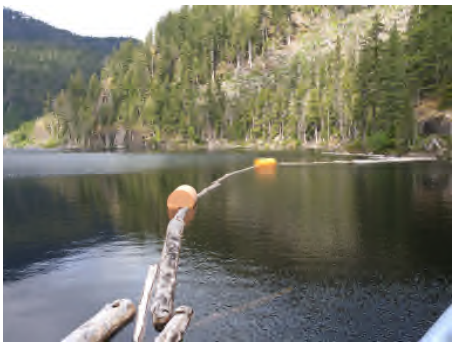
Appendix 2

Support Documents

TETRA TECH EBA

OQM | Organizational Quality Management Program

ARROWSMITH DAM INUNDATION STUDY


PRESENTED TO

ARROWSMITH WATER SERVICE

NOVEMBER 2014
ISSUED FOR USE
FILE: 704-V13103156

CONSULTING ENGINEERS & SCIENTISTS · www.eba.ca

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EXECUTIVE SUMMARY

Arrowsmith Water Service (AWS) engaged Tetra Tech EBA Inc. to undertake a dam breach and inundation study for Arrowsmith Dam. The inundation study includes five components:

- Background review.
- Site reconnaissance.
- Estimation of the dam-break outflow hydrograph.
- Flood routing and mapping of inundation area.
- Identification of downstream losses.

A site inspection was conducted on June 11, 2014 to gather information on the dam and to inspect the downstream community and infrastructure that may be affected by the flood wave resulting from a dam breach. Representative photographs taken during the inspection are presented in Appendix A.

A breach of Arrowsmith Dam was simulated using the US Army Corps of Engineers HEC-RAS model. The model characterizes breach formation and computes outflow hydrograph from a hypothetical failure. Estimation of the breach parameters, such as breach width and development time, was done from a literature review and coupled with a sensitivity analysis. The model simulates the breach development process, including vertical erosion and breach widening, at a 1-minute computational interval. The maximum breach outflow was estimated to be 1,906 m^3/s. The outflow hydrograph, as presented in Figure 4.2-1, was routed through the downstream topography using a 2-dimensional model, FLO-2D. The resultant inundation area and the maximum flooding depth are mapped on Figures 5.2-1 and 5.2-2. The model also computes the delay time between the initial dam breach and the time at which flooding reaches maximum flood depth (Figure 5.2-3). This provides a warning time to a downstream point where water level rise has an impact on infrastructure or public safety. In addition, a flood hazard map is presented in Figure 5.2-5. The map defines high, medium and low hazard levels as a function of flow depth and velocity. Descriptions of the hazard levels are provided in Table 5.2-3.

In summary, this study provides a dam breach analysis for Arrowsmith Dam and presents inundation mapping to identify potential downstream loss of life and damage. The investigations and engineering analysis were conducted in accordance with the BC Dam Safety Regulation and Canadian Dam Association 2007 Dam Safety Guidelines.

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Arrowsmith Water Service and its agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Arrowsmith Water Service, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement. Tetra Tech EBA's General Conditions are provided in Appendix B of this report.

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by the Arrowsmith Water Service (AWS) to undertake an inundation study for Arrowsmith Dam. The inundation study includes five components:

- Background review.
- Site reconnaissance.
- Estimation of the dam-break outflow hydrograph.
- Routing of the dam-break hydrograph through the downstream valley.
- Mapping of the inundation area.

This report presents a summary of EBA's investigations and engineering analysis in accordance with the BC Dam Safety Regulation and Canadian Dam Association 2007 Dam Safety Guidelines. Inundation mapping was prepared to identify potential downstream loss of life and damage.

2.0 BACKGROUND DATA AND RECORDS REVIEW

Arrowsmith Dam is a concrete gravity dam located approximately 35 km southwest of Parksville, BC. It was commissioned in 2000 and built as the AWS joint venture comprising the City of Parksville, the Regional District of Nanaimo and the Town of Qualicum Beach. The dam is used to regulate the flow in the Englishman River for release during the summer and fall to meet the domestic water demands in the service area. The reservoir has a storage volume of 9.0 million cubic metres. About half of the live storage volume behind Arrowsmith Dam is provided for release of water during low natural river flows to improve fisheries flows in the downstream reach of the Englishman River. Flows are released based on a Provisional Operating Rule from the Ministry of Environment and Fisheries and Oceans Canada. Water is extracted from the Englishman River via an infiltration gallery operated by the City of Parksville. Arrowsmith Dam currently supplies water to the City of Parksville and the Regional District's Nanoose Peninsula. The Consequence Classification for the Arrowsmith Dam has been established as Very High by the BC Ministry of Environment, Water Stewardship Division. The definitions of the various consequence classifications are provided in Table 2.1-1.

Table 2.1-1: CDA 2007 Consequence Classification Criteria and Design Earthquake and Flood

Dam Classification from CDA 2007	Loss of Life	Economic and Social Losses	Environmental and Cultural Losses	Annual Exceedance Probability Level	
				Earthquake Design Ground Motion	Inflow Design Flood
Extreme	>100	Extreme – Critical Infrastructure or Service	Major Loss of Critical Habitat – No Restoration Possible	1/10,000	PMF
Very High	10-100	Very High –Important Infrastructure or Services	Significant Loss of Critical Habitat – Restoration Possible	1/5,000	2/3 between 1/1000 year and PMF
High	1-10	High –Infrastructure, Public Transit and Commercial	Significant Loss of Important Habitat – Restoration Possible	1/2,500	1/3 between 1/1000 year and PMF
Significant	Unspecified	Temporary and Infrequent	No Significant Loss of Habitat – Restoration Possible	1/1,000	Between 1/100 and 1/1000 year
Low	0	Low	Minimal Short Term Loss	1/500	1/100 year

The following documentation was reviewed to extract relevant information with respect to Arrowsmith Dam, Englishman River floodplain and bridge structures:

- BC Ministry of Environment, 1980. Englishman River Floodplain Mapping, Drawings 1 to 7.
- EBA, 2012. Arrowsmith Dam – Dam Safety Review.
- EBA, 2011. Arrowsmith Dam 2011 Annual Inspection Report.
- EBA, 2009. Arrowsmith Dam Inspection Report 2008.
- EBA, 2008. Arrowsmith Dam Annual Inspection Report 2007.
- Department of Public Works BC, Englishman's River Bridge Layout.
- KRC Consultants/Agra Monenco, 1997. Arrowsmith Dam Preliminary Design. Drawing – Sheets 1 to 28.
- Koers & Associates Engineering Ltd, 1992. Craig Bay Water Supply Main Drawing, M9103-02.

In addition, the guidelines of the BC Ministry of Environment (BC MoE) Dam Safety Branch and the Canadian Dam Association (CDA) were reviewed.

3.0 SITE RECONNAISSANCE

A site inspection was conducted on June 11, 2014. The purpose of the inspection was to gather information on the dam and to confirm the downstream conditions, such as river crossings, residential and recreational areas and other infrastructure that may be affected by the flood wave resulting from a dam breach. The following staff participated in the site inspection:

- Mr. Scott Churko, Water Supply & Distribution Chief Operator, City of Parksville.
- Mr. Geoff McMillan, Senior Trades Supervisor Utilities, City of Parksville.
- Ms. Barbara Silenieks, Utilities Technician II, City of Parksville.
- Mr. Adrian Chantler, P.Eng., Tetra Tech EBA.
- Ms. Eva Li, P.Eng., Tetra Tech EBA.

