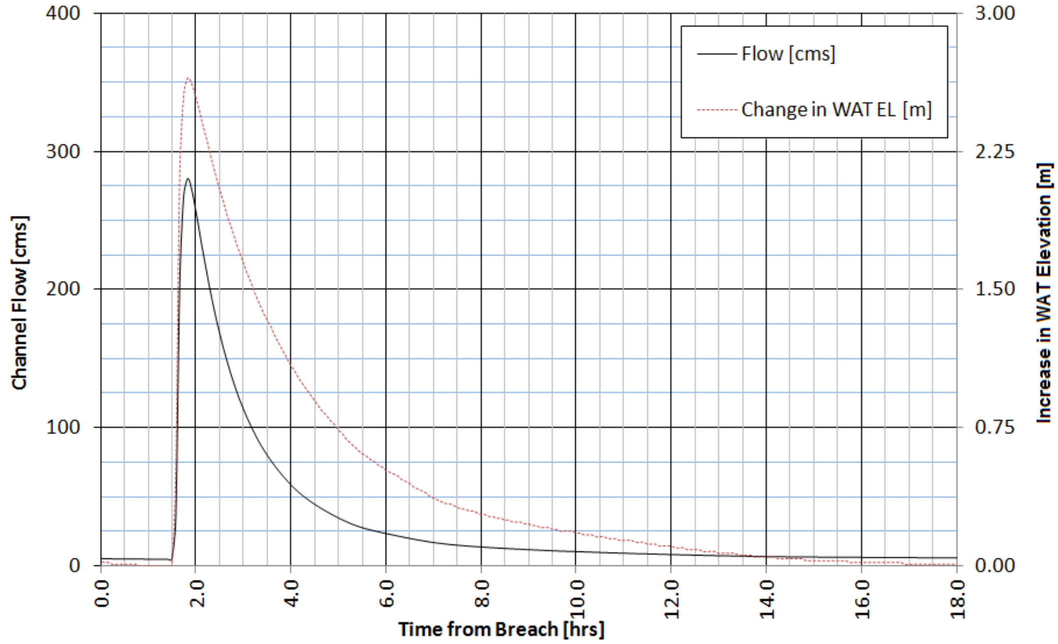


Figure B.8 - Output for Station 8+976 – 2.5 Hour Dam Breach Duration
(XS#3 - Wildhorse Rd & Garnett Valley Rd)

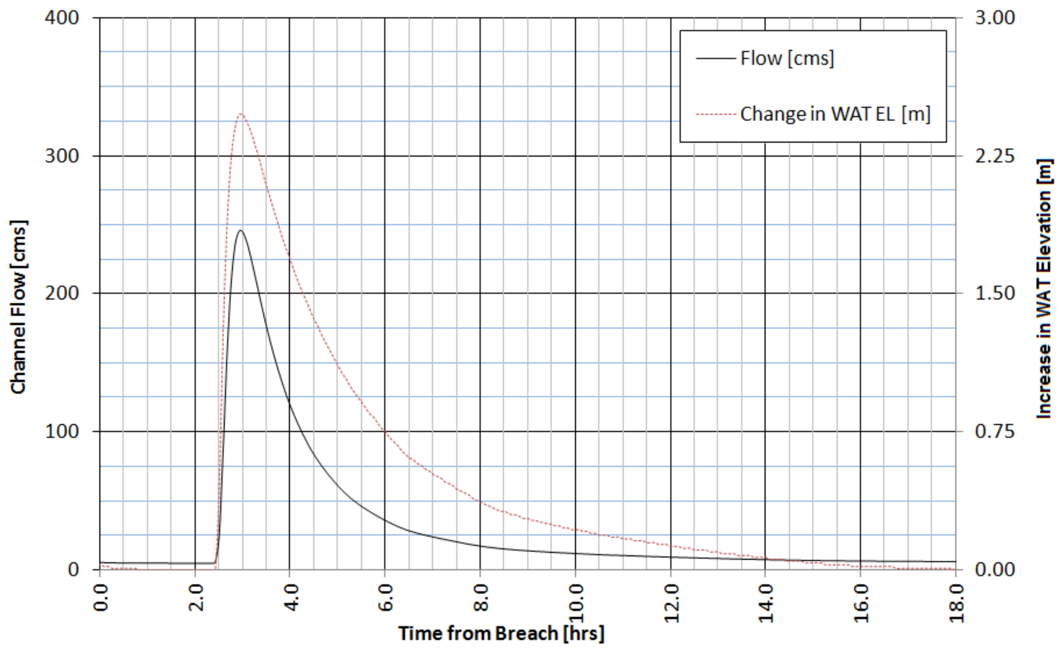


Figure B.9 - Output for Station 6+026 - 1.0 Hour Dam Breach Duration
(XS#4 - Lookout Turnoff)

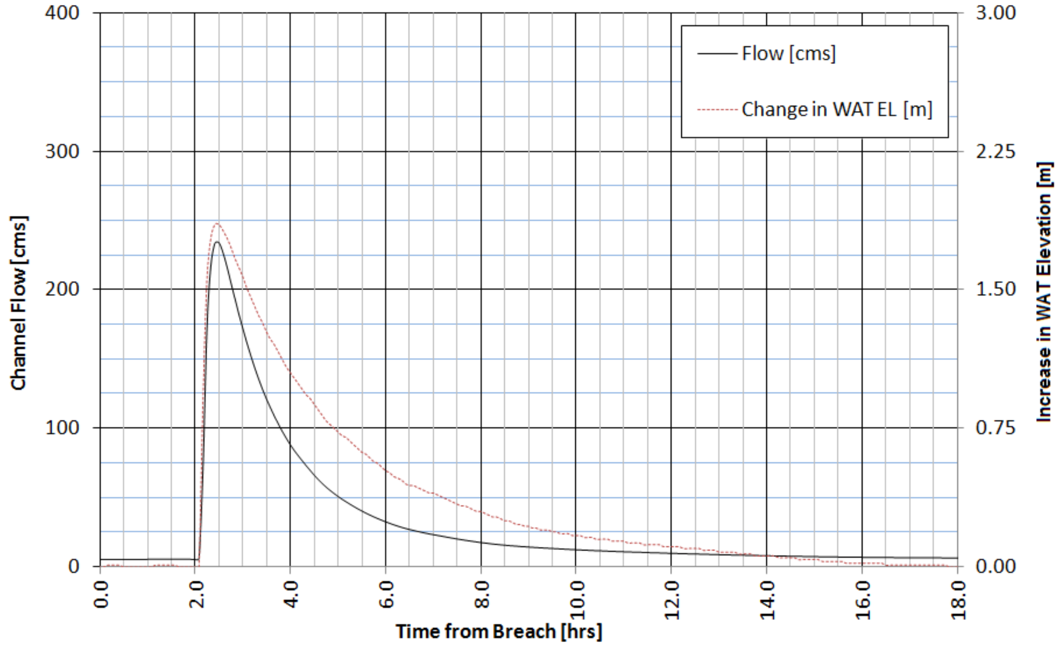


Figure B.10 - Output for Station 6+026 – 2.5 Hour Dam Breach Duration
(XS#4 - Lookout Turnoff)

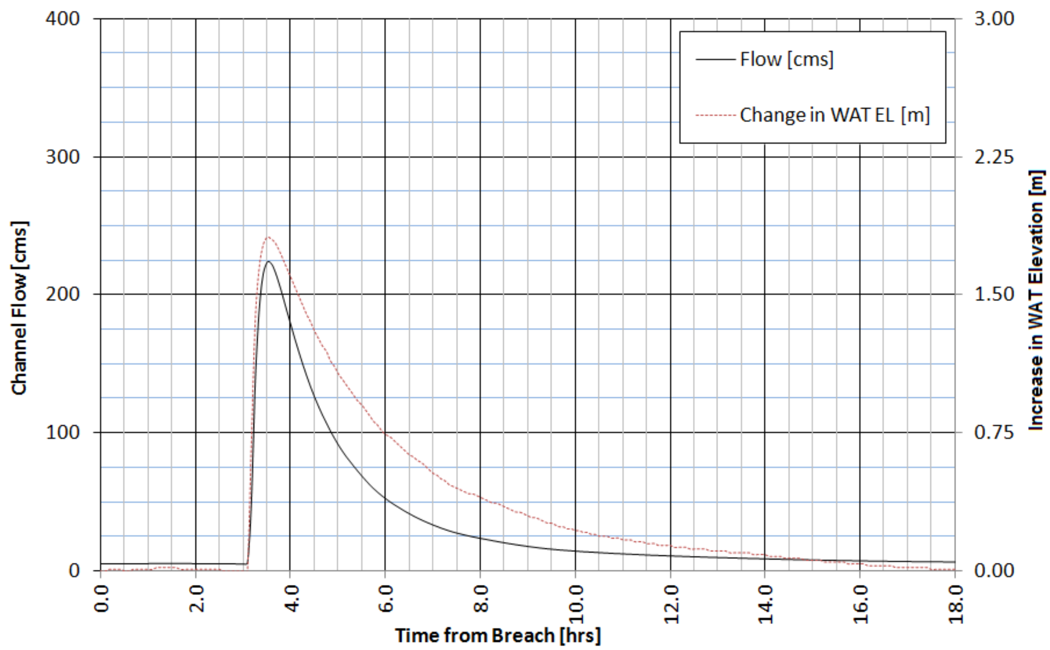


Figure B.11 - Output for Station 4+226 - 1.0 Hour Dam Breach Duration
(XS#5 - Jones Rd & Garnett Valley Rd)

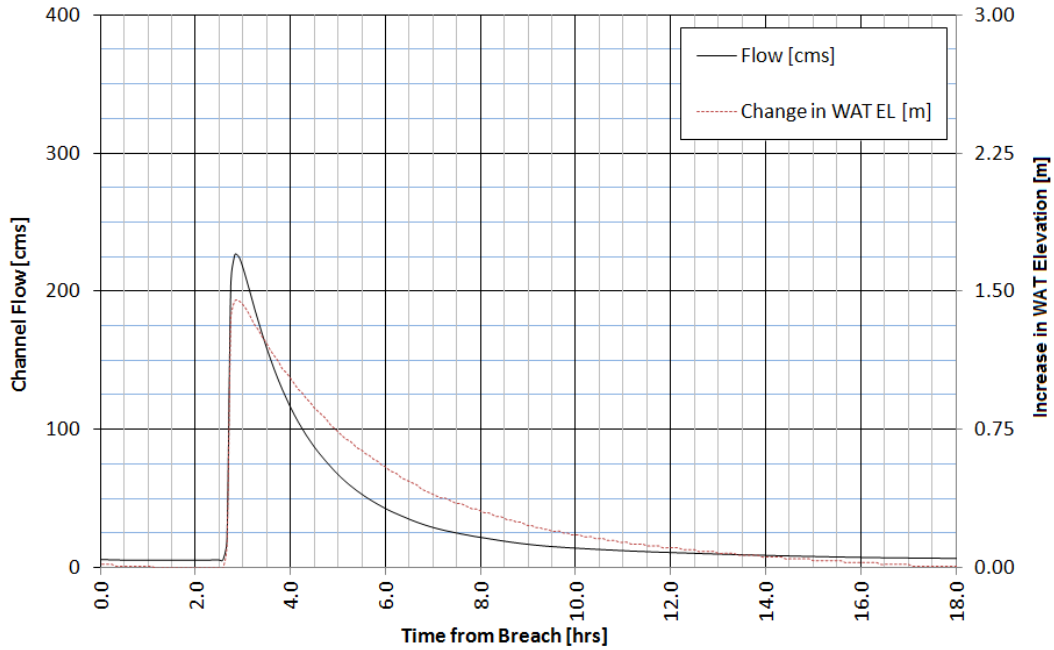


Figure B.12 - Output for Station 4+226 – 2.5 Hour Dam Breach Duration
(XS#5 - Jones Rd & Garnett Valley Rd)

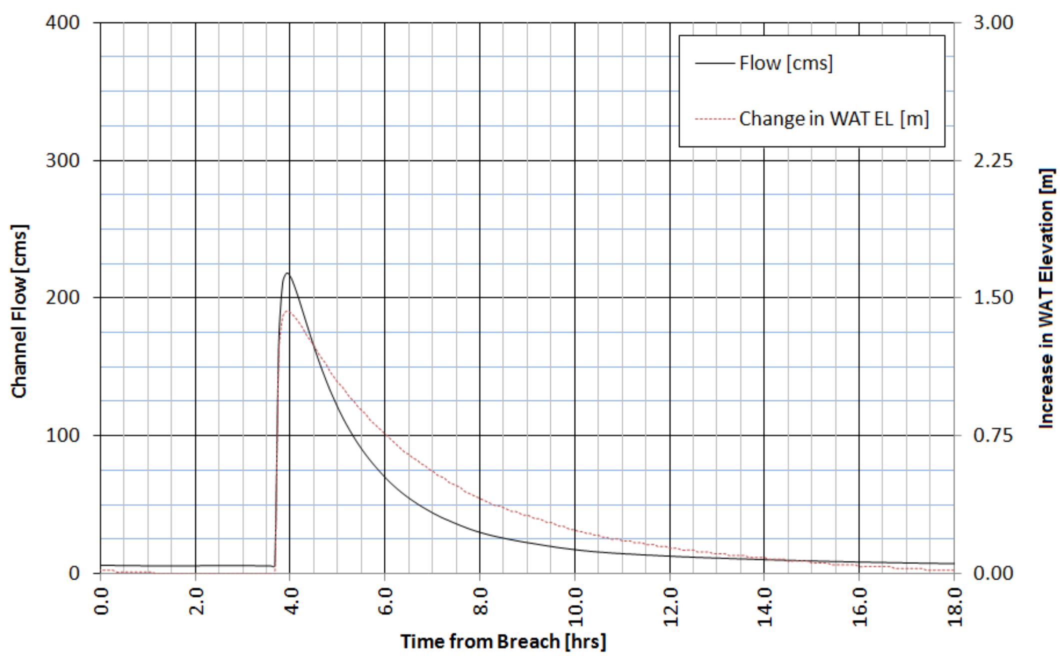


Figure B.13 - Output for Station 2+987 - 1.0 Hour Dam Breach Duration
(XS#6 - Washington Rd & Dunsdon Crt)

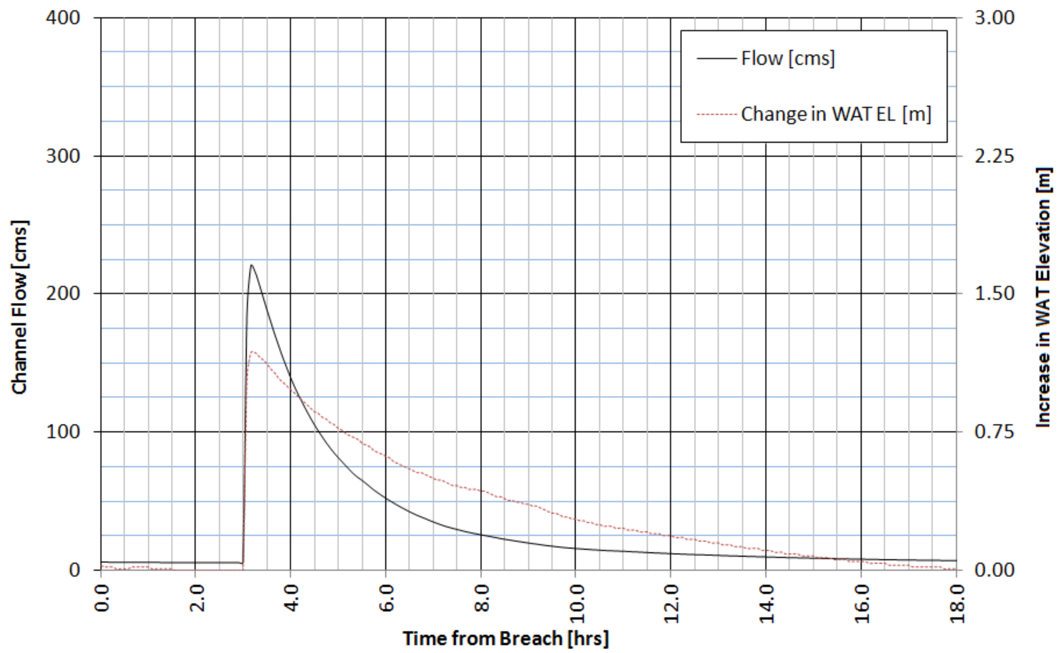


Figure B.14 - Output for Station 2+987 – 2.5 Hour Dam Breach Duration
(XS#6 - Washington Rd & Dunsdon Crt)

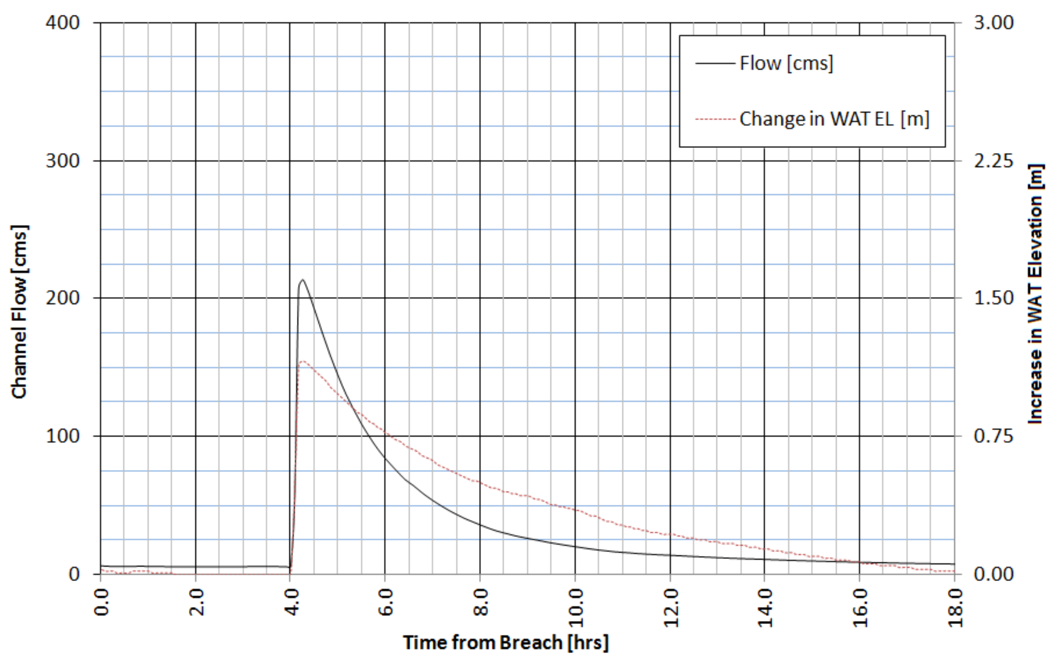


Figure B.15 - Output for Station 2+431 - 1.0 Hour Dam Breach Duration
(XS#7 - Victoria Rd Crossing)

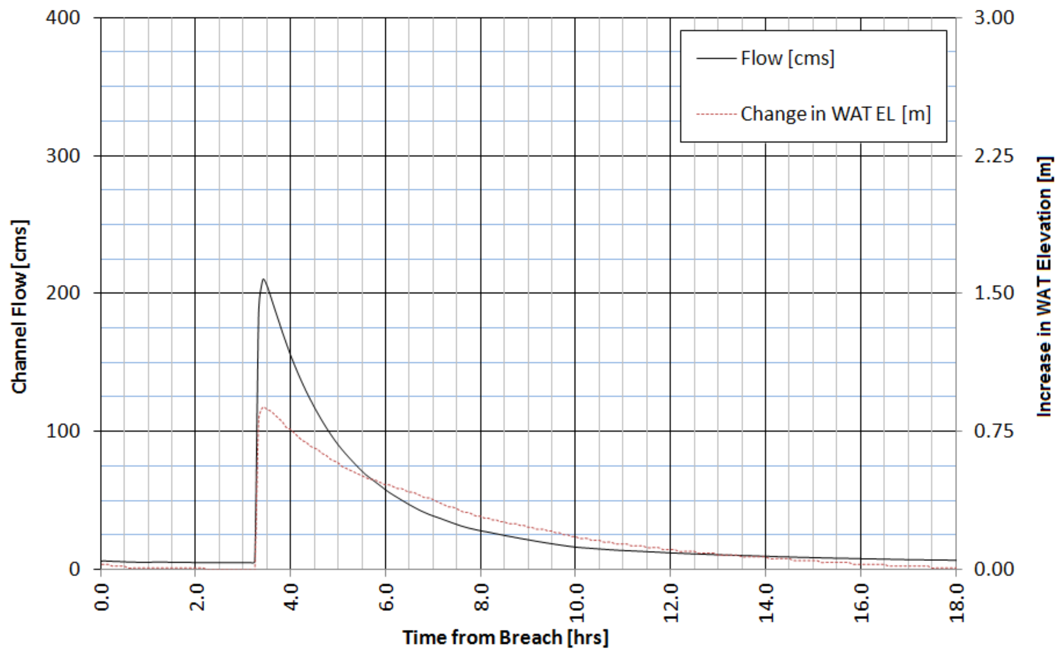


Figure B.16 - Output for Station 2+431 – 2.5 Hour Dam Breach Duration
(XS#7 - Victoria Rd Crossing)

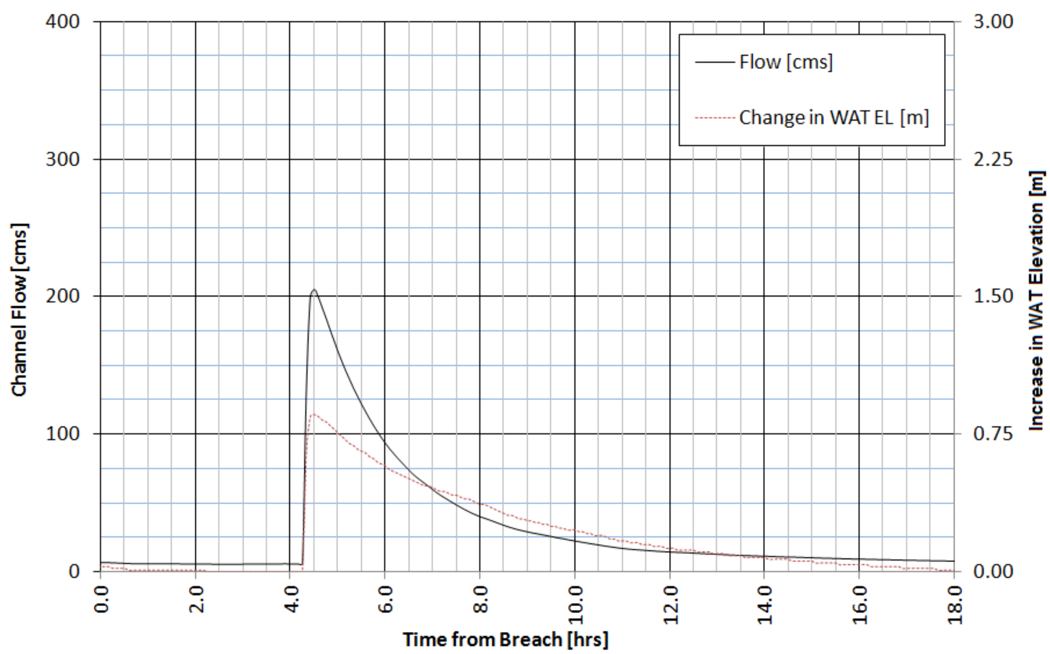


Figure B.17 - Output for Station 1+792 - 1.0 Hour Dam Breach Duration
(XS#8 - Hwy 97 – North Crossing)

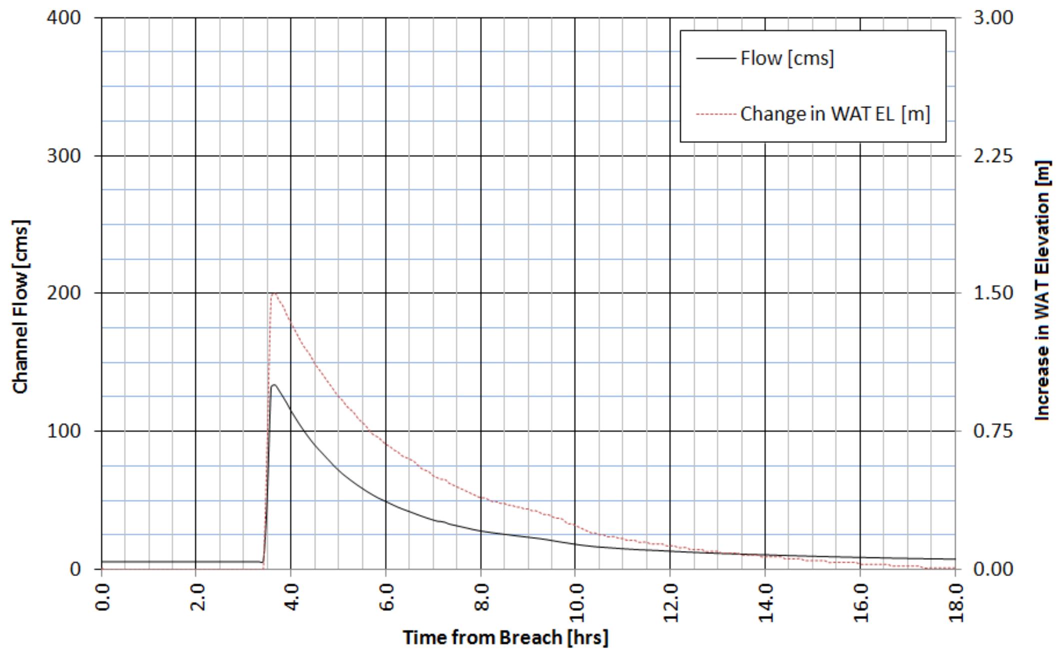


Figure B.18 - Output for Station 1+792 – 2.5 Hour Dam Breach Duration
(XS#8 - Hwy 97 – North Crossing)