After a brief meeting at the City office, a visit was made to the Arrowsmith Dam site attended by the above people. Vehicle access to the dam was by way of unpaved road.

3.1 Inspection of the Dam Structure

Arrowsmith Dam is a concrete gravity structure founded on bedrock. The dam is 14 m in height and 75 m long with a maximum base width of 12 m. The dam crest, at an elevation of 830 m, is accessible by a walkway. A surveillance camera and an alarm system have been installed to monitor rapid water level decreases in the lake. The dam has a vertical upstream face, a 1.5 m wide crest and a 0.83H: 1V downstream face, except that the upper 1.4 m of the downstream face is vertical. The embankment comprises six concrete blocks or monoliths. Minor seepage was noted during the site inspection. Signage was present at the dam site with emergency contact information.

The dam has three outlet structures, including a high level gravity outlet, a low level conduit and an overflow spillway. The high level outlet is a 900 mm HDPE pipe. The outflow is control by motorized valves to handle the maximum anticipated flows for domestic and fisheries requirements. The lower level outlet is a 600 mm HDPE siphon pipe which projects into the lake. The pipe flow is controlled by a hydraulically operated butterfly value at the dam face for isolation and maintenance purposes. The spillway comprises a concrete ogee weir with a crest elevation of 810.45 m. The spillway is 12 m wide and the chute terminates onto bedrock cascades.

Dam history, operations, surveillance, maintenance, communications, and security were discussed. Representative photographs taken during the inspection are presented in Appendix A.

3.2 Inspection of the Downstream Area

Following the visit to the dam, the downstream points of interest were inspected. As shown in Figure 3.2-1, the areas include roads and bridges, municipal water supply facilities, parks and recreational area, and low-lying land subject to frequent flooding. A list of the inspected areas, extending along a 32 km reach of the Englishman River, is provided as follows:

- Three wooden bridges.
- Highway 19 bridge.
- Proposed water intake site.
- Top bridge.
- Current water intake site.
- Englishman River Falls Provincial Park.
- Low-lying residential properties on Levirs Road.
- Sewer lifts station.
- Island Highway Bridge (Orange Bridge).
- Estuary.

Arrowsmith Dam discharges to a tributary of the Englishman River, which flows for about 5.5 km before joining the mainstem. The bridges over the Englishman River are generally founded high above the river valley, with the exception of the wooden bridge immediately downstream of the dam. The bridge deck has a clearance of about 2.2 m from the underside of the bridge deck to the creek bottom. It would likely be washed out during a dam breach event. Other risks identified during the inspection include the temporary population at risk at Top Bridge Park, which is a popular spot for recreational fishing and swimming. The permanent population in the low-lying residential area by Martindale Road is also subject to flooding. Depending on the flood depth, the sewer lift station may suffer damage. In addition, excessive sedimentation resulting from the dam breach could also block the infiltration gallery, impacting domestic water supply. A section of highly erodible clay river banks was not covered by the field inspection. A video was later sent by the City of Parksville to show the site conditions. The clay banks are nearly vertical and unvegetated. Reoccurring bank failures have caused closures of the Arrowsmith Water Service water intake. Loose material from historical failures is evident at the toe of the steep slope.

The site inspection established that TRIM mapping with a 20 m contour interval would be adequate for inundation mapping of the upper Englishman River basin, which has steep valley sides. With respect to the relatively flat area within the City boundary (i.e. north of Highway 19), Lidar data with a smaller contour interval is preferred for improved accuracy.

4.0 DAM BREACH ANALYSES

The CDA Dam Safety Guidelines suggest that two hypothetical modes of dam failure be considered in developing the outflow hydrograph immediately downstream of the dam, namely sunny day failure and flood-induced failure. The sunny day failure occurs during normal operations. It may be caused by shear failure of the foundation, internal erosion, seepage through the foundation, earthquake, etc. For this mode, e.g. foundation failure, it is assumed that the flood level is at the dam crest elevation with the spillway discharging at full capacity when the dam breach begins. For the flood induced failure, e.g. overtopping failure, it is assumed that the lake is receiving a 100-year inflow and that the spillway is fully blocked when the breach begins. However, the flood induced failure mode is not applicable to a concrete dam. In an overtopping event, the dam crest would perform like a spillway, and the integrity of the concrete dam structure is not likely to be jeopardized.

4.1 Model Description

The US Army Corps of Engineers HEC-RAS model was used to characterize the dam breach. This is considered an industry standard tool to assess the failure parameters and to compute the outflow hydrograph from a dam failure. The dam is modelled as an in-line structure at the upstream end of the reach. The reservoir storage is defined by paired Storage-Area data. Using the unsteady flow routing option, the model simulates the breach formation and development process including vertical erosion and breach widening. The analysis is performed for a sunny day failure with a computational interval of 1-minute.

4.2 Breach Input Parameters

Estimation of the breach parameters, such as breach width and development time, is done external to the HEC-RAS model. Literature review identified the following breach parameters for a concrete gravity dam, see Table 4.2-1. The parameters are derived from hundreds of documented dam failure case studies.

Table 4.2-1: Breach Parameters for Concrete Gravity Dam

Reference	Final Breach Width	Side Slope	Breach Formation Time
WSDE, 2007	Integer Multiples of Monolith Widths	Vertical	0.1 h to 0.5 h
USACE, 2007	Multiples of Monolith	Vertical	0.1 h to 0.5 h
FERC, 1998	Usually ≤ 0.5 dam length	Vertical	0.1 h to 0.3 h
NWS	Usually ≤ 0.5 dam length	Vertical	0.1 h to 0.2 h

A sensitivity analysis was conducted on the given range of breach parameters. The resultant peak discharge was found to be more sensitive to the breach formation time than the final breach width and side slopes. A formation time of 0.5 hours resulted in a 20% reduction in peak flow compared to a formation time of 0.1 hours. However, if the areas of interest (e.g. a population centre) are located well downstream of a dam, details of the breaching process have little effect on the inundation result. Factors such as the travel time and attenuation effects predominate.

Based on the above table, the breach width of Arrowsmith Dam was assumed to be 40 m, which are four monolith widths. The breach formation time was determined to be 0.1 hours as a conservative approach. A summary of the overall dam breach parameters for Arrowsmith Dam is provided in Table 4.2-2.

Table 4.2-2: Summary of Dam Breach Parameters

Dam Breach Parameter	Value (Note)
Type of Dam	Concrete Gravity Dam
Final Breach Width	40 m (assume four monoliths)
Dam Breach Elevation	830.0 m (assumed at dam crest)
Final Breach Elevation	816.5 m
Left Side Slope	0
Right Side Slope	0
Breach Weir Coefficient	1.8
Full Formation Time (h)	0.1
Volume of Reservoir at Breach (m^3)	5,900,000
Failure Mode	Seismic/Foundation Failure
Piping Coefficient	0.6

The maximum breach outflow was computed to be 1,906 m^3/s. The breach outflow hydrograph is provided in Figure 4.2-1.

5.0 INUNDATION MAPPING

5.1 FLO-2D Model

The breach hydrograph for Arrowsmith Dam was routed using a 2-dimensional model, FLO-2D. This is a flood routing model that can simulate unconfined overland flow over complex topography. The model routes the flood wave through the downstream area to identify the extent of inundation and the maximum flooding depth. It also accounts for valley storage and frictional resistance over different land uses. Digital TRIM data with a 20 m contour interval was used to generate a surface for the upper Englishman River basin from the Arrowsmith Dam site to Highway 19. Lidar data with a 2 m contour interval was used for the City area to provide improved accuracy in flow direction and flood extent. It should be noted that in the FLO-2D model, the ground surface is represented by a grid system. The grid size selected for this project is 25 m by 25 m based on the magnitude of the peak flow and an optimized computational speed. As elevation variations are averaged out within a grid cell, sudden changes in topographic relief, such as channels, roads and buildings, when not modelled specifically may not be accurately characterized at this resolution. Also, some localised variations in flow depths from those modelled are anticipated.

5.2 Inundation Maps

Figures 5.2-1 and 5.2-2 present the results of the inundation mapping and the maximum depth of flooding caused by an Arrowsmith Dam failure. Upstream of the Highway 19 Bridge, the breach outflow is contained within the Englishman River corridor. The majority of the flood impact appears to be within the City of Parkville area. Figures 5.2-3 and 5.2-4 show the delay time between the initial dam breach and the time at which flooding reaches the maximum depth. This provides a warning time to a downstream point where water level rise would have an impact on infrastructure or public safety.

5.2.1 Impact of Residential and Recreational Areas

A number of low lying residential areas along the Englishman River were identified within the flood inundation zone. They include subdivisions with permanent population, as well as a golf course and RV parks with temporary population. Table 5.2-1 provides maximum flood depth and the associated warning time to the areas of impact.

Table 5.2-1: Populated Areas within the Inundation Zone

Location	Distance from Dam (km)	Description	Max Flood Depth (m)	Time to Max Water Elev. (h)
Martindale Area	29	Approx. 50 homes along Wain Rd, Despard Ave, and Parrys Park Rd.	0.4-3.6	6-10
Brigadoon Golf Course	29	Golf Course	0.3-3.5	8-10
Greig Rd	29	One single family house at the west end of Greig Rd	1.5-2.7	6-8
San Pareil Subdivision	31	Approx. 230 homes within the subdivision	0.2-1.9	13-18
Nerbus Lane Trailer Homes	31	Approx. 60% of the trailer homes	0.2-0.8	26
Surfside RV resort	33	Waterfront RV Site	0.2-0.4	32

5.2.2 Impact on Bridge Structures

Drawings of the Top Bridge and Island Highway Bridge (Orange Bridge) were obtained from the Regional District of Nanaimo and Public Works, respectively, to assess the impact of the flood wave on the bridge structures. Available clearance from the underside of the bridge deck to the high water level was determined for the maximum flood depth expected from the dam breach event. The results are summarized in the following table.

Table 5.2-2: Assessment of the Bridge Structures

Location	Distance from Dam (km)	Max Water Depth (m)	Available Clearance (m)	Time to Max Water Elev. (h)	Comments
Top Bridge	27	4.4	1.6	6.0	Bridge deck free of flooding. Should be monitored against potential debris build-up due to limited clearance.
Highway 19 Bridge	28	5.7	N/A	6.7	Sufficient freeboard based on visual inspection
Railway Bridge	28	2.6	N/A	6.8	Sufficient freeboard based on visual inspection
Island Highway Bridge	30	2.7	0.5	13.1	Bridge deck free of flooding

5.2.3 Environmental and Cultural Losses

The Englishman River system is an important watercourse for juvenile salmon migration. The estuaries and foreshore zones also provide vital rearing habitat for other pacific salmon species, as well as steelhead, and cutthroat trout. BC Provincial geographic database (iMapBC) has identified the middle to lower reaches of the Englishman River as an area of endangered fish species and ecosystem. A breach of Arrowsmith Dam would degrade fish habitat by smothering the fish eggs with excessive sedimentation. The flood wave could also trigger bank failure and erosion at the clay banks area referred to in Section 3.2.Water quality deterioration and clogging of the infiltration gallery, would also impact domestic water supply to the City of Parksville and the community of Nanoose Peninsula. Recreation areas, such as Top Bridge Park, are likely to be closed following a dam breach. The environmental and cultural losses resultant from the Arrowsmith dam breach would be temporary. Restoration or compensation in kind is highly possible.

5.2.4 Infrastructure and Economic Losses

Notable infrastructure within the flood inundation zone includes the sewer lift station and the proposed water intake and pump station. The flood wave would also inundate multiple residential subdivisions and RV parks as it continue along the Englishman River.

As a detailed economic analysis of the flood inundation zone is outside the scope of this assessment, US Federal Emergency Management Agency (FEMA) guide on flood insurance was used to estimate the economic losses in the urban inundation area. Assuming property improvements comprise 25%-75% of the building and contents values based on flood depth, the potential economic losses for the urban inundation area could be around $20,000,000 (excluding the value of any public infrastructure, RV vehicles, and chattels).

As well, the flooding at the sewer life station and the proposed water intake and pump station might reach a maximum depth of 2.0 to 3.0 m. Maximum economic losses at these utility stations is estimated to be about $5,000,000.

5.2.5 Flood Hazard Map

A flood hazard map is presented in Figures 5.2-5 and 5.2-6. The map uses three colours to define high (red), medium (orange) and low (yellow) hazard levels. The flood hazard level at a specific location is determined as a function of the flow depth and velocity. The descriptions of each hazard level are provided in Table 5.2-3.

Table 5.2-3: Flood Hazard Rating

Hazard Level	Color	Description
High Hazard	Red	Persons are in danger both inside and outside of buildings. Structures are at risk of being destroyed.
Medium Hazard	Orange	Persons are in danger outside of buildings. Structures may suffer damage and possible destruction depending on construction characteristics.
Low Hazard	Yellow	Danger to persons is low or non-existent. Buildings may suffer little structural damage, however, may undergo significant non-structural damage to interiors.

6.0 CONCLUSIONS AND RECOMMANDATIONS

Based on the results of the dam breach study, a series of conclusions and recommendations were developed as summarized in Table 6.0-1.