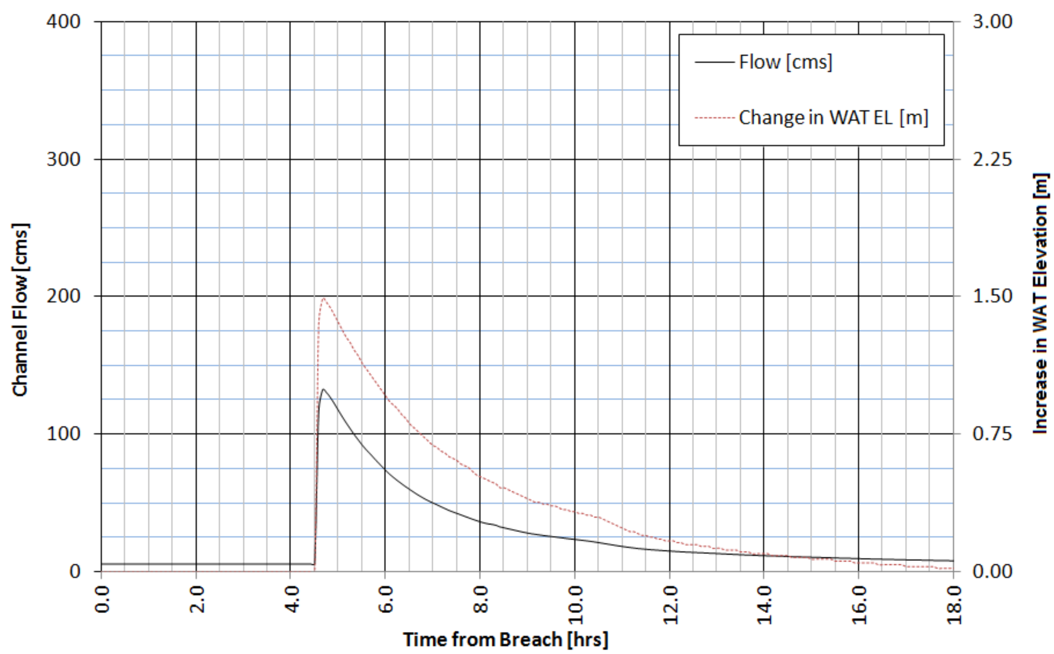


Figure B.19 - Output for Station 0+247- 1.0 Hour Dam Breach Duration
(XS#9 – Charles Ave & Orchard Rd)

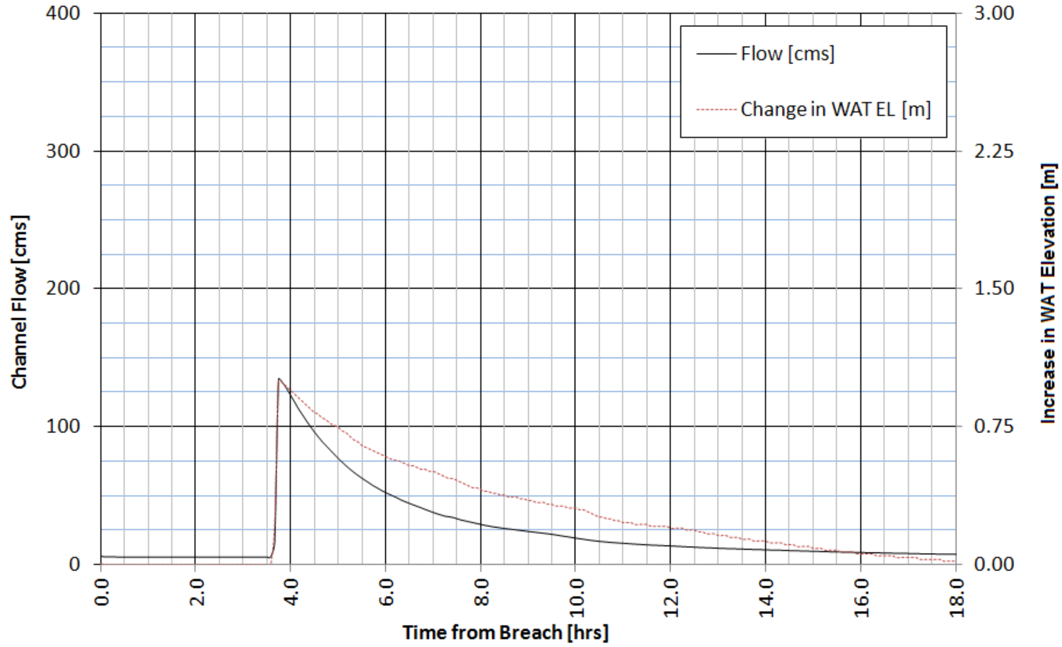


Figure B.20 - Output for Station 0+247 – 2.5 Hour Dam Breach Duration
(XS#9 - Charles Ave & Orchard Rd)

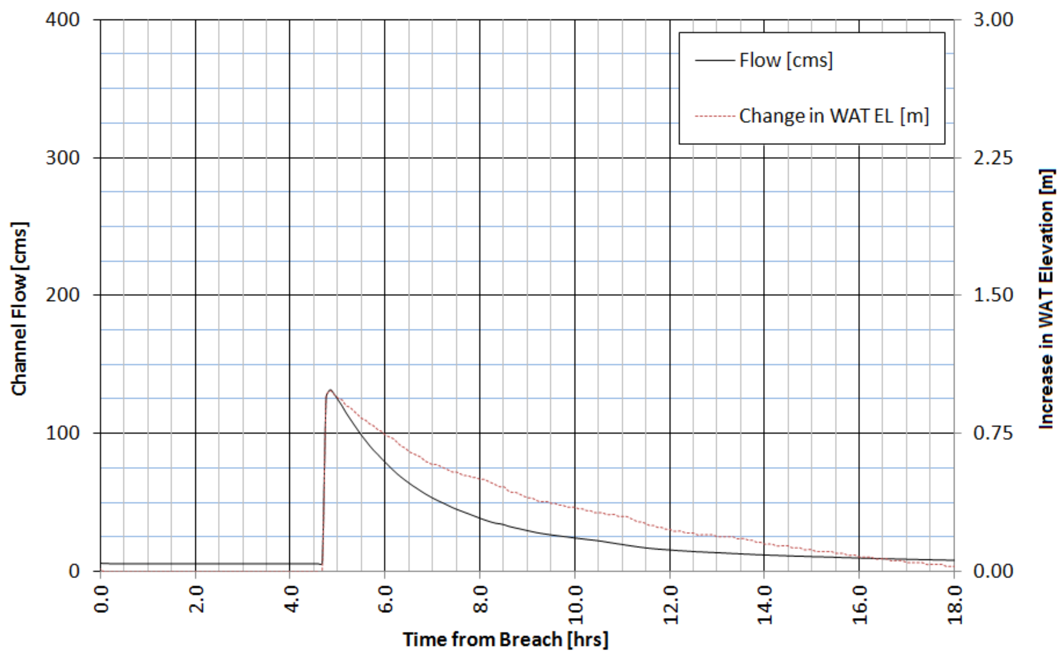


Figure B.21 - Output for Station 2+311 - 1.0 Hour Dam Breach Duration
(South Flow Split XS#10 – Wharton St & Prairie Valley Rd)

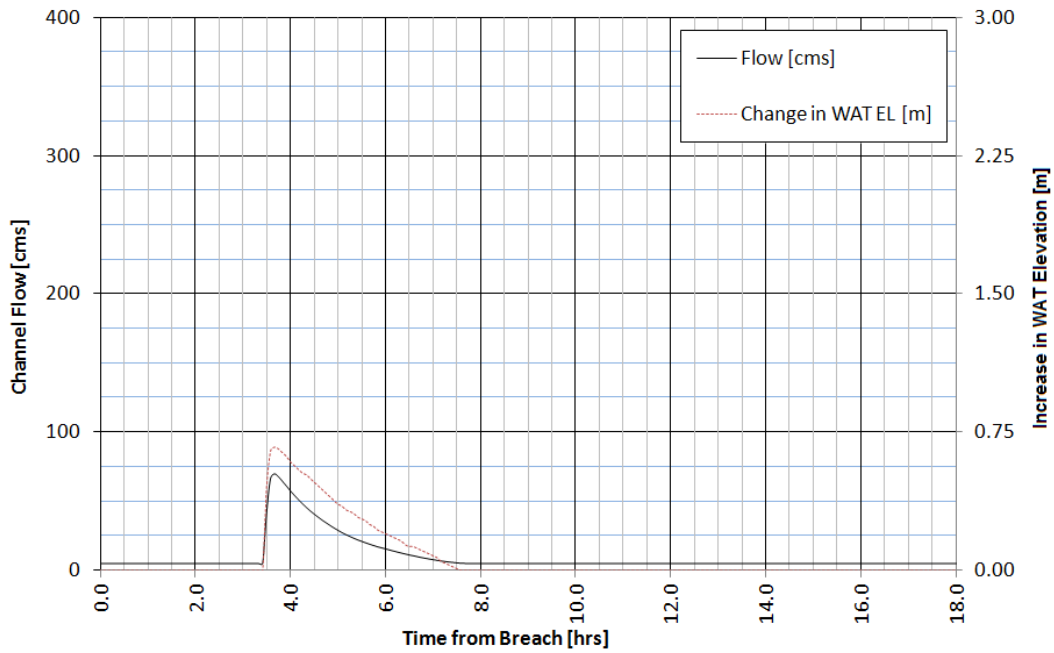


Figure B.22 - Output for Station 2+311 – 2.5 Hour Dam Breach Duration
(South Flow Split XS#10 - Wharton St & Prairie Valley Rd)

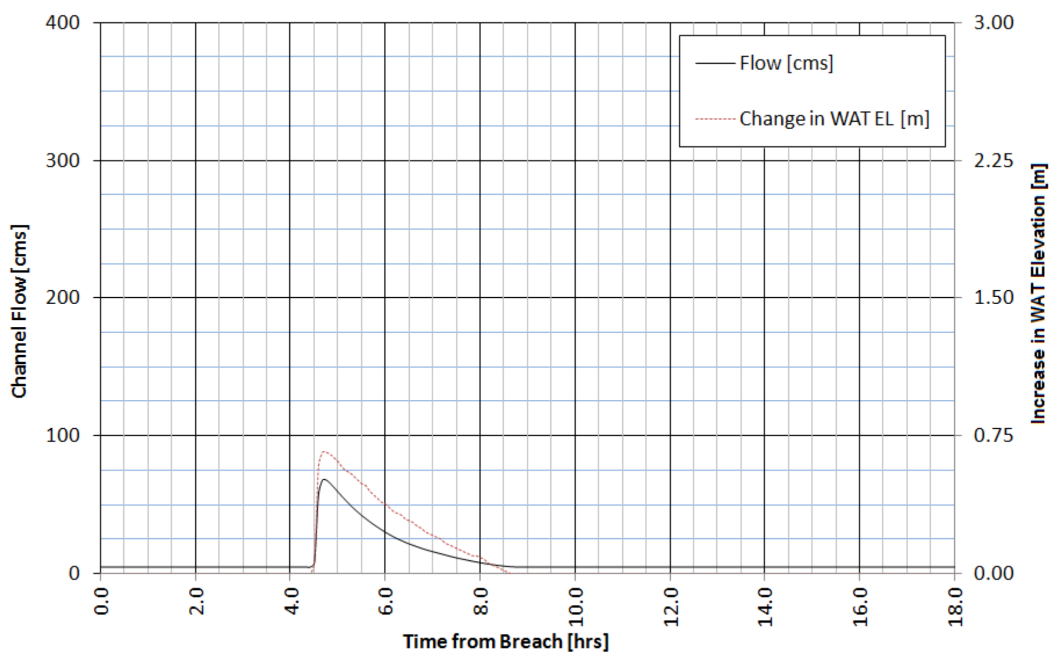


Figure B.23 - Output for Station 1+461 - 1.0 Hour Dam Breach Duration
(South Flow Split XS#11 – Atkinson Rd & Prairie Valley Rd)

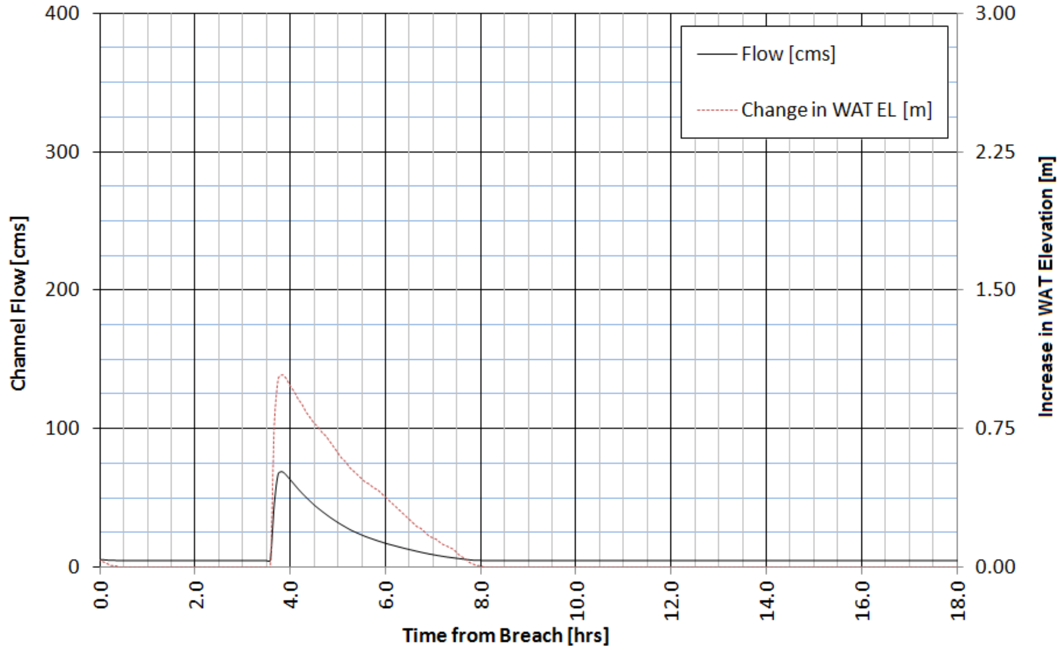


Figure B.24 - Output for Station 1+461 – 2.5 Hour Dam Breach Duration
(South Flow Split XS#11 - Atkinson Rd & Prairie Valley Rd)

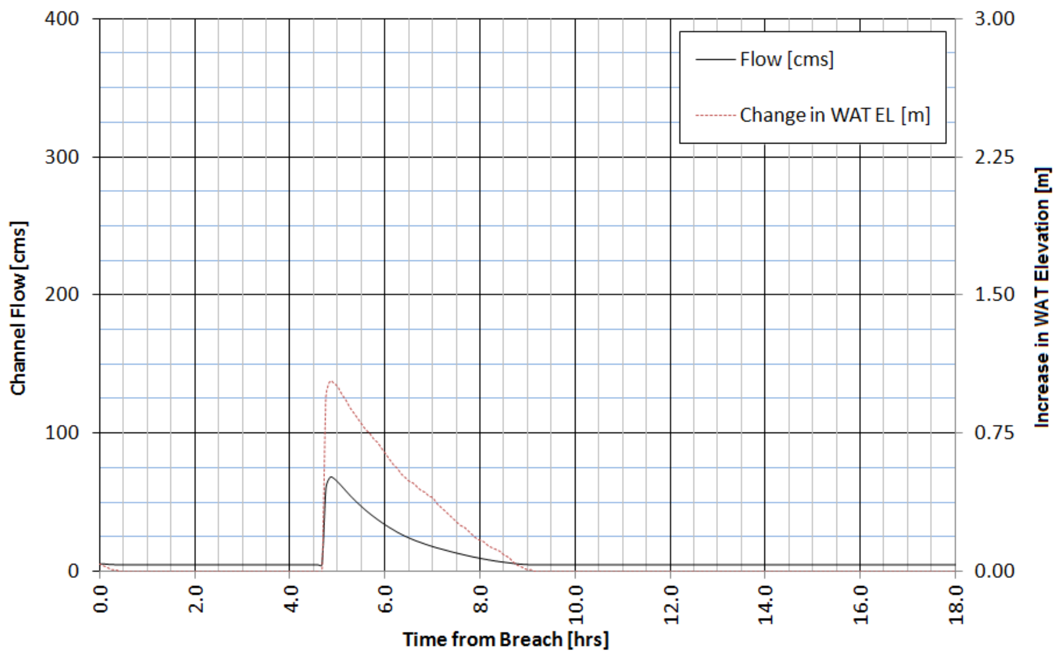


Figure B.25 - Output for Station 0+161 - 1.0 Hour Dam Breach Duration
(South Flow Split XS#12 – Shaughnessy Ave)

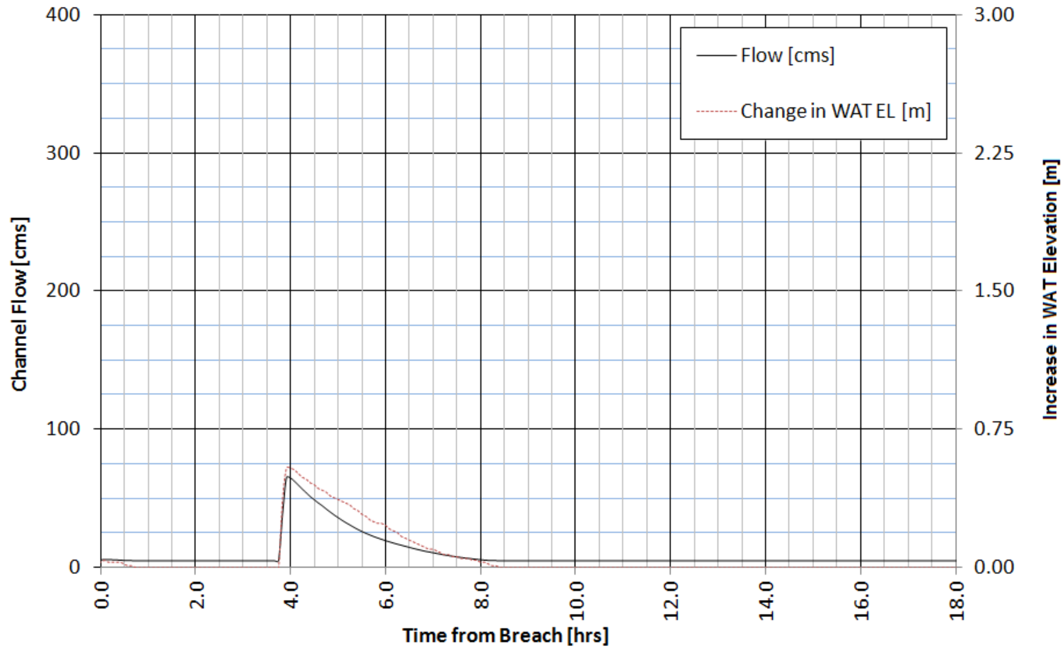
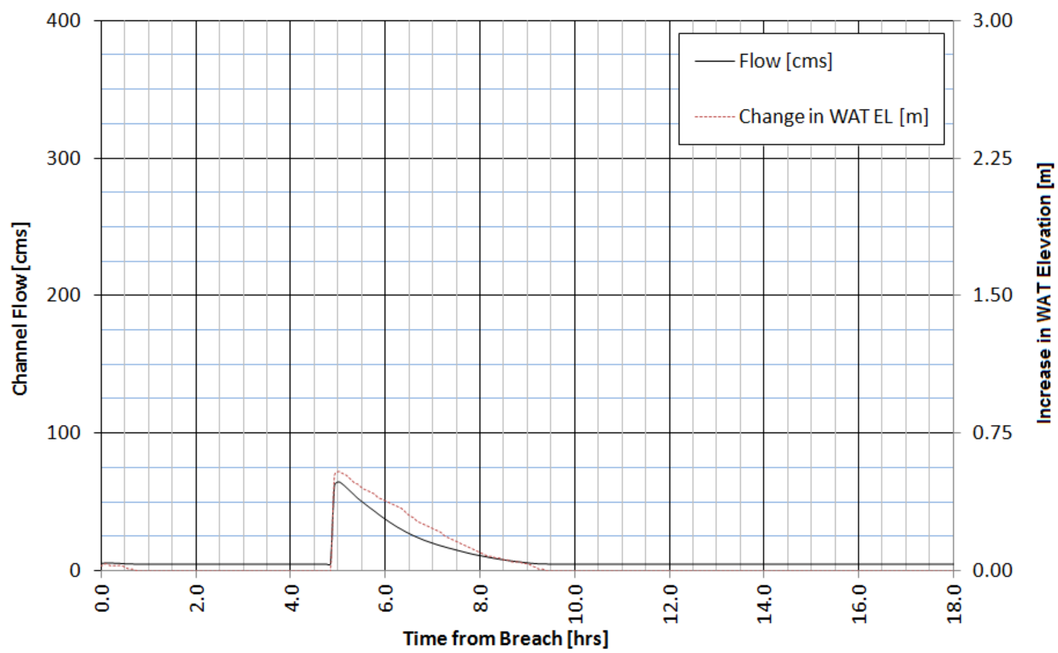


Figure B.26 - Output for Station 0+161 – 2.5 Hour Dam Breach Duration
(South Flow Split XS#12 - Shaughnessy Ave)



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APPENDIX C - GARNETT RESERVOIR PROBABLE MAXIMUM FLOOD REVIEW

C.1 SUMMARY

This technical memorandum is in response to the District of Summerland's (DOS) request to assess the Maximum Probable Flood and spillway capacity for Garnett Dam. Agua Consulting reviewed all aspects of the Garnett Dam's spillway, watershed, and applicable design guidelines. Using these guidelines, a simulated design storm was developed and tested through the structures using applicable computer modeling. The 12-hour duration 1-in1000-year storm was determined to be the worst case scenario which generated the highest flow through the spillway. This storm produces a maximum inflow to the Garnett Reservoir of 58 m^3/s. The Garnett Reservoir is capable of attenuating (buffering) this flow to just 43 m^3/s through the spillway. The Garnett Dam Spillway is capable of conveying 43 m^3/s without overtopping the Garnett Dam. Under these circumstances a portion of the spillway is breached at the first section change immediately downstream of the spillway inlet. This can be easily mitigated by increasing this short section's channel banks by 0.5 m of rock, concrete or some type of stable structural containment. This should mitigate the risk of undermining the Garnett Dam under a spillway flow of 43 m^3/s. Without correction, the dam can only convey 38 m^3/s through the spillway which is insufficient to control the Maximum Probable Flood.

C.2 INTRODUCTION

All dams in the province of British Columbia having a High or Very High hazard classification rating are required to have a Dam Safety Review (DSR) conducted every 10 years. In December of 2010, Summerland retained Associated Engineering to conduct a DSR for all required dams. In the resulting DSR report, coarse estimates comparing the spillway capacity to the 1 in 1000 year inflow design flood were conducted. The spillway capacity and the IDF flows were determined to be 70 m^3/s and 164 m^3/s respectively. The recommendations of that DSR suggested further study of the spillway requirement should be conducted. This section of the report is intended to fulfill that requirement.

This memorandum summarizes the methodology used to determine the aforementioned spillway capacity requirement of 43 m^3/s

C.3 METHODOLOGY

In general, two events were estimated, the Maximum Probable inflow to Garnett Reservoir, and the resulting Spillway outflow for the Garnett Reservoir. The differences between these flow rates creates the water elevation change in reservoir and the volume of storage that must be attenuated by the reservoir. If the maximum change in volume can be safely retained by the reservoir's freeboard, then the reservoir spillway capacity should be sufficient to convey the Maximum Probable Flood.

Due to the size of the watershed and the variety of possible storms, a computer model was employed to model the rainfall, the runoff routing through the watershed, and the elevation of water in Garnett Reservoir. The Environmental Protection Agency's Storm Water Management Model (*EPA SWMM*) software was selected due to its cost, availability, its robust drainage modeling capabilities, and its general acceptance by the engineering industry.

The *EPA SWMM* routing model required an accurate characterization of the Garnett Dam's spillway performance with respects to the reservoir's water elevation. This spillway capacity determination required a second computer model. The model used the Hydrologic Engineering Centers River Analysis System (*HEC-RAS*) software package. It can assess the backwater effect in channels and flows through stream courses.

C.4 HEC-RAS SPILLWAY DETERMINATION

Due to the irregularity in slope, surface material, and cross-sectional areas throughout the spillway channel, computer modeling with *HEC-RAS* was necessary. The physical descriptions of the spillway were mapped in *HEC-RAS* and the simulation of the flow through the spillway under various reservoir depths was calculated. This stage-discharge was entered into the *EPA SWMM* model for accurate flow determination through the reservoir. The dimensions of the reservoir were obtained from the plan and section map included at the end of this section. Figure B.1 shows the modelled structure used in our analysis.