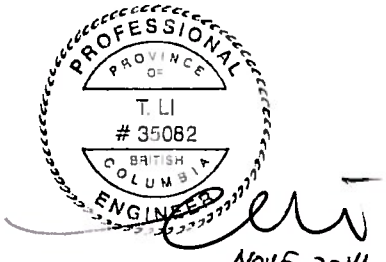
Table 6.0-1: Conclusions and Recommendations

Conclusions	Recommendations
▪ A sunny day failure (i.e. piping or foundation failure) was determined to be the most applicable failure mode for the Arrowsmith Dam. ▪ The maximum breach outflow was computed to be 1,906 m^3/s. ▪ Upstream of the Highway 19 Bridge, the breach outflow is contained within the Englishman River corridor. The majority of the flood impact appears to be within the City of Parkville area. ▪ The dam breach inundation mapping indicates flooding of multiple commercial, recreational and residential lots, including the Brigadoon Golf Course, Surfside RV Resort, Trailer Homes by Nerbus Lane and multiple residential areas in San Pareil Subdivision, and by Martindale Road and Greig Road. ▪ The bridge decks on the Englishman River, including Top Bridge, Highway 19 Bridge, Railway Bridge and Island Highway Bridge are estimated to be above the maximum flood level. ▪ Degrading of the fish habitat and water quality is expected but considered to be temporary with possible restoration or compensation. ▪ The potential economic losses for the urban inundation area could be around $20,000,000 (excluding the value of any public infrastructure, RV vehicles, and chattels) using FEMA flood insurance standard.	▪ The highly erosive Clay Banks should be monitored for slope failure following a dam breach event. ▪ The integrity of the bridge piers and abutment should be assessed following a dam breach event. ▪ The Island Highway Bridge (Orange Bridge) should be monitored against potential debris build-up due to limited clearance. ▪ The consequence classification rating of the Arrowsmith Lake Dam should be reviewed in terms of loss of life and downstream damages. ▪ Update the Emergency Preparedness Plan (EPP) to include the inundation mapping.

7.0 CLOSURE

We thank you for assigning this work to Tetra Tech EBA Inc. and trust the information provided in this report meets your needs. Please contact either of the undersigned if you require any clarification or further information.

Respectfully submitted by,
Tetra Tech EBA Inc.



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EL/AC/db

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FIGURES

LEGEND

- Dam Location
- Watercourse/Waterbody

NOTES
Base data source:
Imagery from Google Earth (2013)

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Area of Interest

PROJECTION UTM Zone 10		**DATUM** NAD83		**CLIENT** Arrowsmith Water Service
Scale: 1:70,000 (1 0.5 0 1 Kilometres)				TETRA TECH EBA
FILE NO. V13103156-01_Figure3-2-1.mxd				
PROJECT NO. V13103156-01	**DWN** MEZ	**CKD** MS	**APVD** EL	**REV** 0
OFFICE Tt EBA-VANC	**DATE** September 30, 2014			**Figure 3.2-1**

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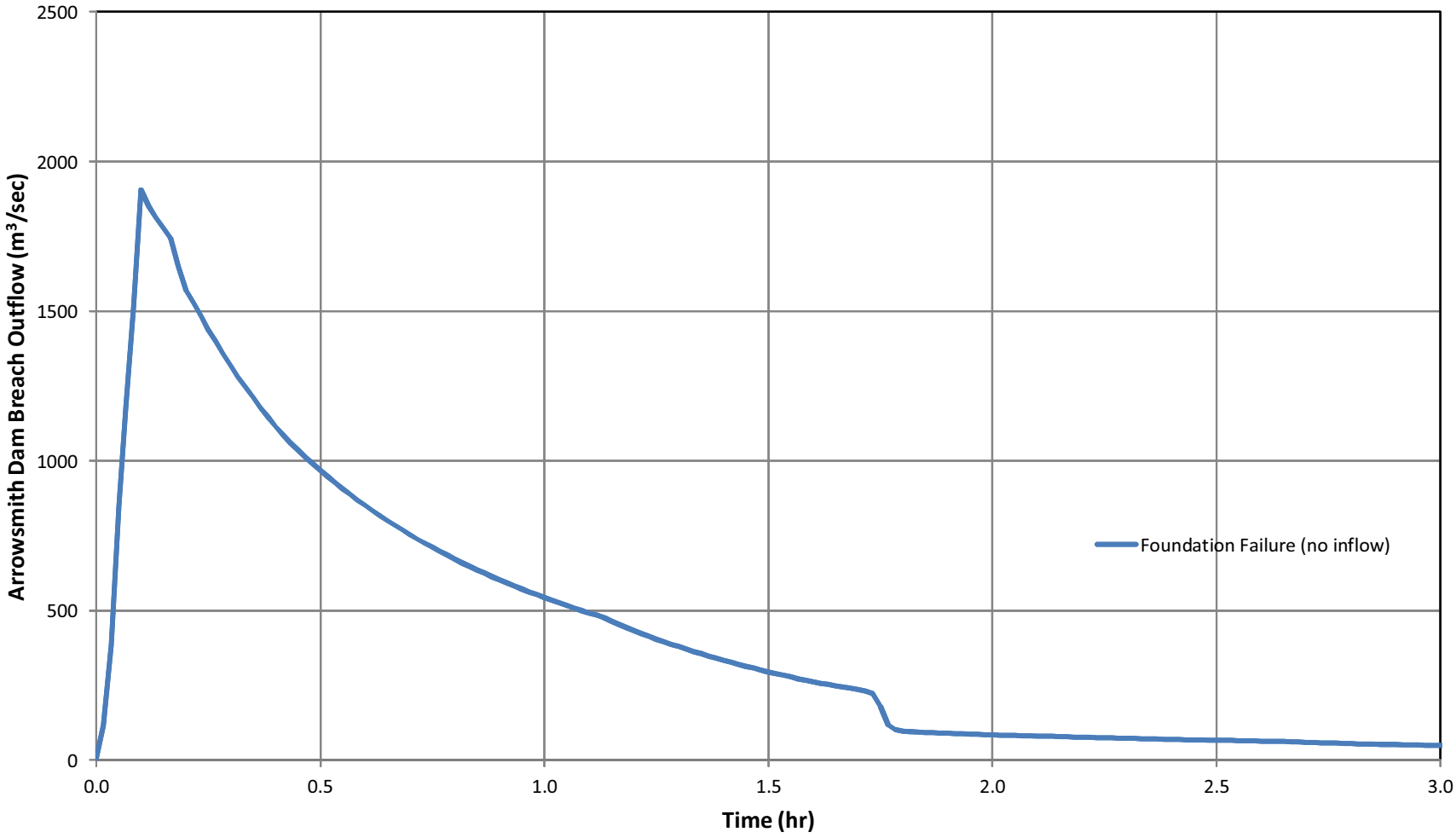

NOTES

CLIENT
Arrowsmith Water Service

ARROWSMITH LAKE DAM INUNDATION STUDY

Breach Outflow Hydrograph

STATUS
ISSUED FOR USE

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
V13103156-01	EL	AGC	AGC	0

OFFICE: EBA-VANC
DATE: August, 2014

Figure 4.2-1

LEGEND

- Dam Location
- Watercourse/Waterbody

Maximum Flood Depth (m)

- 11.9 - 14.9
- 9.8 - 11.9
- 8.1 - 9.8
- 7.0 - 8.1
- 6.3 - 7.0
- 5.7 - 6.3
- 5.2 - 5.7
- 4.7 - 5.2
- 4.1 - 4.7
- 3.6 - 4.1
- 3.1 - 3.6
- 2.7 - 3.1
- 2.4 - 2.7
- 2.0 - 2.4
- 1.7 - 2.0
- 1.3 - 1.7
- 1.0 - 1.3
- 0.7 - 1.0
- 0.3 - 0.7
- 0.0 - 0.3