Figure B.1 - Spillway HEC-RAS Sections

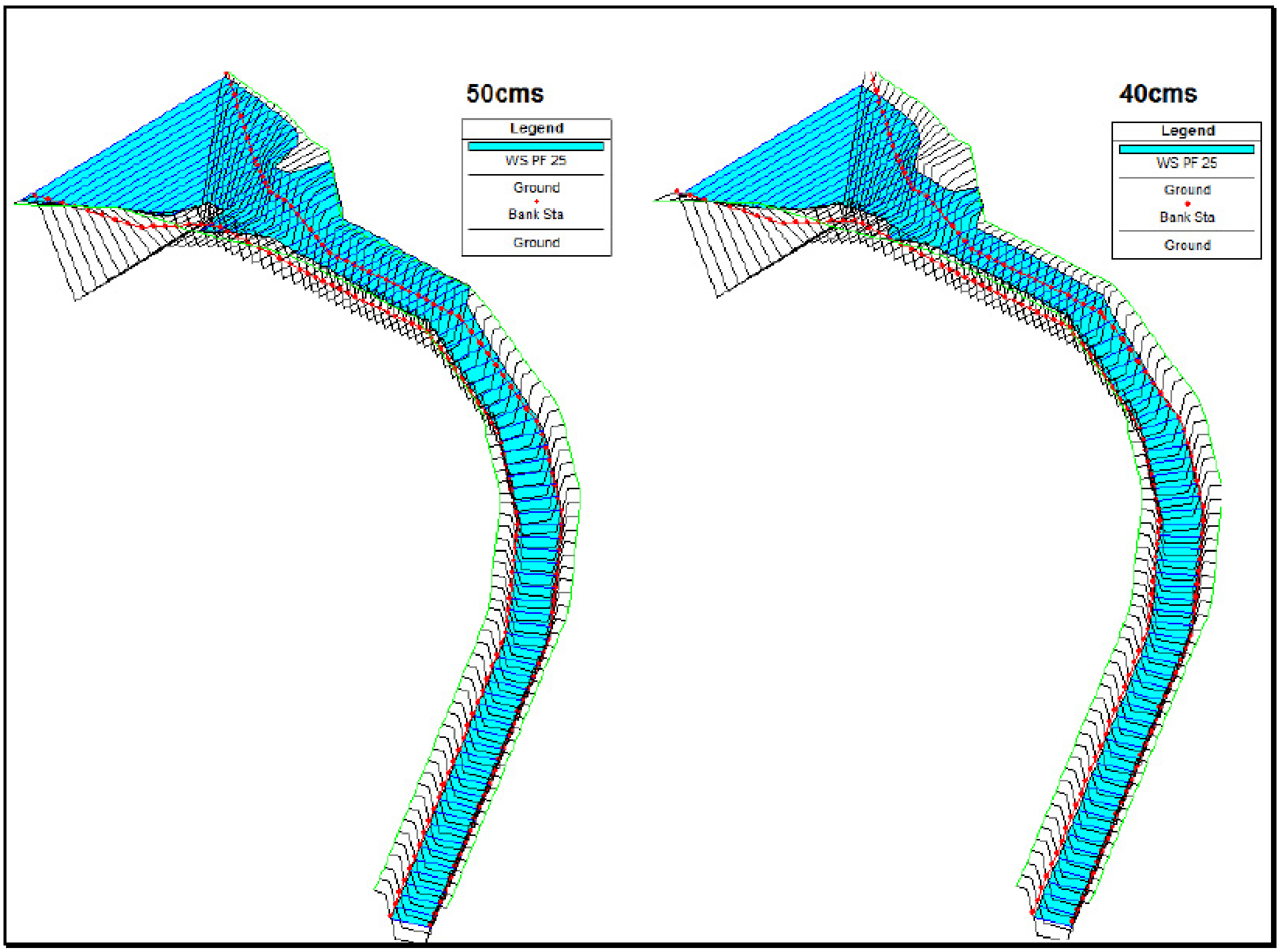


Table B.1 - Garnett Dam Spillway – Stage - Discharge

Flow m3/s	Elevation m
0	632.76
1	632.87
2	632.92
4	633.00
6	633.06
8	633.12
10	633.18
12	633.23
14	633.27
16	633.33
18	633.37
20	633.41
22	633.53
24	633.63
26	633.72
28	633.80
30	633.88
32	633.96
34	634.03
36	634.10
38	634.17
40	634.24
42	634.30
44	634.36
46	634.41
48	634.46
50	634.51
52	634.56
54	634.61

Table B.1 provides the stage (elevation) discharge (cms) for the Garnett Dam spillway.

The spillway elevation is at 632.76 metres (geodetic elevation).

The maximum safe flow through the spillway without improvements to the shoulders of the spillway is 38 m^3/s

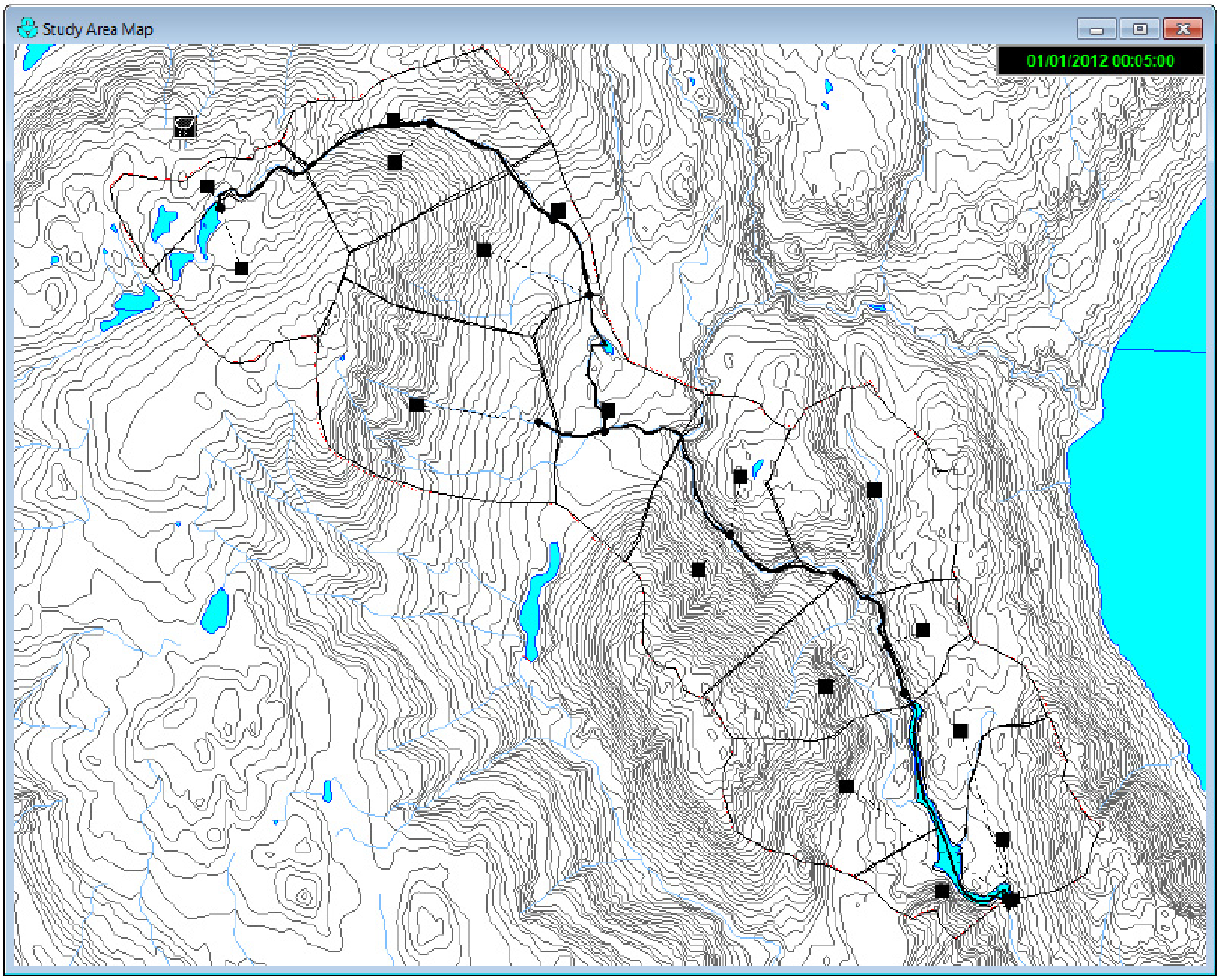
The maximum safe flow over the spillway with improvements to the sides of the Garnett Dam spillway channel is 43 m^3/s.

C.5 STORM ROUTING AND EPA SWMM MODEL CONSTRUCTION

Before the routing could be simulated, a map of the Garnett watershed was imported into the model. This was used to divide the watershed topography into 13 sub-catchment areas. Using *Google Earth*, these areas were hydraulically characterized and the connecting channels described. For a conservative estimate, the areas were assumed to be impervious. This could mean that the ground surface is frozen and no water is capable of penetrating the ground. This is very conservative and runoff would be generated from all rainfall and snow-melt water over frozen ground conditions.

The 13 subcatchment areas are illustrated in Figure B.2.

Figure B.2 - Aeneas Creek Upstream Sub catchment Areas

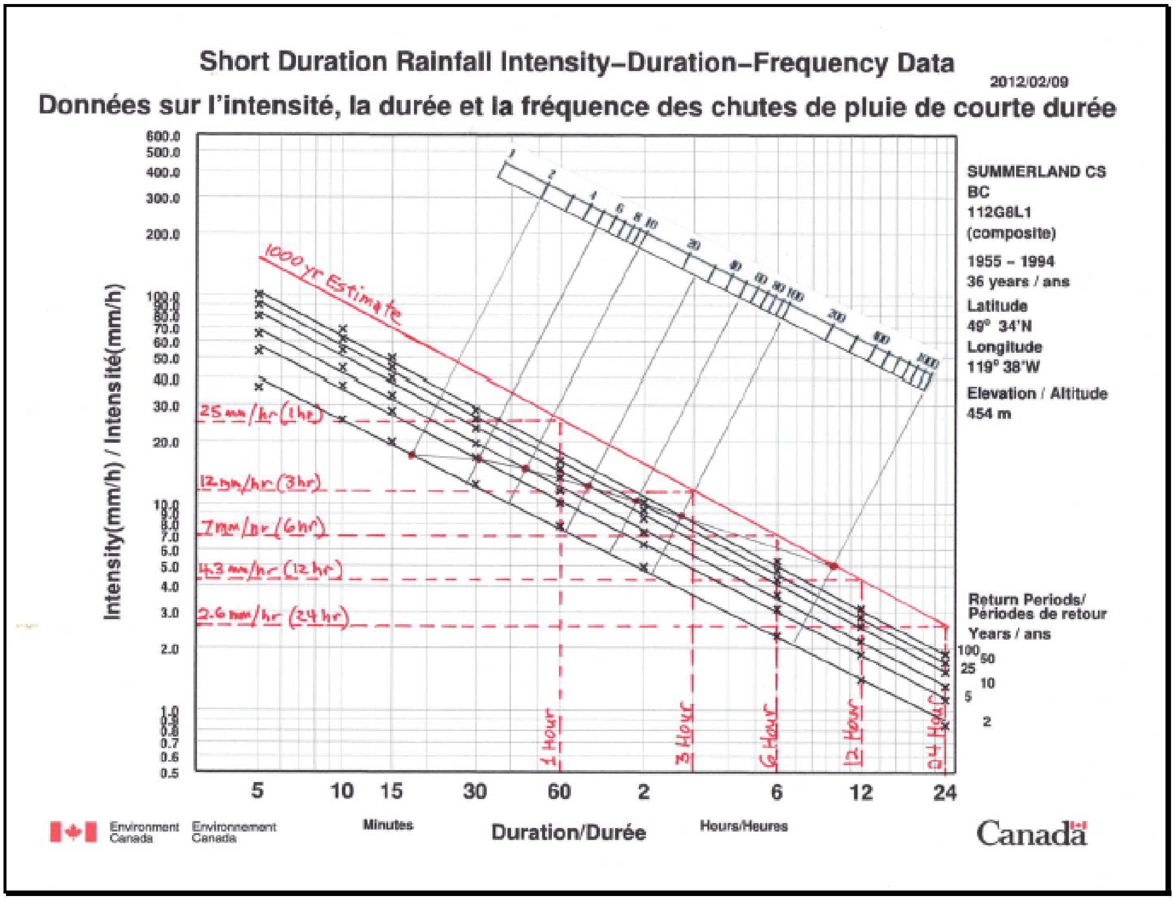


Next, the reservoir storage details and spillway relationships were entered into the model. This information is required for the model to determine the attenuation in the reservoir.

Finally, rainfall is needed to be determined for the model input. According to the Canadian Dam Authority, the rainfall should be determined using the inflow design flood curves (IDFs) based on 1 in 1000 year recurrence intervals (CDA, 2007). To extend the existing data to 1:1000 year frequency, an IDF graph available for the Summerland was used to interpolate the 1 in 1000 year recurrence interval intensities using a log-relationship. Rainfall intensities for 1 hr, 3 hr, 6 hr, 12 hr and 24 hr storms were determined and distributed using local unit hyetographs.

The IDF curve is presented as Figure B.3. Unit hyetographs, and resulting input hyetographs are included at the end of this Appendix.

Figure B.3 - Summerland 1:1000 IDF Curve



In general, the model simulates all five rainfall storms and routes the water through the watershed. The worst case was the 12 hr event. Table 1 summarizes these simulation results. For all simulation results see the appendix.

3hr Storm Results (1 in 1000 RI):	
Peak Simulated Reservoir Inflow	58 m^3/s
Peak Simulated Spillway Flow	43 m^3/s
Actual Spillway Capacity	38 m^3/s (43 m^3/s with slight modification)
Garnett Reservoir Elevation Increase	1.58 m
Garnett Available Freeboard	1.83 m
Total Volume Routed	2,786 ML

As expected, the Garnett Reservoir attenuated the peak simulated flow of 58 m^3/s to the peak simulated spillway flow of 43 m^3/s. Since (1) the reservoir elevation increase of 1.58 m resulting from the flood is less than the available freeboard of 1.83 m, and (2) the actual spillway capacity of 43 m^3/s is capable to be conveyed without breaching the dam, it is concluded that the spillway is satisfactory.

Note that the spillway can only convey 38 cms but 43 cms can be conveyed with minor changes to the spillway).