NOTES
Base data source:
Imagery from Google Earth (2013)

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Maximum Flood Depth - Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Arrowsmith Water Service

Scale: 1:70,000
1 0.5 0 1
Kilometres

TETRA TECH EBA

FILE NO. V13103156-01_Figure5-2-1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
V13103156-01	MEZ	MS	EL	1

OFFICE	DATE
Tt EBA-VANC	September 30, 2014

Figure 5.2-1

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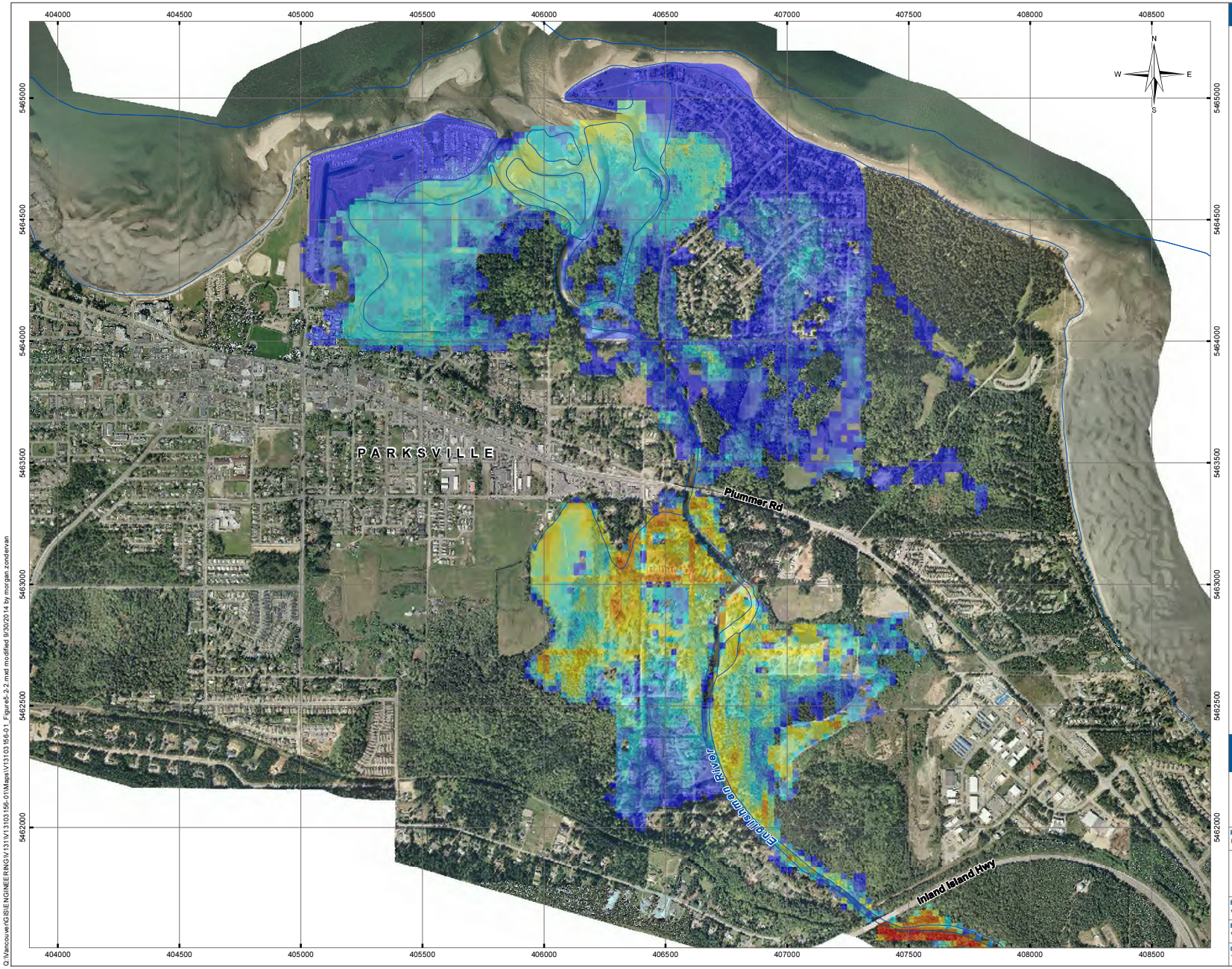

LEGEND

Watercourse/Waterbody

Maximum Flood Depth (m)

- 6.0 - 7.8
- 4.9 - 6.0
- 4.1 - 4.9
- 3.6 - 4.1
- 3.3 - 3.6
- 3.0 - 3.3
- 2.7 - 3.0
- 2.5 - 2.7
- 2.3 - 2.5
- 2.1 - 2.3
- 1.9 - 2.1
- 1.7 - 1.9
- 1.5 - 1.7
- 1.3 - 1.5
- 1.1 - 1.3
- 0.8 - 1.1
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2

NOTES
Base data source:
Imagery from City of Parksville

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Maximum Flood Depth – City of Parksville

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Arrowsmith Water Service

Scale: 1:15,000
200 100 0 200
Metres

TETRA TECH EBA

FILE NO.				
V13103156-01_Figure5-2-2.mxd				
PROJECT NO.	**DWN**	**CKD**	**APVD**	**REV**
V13103156-01	MEZ	MS	EL	1
OFFICE	**DATE**			
Tt EBA-VANC	September 30, 2014			

Figure 5.2-2

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LEGEND

- Dam Location
- Watercourse/Waterbody

Time to Maximum Depth (hours)

- 32.3 - 35.7
- 29.3 - 32.3
- 26.6 - 29.3
- 24.4 - 26.6
- 22.4 - 24.4
- 20.4 - 22.4
- 18.7 - 20.4
- 17.4 - 18.7
- 16.2 - 17.4
- 14.8 - 16.2
- 13.3 - 14.8
- 11.4 - 13.3
- 9.7 - 11.4
- 8.2 - 9.7
- 6.6 - 8.2
- 5.2 - 6.6
- 4.4 - 5.2
- 3.3 - 4.4
- 1.2 - 3.3
- 0.0 - 1.2

NOTES
Base data source:
Imagery from Google Earth (2013)

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Time to Maximum Flood Depth – Overview

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Arrowsmith Water Service

Scale: 1:70,000
1 0.5 0 1
Kilometres

TETRA TECH EBA

FILE NO.				
V13103156-01_Figure5-2-3.mxd				
PROJECT NO.	**DWN**	**CKD**	**APVD**	**REV**
V13103156-01	MEZ	MS	EL	1
OFFICE	**DATE**			
Tt EBA-VANC	September 30, 2014			

Figure 5.2-3

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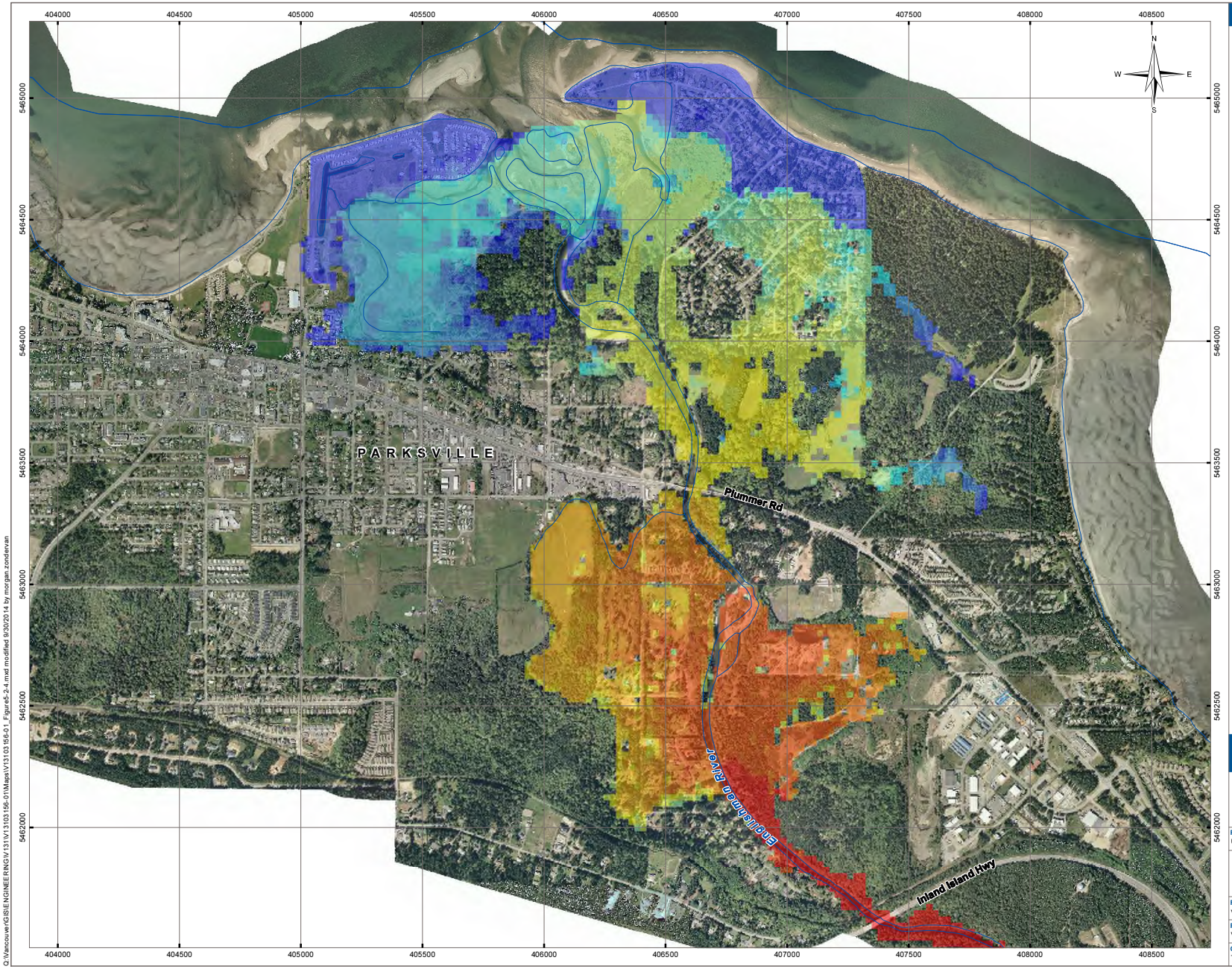

LEGEND

Watercourse/Waterbody

Time to Maximum Depth (hours)

- 33.1 - 35.7
- 30.5 - 33.1
- 28.1 - 30.5
- 25.9 - 28.1
- 24.2 - 25.9
- 22.8 - 24.2
- 21.4 - 22.8
- 20.0 - 21.4
- 18.6 - 20.0
- 17.6 - 18.6
- 16.6 - 17.6
- 15.4 - 16.6
- 14.4 - 15.4
- 12.9 - 14.4
- 11.3 - 12.9
- 10.1 - 11.3
- 9.1 - 10.1
- 8.2 - 9.1
- 7.3 - 8.2
- 6.0 - 7.3

NOTES
Base data source:
Imagery from City of Parksville

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Time to Maximum Flood Depth – City of Parksville

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Arrowsmith Water Service

Scale: 1:15,000
200 100 0 200
Metres

TETRA TECH EBA

FILE NO.				
V13103156-01_Figure5-2-4.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
V13103156-01	MEZ	MS	EL	0
OFFICE	DATE			
Tt EBA-VANC	September 30, 2014			

Figure 5.2-4

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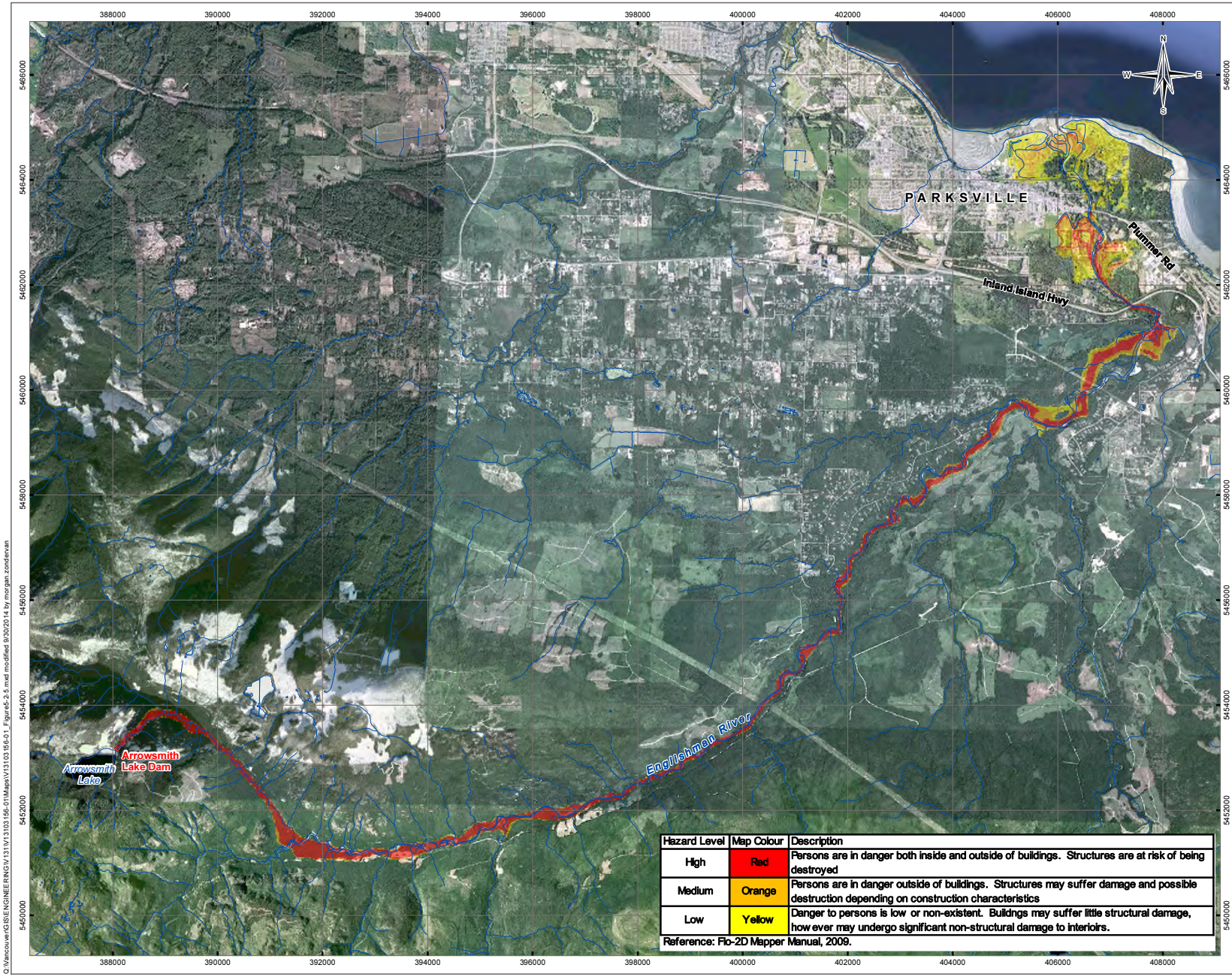