C.6 SUMMARY OF PROBABLE MAXIMUM FLOOD AND ATTENUATION

Table B.2 provides a summary of information related the 1:1000 storm events. The 1 hr, 3 hr, 6 hr, 12 hr and 24 hr storms were run through using the *EPA SWMM* model. The estimated Garnett Reservoir inflow, total volume of inflow, and resulting water elevation in Garnett Reservoir are summarized in Table B.2.

Table B.2 - 1:1000 Year Storm Event Summary

Storm Event	Peak Reservoir Inflow (m^3 / s)	Total Inflow (ML)	Reservoir Stage (elev. in metres)	Comment
1 hour	30	1,350	0.58	
3 hour	54	1,944	1.07	
6 hour	56	2,268	1.30	
12 hour	**58**	**2,780**	**1.58**	**Critical peak flow**
24 hour	28	3,370	0.72	Total inflow time > 48 hrs
AE Results (DSR)	85	n/a	n/a	From DSR by Associated Eng.
Rational Method	80	n/a	n/a	Rational Method Check

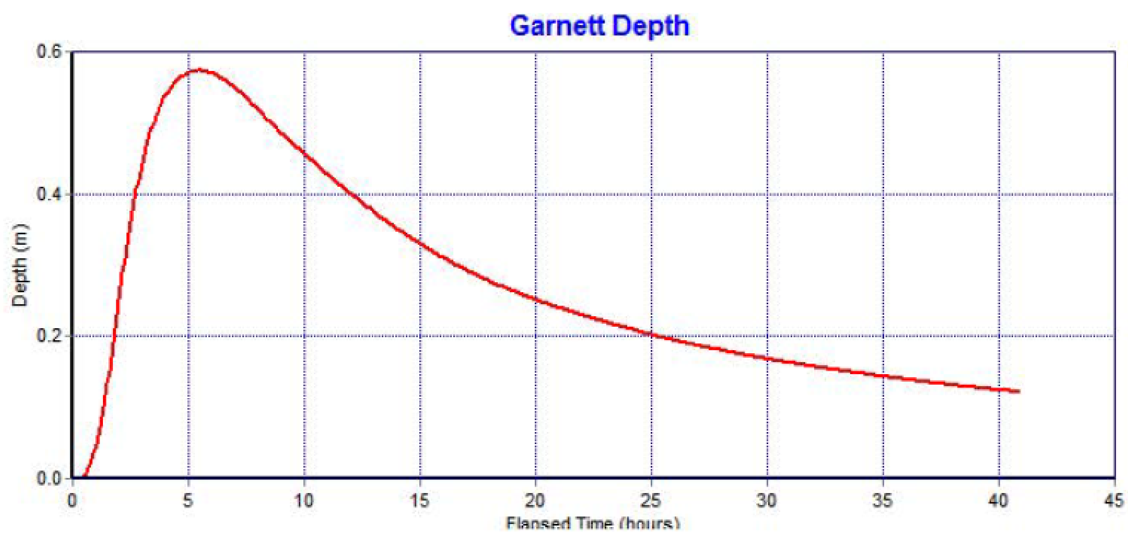
Two methods were used to verify the inflow design flood peak flow. Both methods are recommended by the Dam Safety Authority and are to be considered as only coarse methods for smaller dams. In addition, they are typically conservative in nature due to their generic applications.

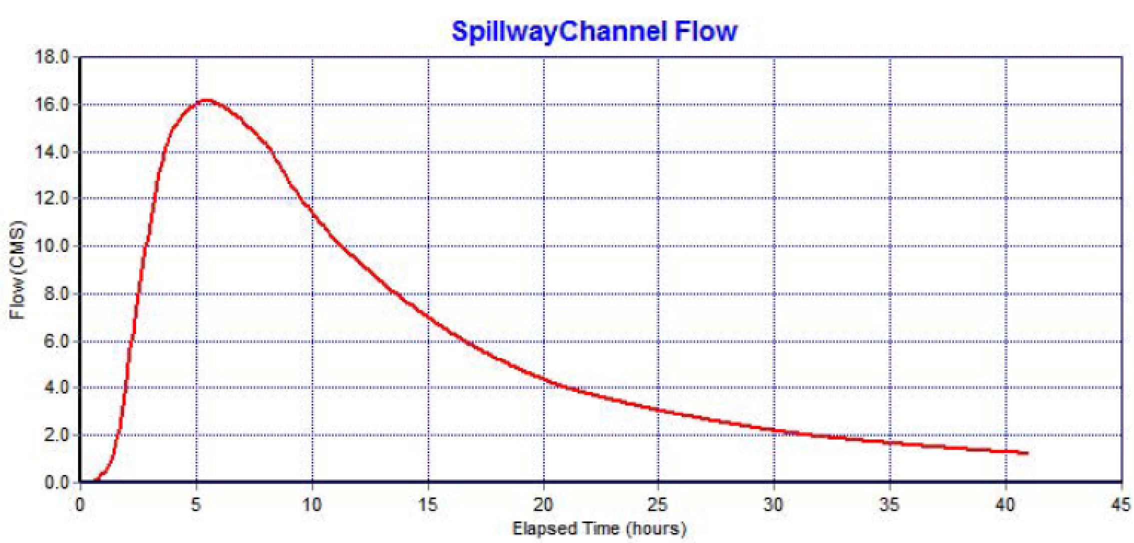
According to the Canadian Dam Association, the IDF should be compared to the Peak Maximum Flood (PMF) (CDA, 2007). Hand calculations determined the PMF to be 85 m^3/s.

In addition to the PMF verification, the rational method approach was employed as described in the Dam Safety Guideline's recommended procedure (Manual of Operational Hydrology in BC, 1991). The resulting peak design inflow was estimated to be 80 m^3/s.

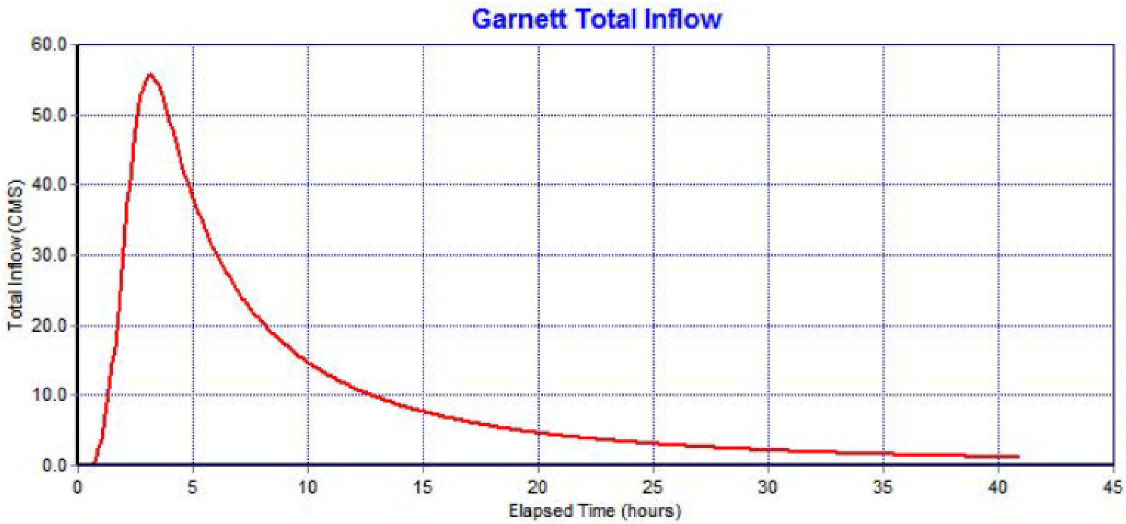
The model simulations provide a full runoff estimate of the PDF curve intensity storms with a higher degree of accuracy as the model takes into account the ground shape, topography and travel time with much greater degree of confidence. In comparison with the Rationale Method, we would consider the model results to be reasonable.

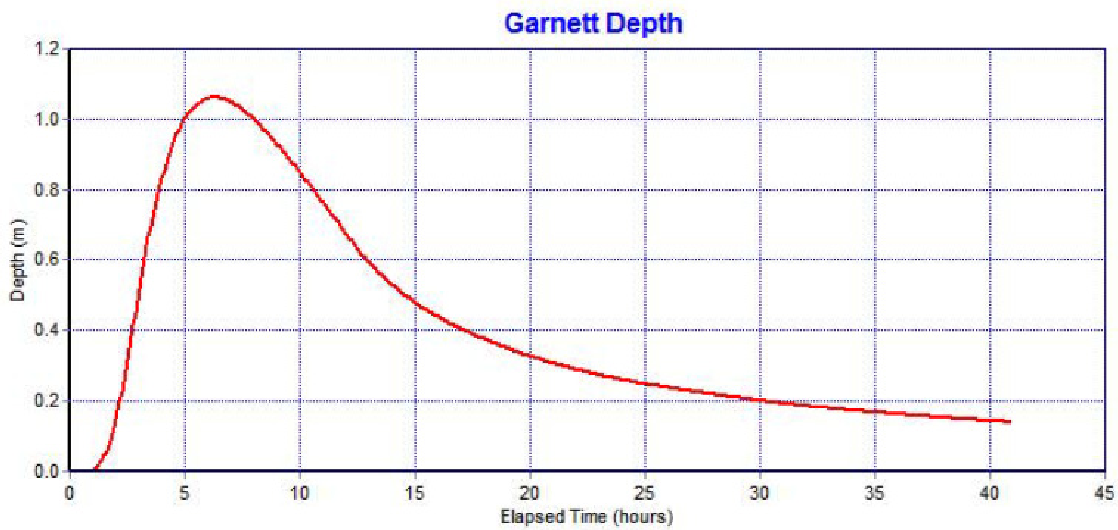
1 Hour Simulation (1/1000 Year RI)

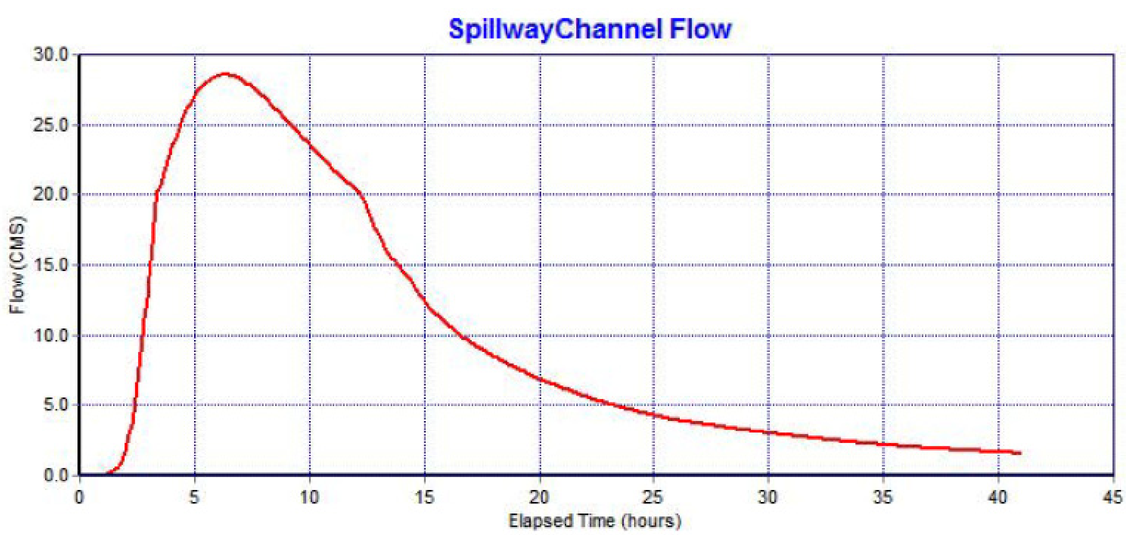




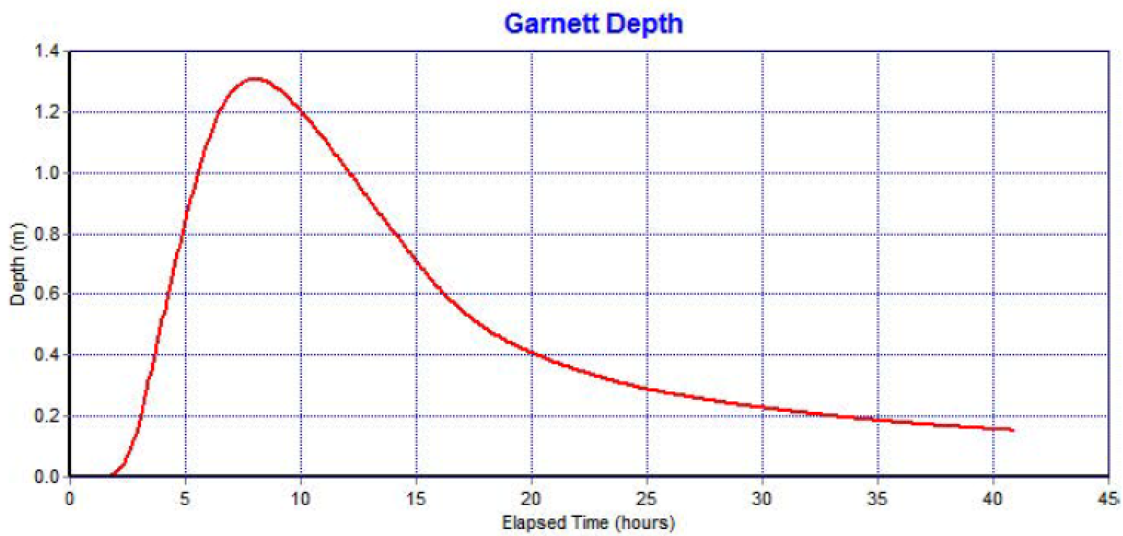
3 Hour Simulation (1/1000 Year RI)