Hazard Level	Map Colour	Description
High	Red	Persons are in danger both inside and outside of buildings. Structures are at risk of being destroyed
Medium	Orange	Persons are in danger outside of buildings. Structures may suffer damage and possible destruction depending on construction characteristics
Low	Yellow	Danger to persons is low or non-existent. Buildings may suffer little structural damage, how ever may undergo significant non-structural damage to interioirs.

Reference: Flo-2D Mapper Manual, 2009.

LEGEND

- Dam Location
- Watercourse/Waterbody

Hazard Rating

- High
- Medium
- Low

NOTES
Base data source:
Imagery from Google Earth (2013)

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Flood Hazard Map - Overview

PROJECTION: UTM Zone 10			DATUM: NAD83		CLIENT: Arrowsmith Water Service
Scale: 1:70,000 (1 0.5 0 1 Kilometres)					TETRA TECH EBA
FILE NO.: V13103156-01_Figure5-2-5.mxd					
PROJECT NO.: V13103156-01	DWN: MEZ	CKD: MS	APVD: EL	REV: 1	Figure 5.2-5
OFFICE: Tt EBA-VANC	DATE: September 30, 2014				

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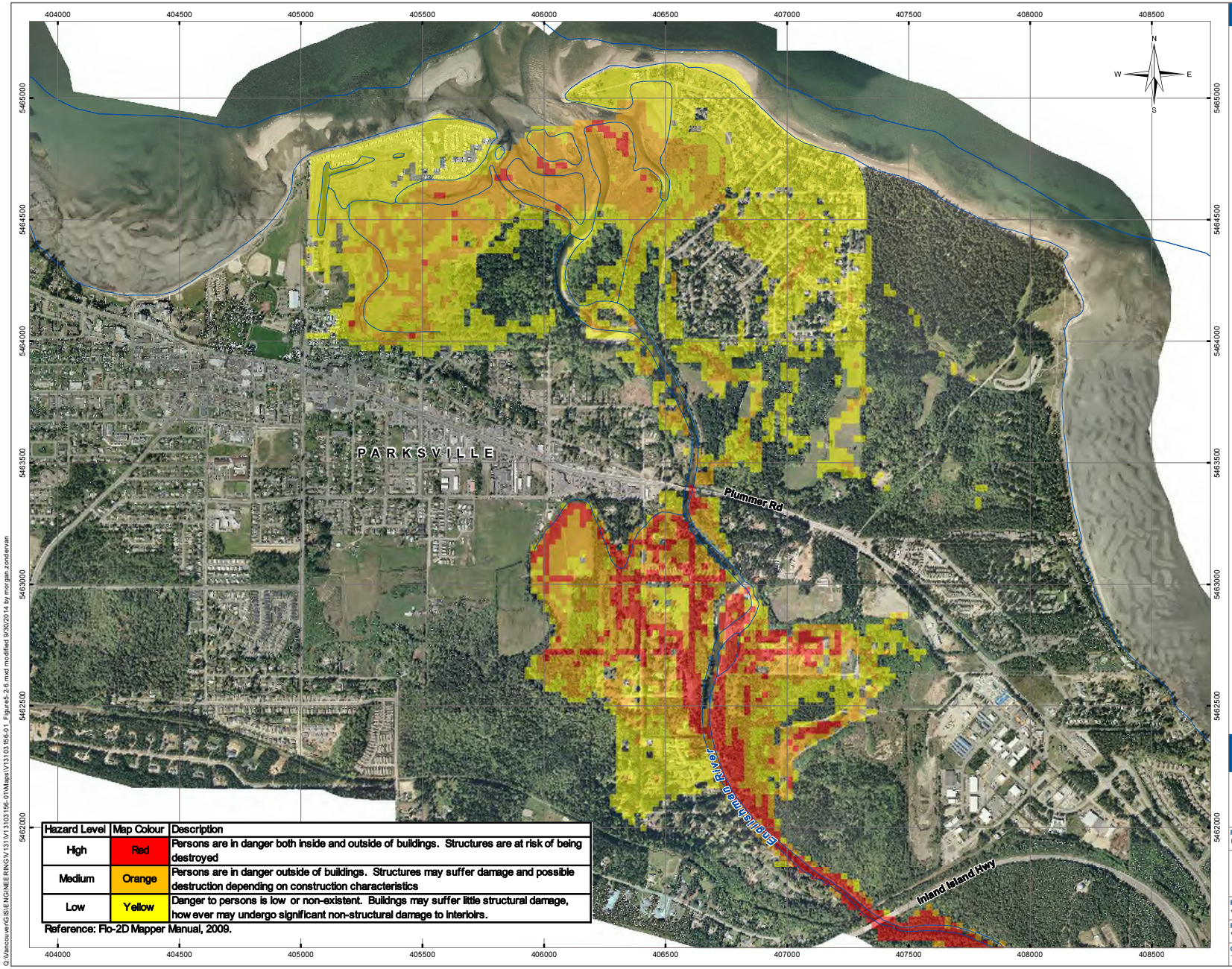

Hazard Level	Map Colour	Description
High	Red	Persons are in danger both inside and outside of buildings. Structures are at risk of being destroyed
Medium	Orange	Persons are in danger outside of buildings. Structures may suffer damage and possible destruction depending on construction characteristics
Low	Yellow	Danger to persons is low or non-existent. Buildings may suffer little structural damage, how ever may undergo significant non-structural damage to interioirs.

Reference: Flo-2D Mapper Manual, 2009.