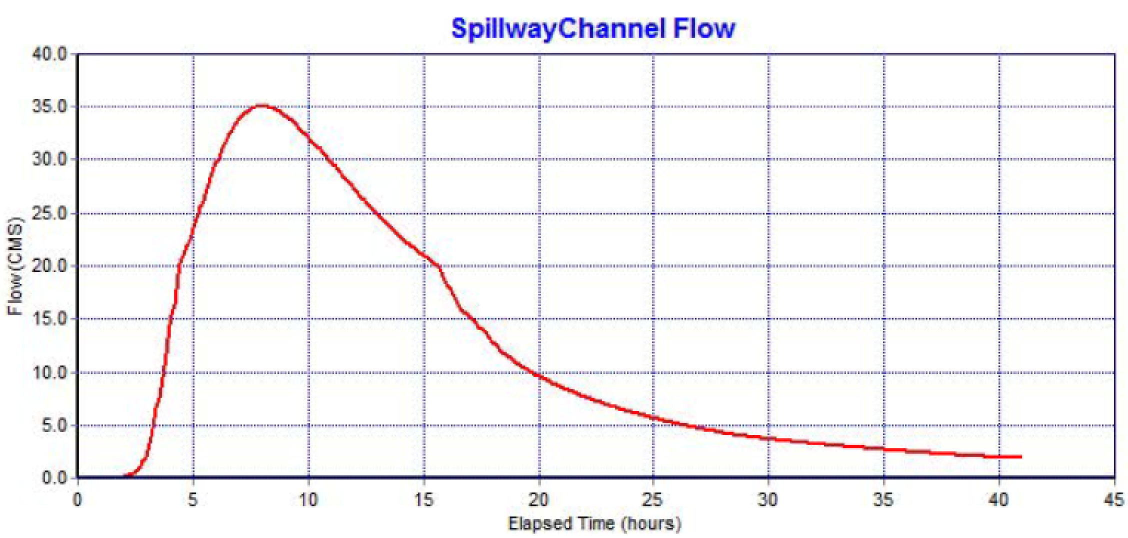




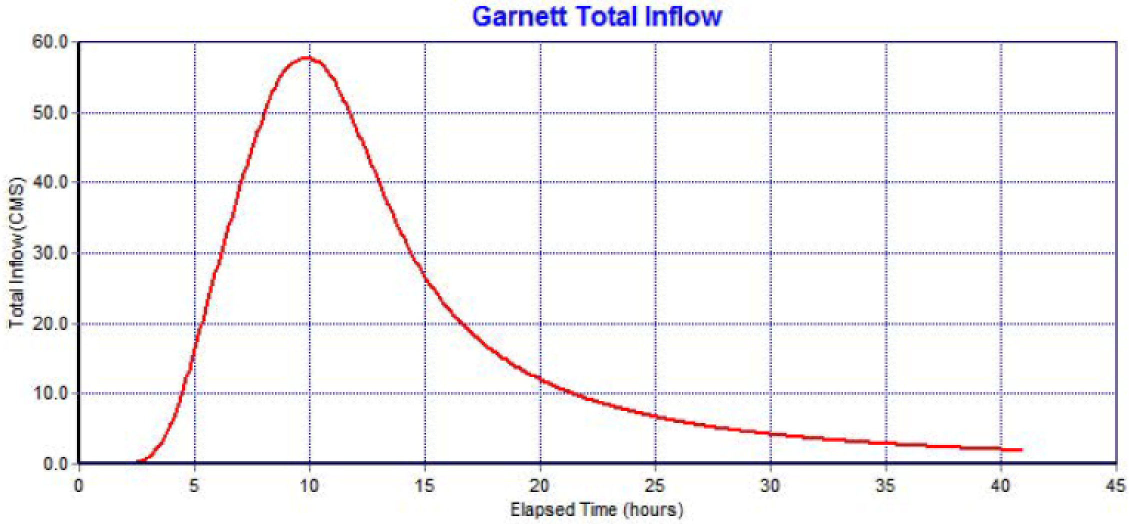


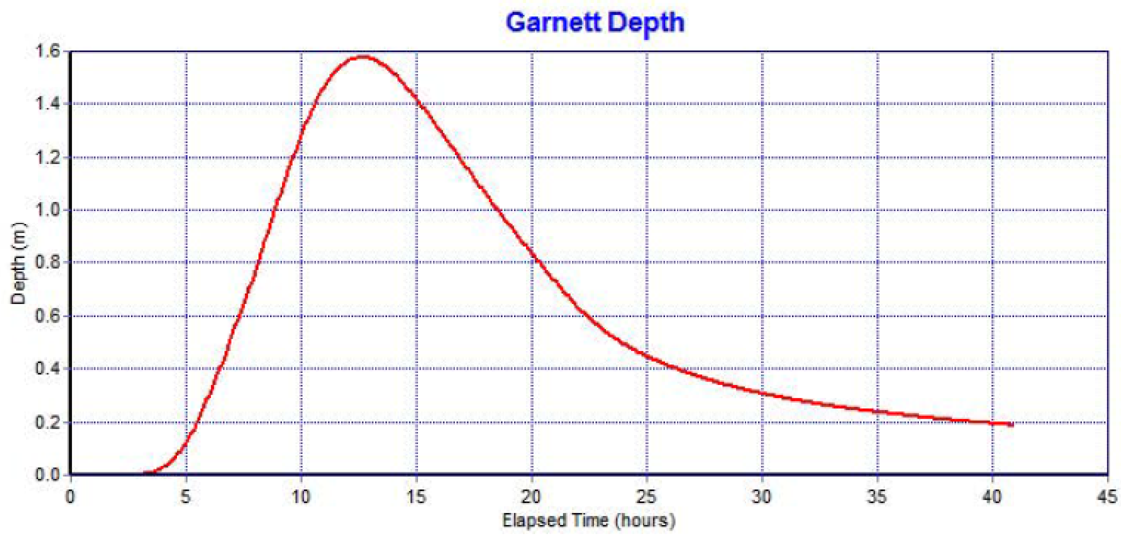
6 Hour Simulation (1/1000 Year RI)

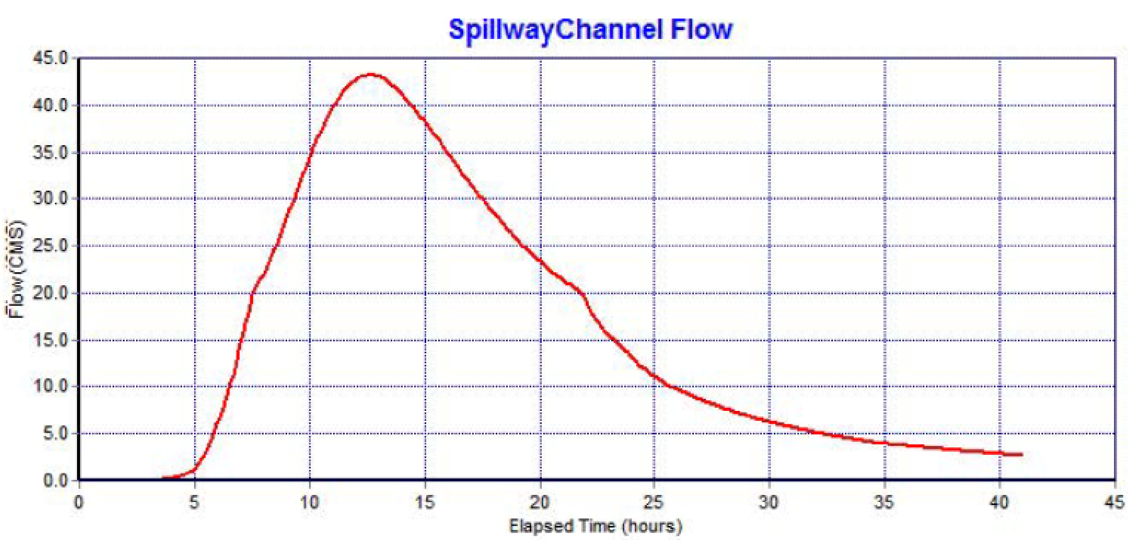




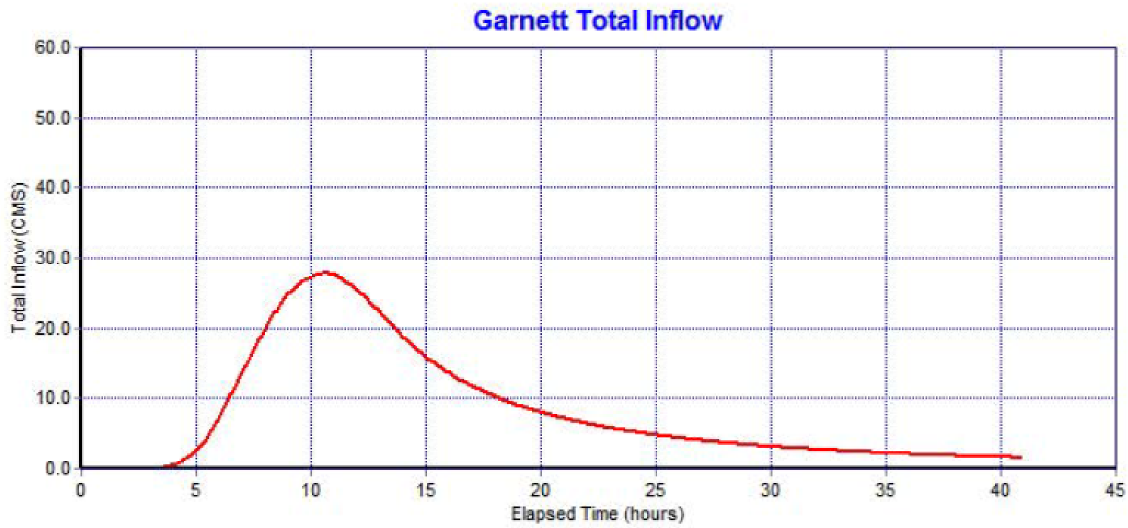
12 Hour Simulation (1/1000 Year RI)