LEGEND

- Watercourse/Waterbody

Hazard Rating

- High
- Medium
- Low

NOTES
Base data source:
Imagery from City of Parksville

STATUS
ISSUED FOR USE

ARROWSMITH LAKE DAM INUNDATION STUDY

Arrowsmith Dam Sunny Day Failure Flood Hazard Map – City of Parksville

PROJECTION: UTM Zone 10	DATUM: NAD83				CLIENT: Arrowsmith Water Service
Scale: 1:15,000 (200 100 0 200 Metres)					TETRA TECH EBA
FILE NO.: V13103156-01_Figure5-2-6.mxd					
PROJECT NO.: V13103156-01	DWN: MEZ	CKD: MS	APVD: EL	REV: 0	Figure 5.2-6
OFFICE: Tt EBA-VANC	DATE: September 30, 2014				

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APPENDIX A

PHOTOS OF THE ARROWSMITH DAM SITE AND DOWNSTREAM AREA

Photo 1: Arrowsmith Dam

Photo 2: Spillway

Photo 3: Spillway Cascade Pool

Photo 4: Dam Crest

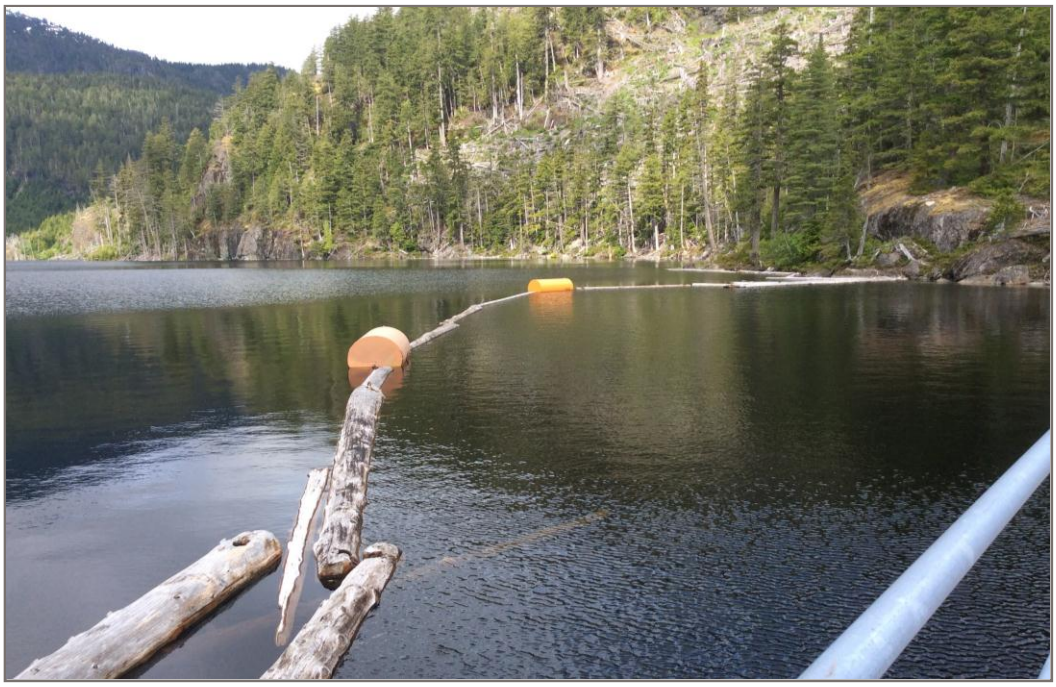

Photo 5: Log Boom

Photo 6: Wooden Bridge

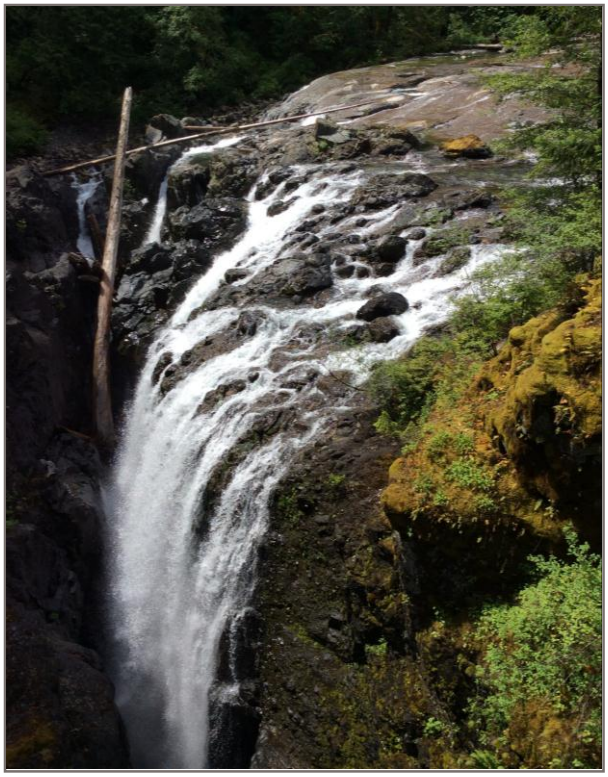

Photo 7: Englishman River Fall

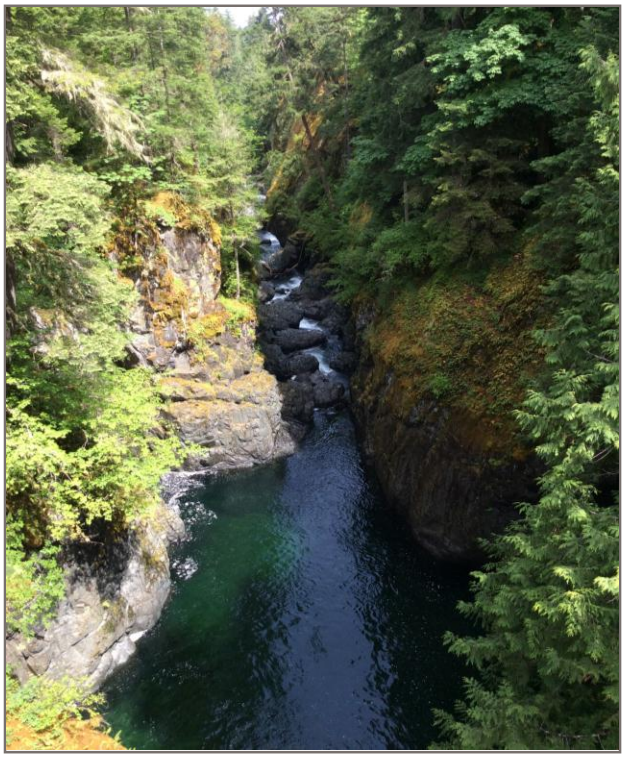

Photo 8: Deep valley at the Englishman River Park

Photo 9: Popular swimming spot at the Top Bridge Park

Photo 10: Highway 19 Bridge

Photo 11: Sewer Lift Station

Photo 12: Island Highway Bridge

Photo 13: Current Water Intake Site-Pump Station

Photo 14: Current Water Intake Site-Infiltration Gallery

Photo 15: Englishman River Estuary

APPENDIX B

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than Tetra Tech EBA’s Client, unless authorized in writing by Tetra Tech EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by Tetra Tech EBA during the performance of the work and other documents prepared by Tetra Tech EBA are considered its professional work product and shall remain the copyright property of Tetra Tech EBA.

2.0 ALTERNATIVE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, Tetra Tech EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

Tetra Tech EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, Tetra Tech EBA’s client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by Tetra Tech EBA’s Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of Tetra Tech EBA.

5.0 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon Tetra Tech EBA’s Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by Tetra Tech EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

Arrowsmith Dam