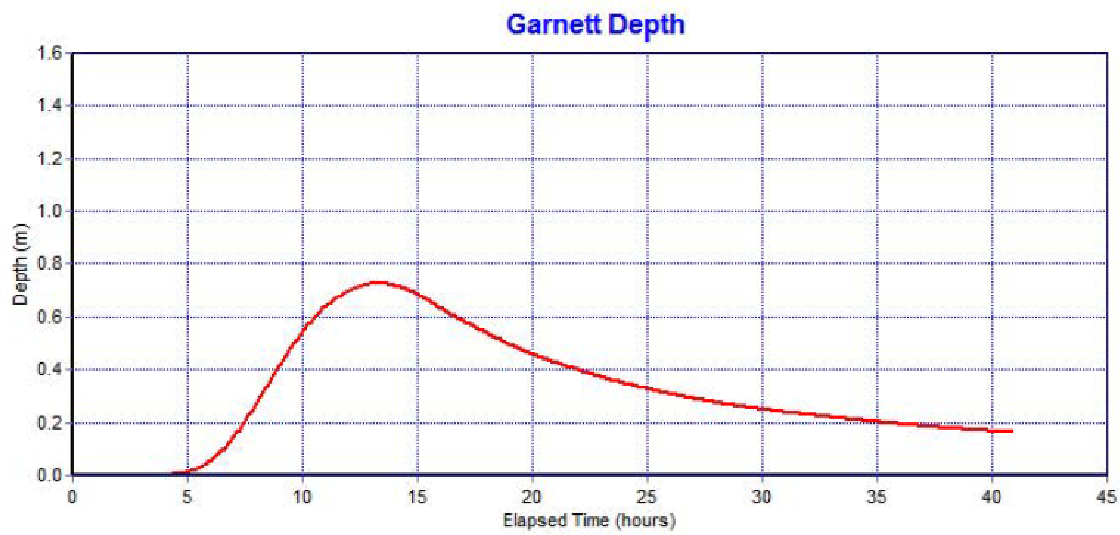


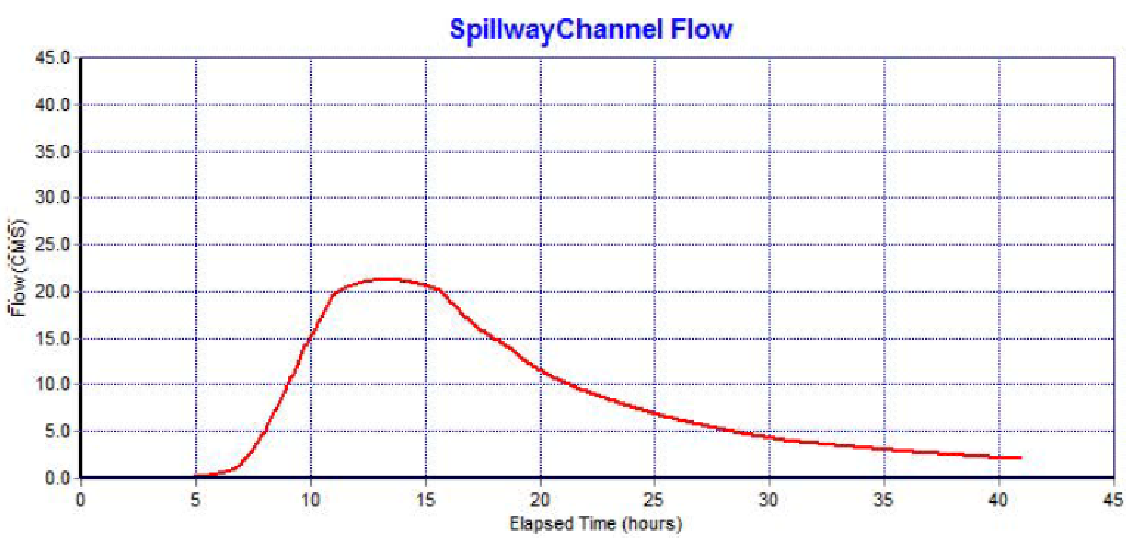


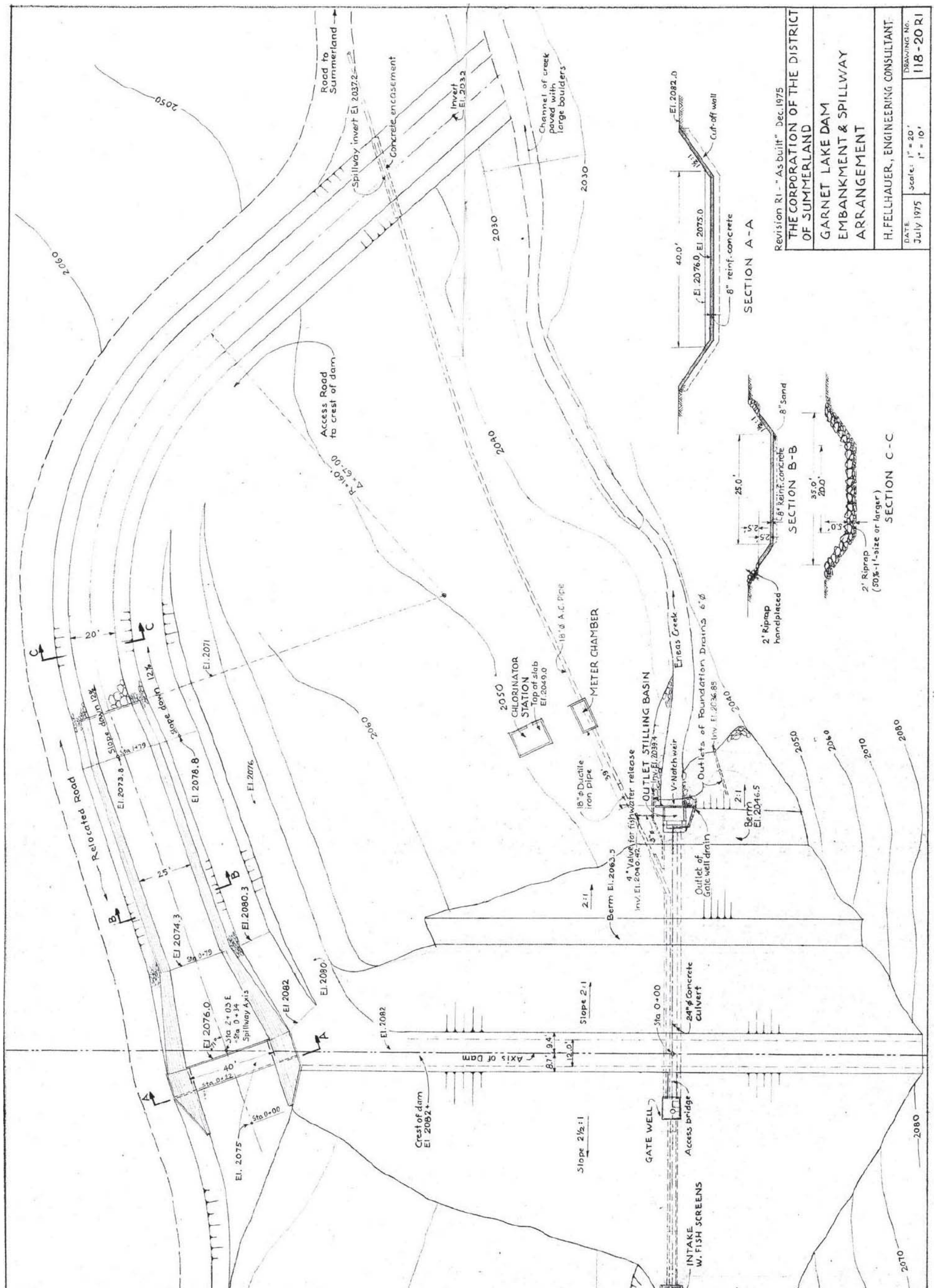


24 Hour Simulation (1/1000 Year RI)








Revision R1 - "As built" Dec. 1975
THE CORPORATION OF THE DISTRICT OF SUMMERLAND
GARNET LAKE DAM
EMBANKMENT & SPILLWAY ARRANGEMENT
H. FELLHAUER, ENGINEERING CONSULTANT
DATE July 1975
Scale 1" = 20' 1" = 10'
DRAWING No. 118-20 R1
SECTION A-A
SECTION B-B
SECTION C-C
Relocated Road
Road to Summerland
Access Road to crest of dam
CHLORINATOR STATION
METER CHAMBER
OUTLET STILLING BASIN
Ereas Creek
Axis of Dam
Crest of dam El. 2082±
GATE WELL
Access bridge
INTAKE W. FISH SCREENS
Impervious blanket
From outlet of old Dam

APPENDIX D - GARNETT RESERVOIR OPERATIONAL LEVELS MEMORANDUM

In June of 2012, a technical memorandum was developed for the District of Summerland Operations staff for the operation of the outlet gates on Garnett Dam. The objective of the memorandum was to set target water levels for Garnett Reservoir so that uncontrolled releases over the Garnett Dam Spillway would be minimized. The memorandum is included within Appendix D of this report.

TECHNICAL MEMORANDUM

AGUA FILE No 023-14

DATE:	June 5, 2012
TO:	Scott Lee, Water Operations Superintendent
FROM:	Bob Hrasko, P. Eng.
RE:	**Garnett Reservoir Operational Levels - Memorandum**

1.0 INTRODUCTION

This memorandum sets out preliminary information related to the limited capacity of Eneas Creek downstream of Garnett Reservoir. The downstream channel is currently being reviewed with respect to normal capacity and reduced capacity due to ice build-up in the channel. The outcome of that work may impact on the final decisions related to the operation of Garnett Reservoir. The draft Garnett Dam Inundation study was also reviewed in the preparation of this document. This document provides preliminary direction for the operation of Garnett Dam.

The District of Summerland operates two reservoirs on Eneas Creek, Eneas Reservoir in Eneas Provincial Park, and Garnett Reservoir. Eneas Reservoir is very small and has limited storage capacity and impact on the overall operation of water storage and releases for this watershed. Garnett Reservoir, located 10 kilometers north of Summerland Town Centre on Eneas Creek, has a much larger impact on the overall hydrology of the creek.

2.0 HYDROLOGICAL SUMMARY

During 2009, the Okanagan Basin Water Board directed a multi-agency study to update overall watershed hydrology in the basin including the Eneas Creek drainage area. The March 2009, *Surface Water Hydrology and Hydrologic Modeling Study* prepared by Summit Environmental was utilized in summarizing the natural flow that is generated by Eneas Creek. The information from that report and the information on actual water use for Garnett Valley is summarized in Table 1.

Table 1 shows that the annual demands from Garnett Reservoir from 1977 to 2005 averaged 1132 megalitres (ML) per year. The demand data and the stream flow runoff data for Eneas Creek are both shown in Table 1 and broken down on a monthly basis. The majority of annual runoff for Eneas Creek occurs in May where almost 50% of the flow is generated.

Operationally, Summerland should work to achieve normal flows in the off-peak demand periods of the year, averaging 25-30 ML/month from November 1 – March 31. This works out to a release rate of only 10 L/s from the dam to maintain downstream flows.

o 3660 Anderson Road, Kelowna, BC, V1X 7V8
o Phone: 250.212.3266

Table 1 - Garnett Reservoir – Annual Inflow / Outflow Data

Month	Ave. Use (ML)	Normalized Flow (ML)
Jan	16.4	21.4
Feb	15.4	14.5
Mar	17.3	34.8
Apr	47.6	355.1
May	138.4	1186.5
Jun	193.3	552.1
Jul	243.1	142.0
Aug	240.8	48.2
Sep	136.2	28.5
Oct	49.8	21.4
Nov	17.4	28.5
Dec	16.5	24.1
TOTAL (ML)	1132.0	2457.2

Table 2 provides a summary of the live (useable) storage within Garnett Reservoir. The storage volume available for use from Garnett Reservoir is 2339 ML. This is approximately double the volume of water used annually by Summerland.

Table 2 - Garnett Reservoir Data

Reservoir Elevation (m)	Flooded Area (ha)	Storage Volume (ML)	Comments
613.7	0.0	-422	Dead Storage
622.4	7.9		
622.8	8.6 (est.)	0	Gate Sill
623.3	8.8	23	
623.6	9.2	52	
624.8	12.1	184	
626.1	17.1	364	
627.3	22.5	609	
628.5	26.8	912	
629.6	31.0	1270	
630.9	36.2	1688	
632.7	**39.4 (est.)**	**2339**	**Spillway Crest**
634.0	41.7	2876	
637.0	46.3	4222	
640.1	51.8	5689	

Last Updated March 2012

3.0 DOWNSTREAM CONSTRAINTS

Summerland historically has operated Garnett Reservoir to maximize the volume of water within the reservoir at the end of spring runoff. Having a secure and reliable water supply is a high priority. A concern related to maximizing storage is that this increases the potential for having releases of water over the spillway through the urban areas of the District.

There are channel restrictions in several sections of Eneas Creek, with one of the critical ones being a 400 metre section between Victoria Road North and Rosedale Avenue. This section of channel is adjacent to the back yards of existing residences.

As part of the detailed channel assessment in this section of Eneas Creek, we modeled this section of channel using the HEC-RAS stream flow channel modeling program. The channel capacity during normal conditions (no-ice build-up) is limited to 1.20 m3/second. Exceeding this flow would result in flooding and property damage beyond the existing berms of the channel.

Figure 1 – Constrained Channel Section – Eneas Creek

The details for channel improvements are being specifically addressed in a separate report; however the best method for risk management is to reduce the potential for water flowing over the spillway at Garnett Reservoir. This provides Summerland with the best operational method for flood protection along the Eneas Creek corridor.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Please note that the conclusions and recommendations are based upon the current data we have on Eneas Creek hydrology and current operations. Please note that these recommendations are preliminary and supplemental data will be available within the Garnett Dam Inundation Study and within the detailed channel assessment for Eneas Creek between Victoria Road North and Rosedale Avenue. Our conclusions are as follows:

C-1 Eneas Reservoir in the upper watershed only has 152 ML of live storage and therefore has a minimal impact on overall flows in lower Eneas Creek;

C-2 Garnett Reservoir has live storage for 2,339 ML of water which is approximately double the annual water demand of 1132 ML;

C-3 The highest demand on record from Garnett Reservoir was 1978 which was 1664 ML. In 1998, 1455 ML of water was used;

C-4 Channel capacity downstream of Garnett Reservoir is limited in sections and a maximum capacity of 1.20 m3/second.

Based on the above conclusions, the following is recommended:

R-1 The best way to reduce the potential for flooding is to operate Garnett Reservoir so that the chance of running water over the spillway is minimized. This can be done by pre-releases while the reservoir is filling. To be accurate with the releases, climatic data such as snowpack and precipitation must be reviewed in conjunction with the reservoir level and time of year so that the most accurate decisions can be made;

R-2 With limited information in regards to climatic data and corresponding runoff over Garnett Reservoir, we would recommend that a height between 10% and 20% below full pool be the desired high water level. The available storage volume operating at 10% below full pool would be 2105 ML, and at 20% below full pool it would be reduced to 1871 ML;

R-3 On the interim, prior to receiving the final version of the Garnett Reservoir Inundation Report and the Eneas Creek drainage report, we would recommend that Summerland use 15% below full pool as the Operational Guidance Level for high water at Garnett Reservoir. This would allow Summerland 1988 ML of annual storage volume to meet demands and a storage buffer of 361 ML in the event of a major storm event. The 15% level is at a height of approximately 631.45m (37.2 ft.) or 0.67 m below full pool.

Please review the information provided and contact us if you have any questions regarding this report.

R. Hrasko, P.Eng.
Principal
Agua Consulting Inc.