GLOBAL PERSPECTIVE.
LOCAL FOCUS.

Date:	February 21, 2015 **File:** E04.00
To:	Russell Martin, P.Eng.
From:	Lisbeth Medina, M.Eng., P.Eng
Project:	2015-3336
Subject:	Hydrotechnical Analysis_ Blakiston Creek

MEMO

1. INTRODUCTION

Photo 1: Canyon Church Camp Bridge over Blakiston Creek

Associated Engineering (AE) was retained by Parks Canada Agency (PCA) to complete a hydrotechnical analysis of the Canyon Church Camp Bridge, located approximately 12 km from the Townsite of Waterton, over the Blakiston Creek in the Waterton Lakes National Park, as shown in **Figure 1.1.** The existing structure was built in 1982 and consists of a three (3) span bridge supported by a timber substructure, as shown in **Photo 1**.

According to PCA, the existing bridge is currently closed as one of the bridge piers was severely damage during the 2013 flood event. Debris accumulation at the bridge opening along with high creek velocities is assumed to be the main cause of the pier damage.

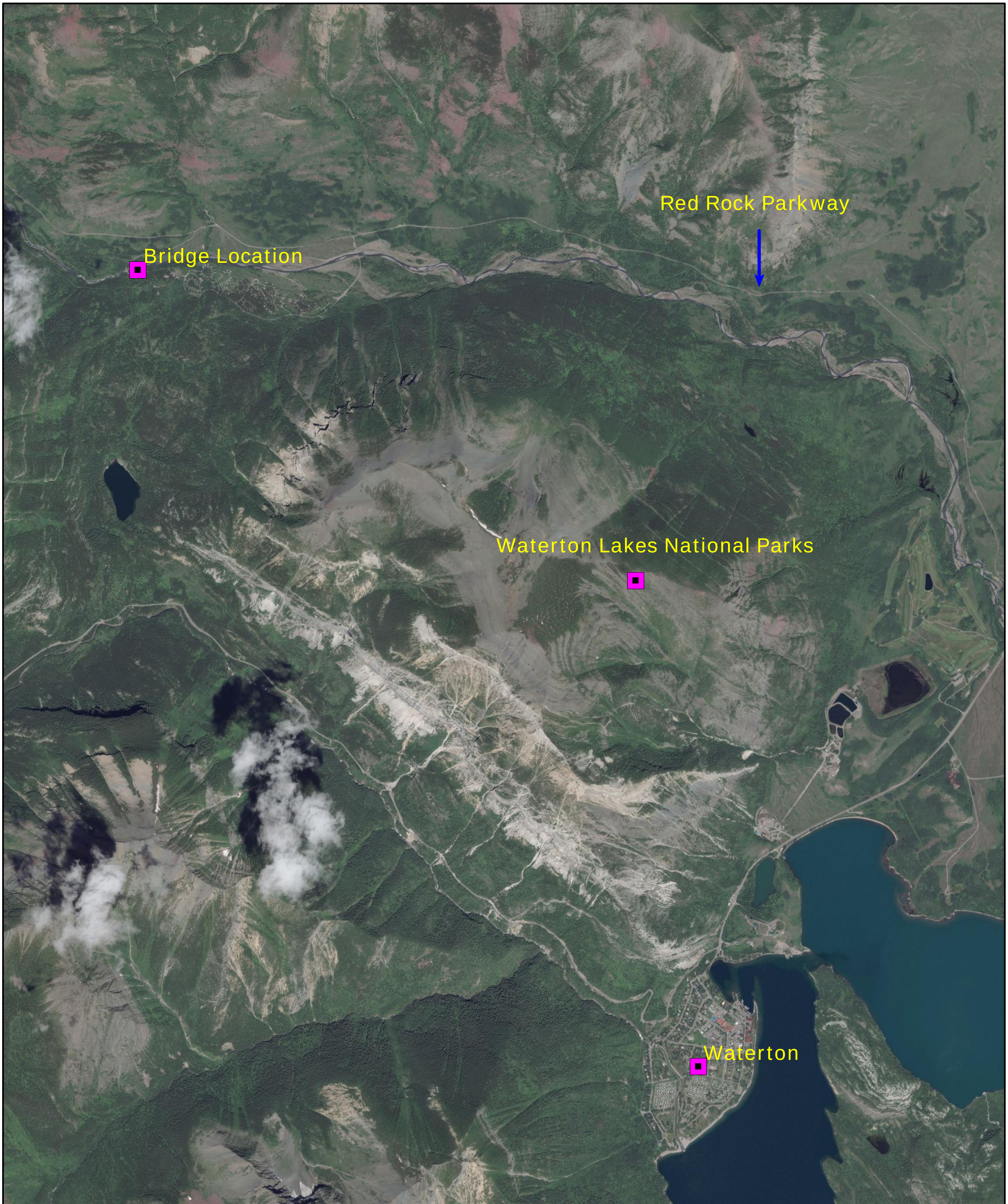
The following memo provides a preliminary hydrotechnical analysis of the crossing and assesses alternatives for the replacement of the existing bridge structure. Recommended design parameters for the replacement structure will also be provided.

2. BACKGROUND INFORMATION

2.1 Parks Canada Bridge History

The historical reports provided by PCA (E. Knox – WLNP – 2015) for the Canyon Camp Bridge noted the following observations (Park Canada files are shown in **Appendix A**):

- 1959 Superintendents report (January to April) noted that the construction of a new bridge across Pass Creek Canyon at Canyon Church Camp was completed.
- A 1964 report by Parks “Area Supervisor” J.R. Webb stated that a new log bridge to the public campground was washed out and covered by debris and that the beam supports of the Church Camp Bridge were ripped away. According to Park´s historical report, the “beam supports” were most likely affected by floating trees and logs.
- Parks Canada report noted that the bridge piers were damaged by the 1975 flood. The report also mentioned that “the Blakiston Creek Bridge should be reconstructed as a clear span to eliminate the present bridge piers acting as obstacles creating debris pile-ups and to allow for adequate channel volumes”.
- Historical Photos from 1991 and 1995 shows debris accumulation at the north pier and high water marks (HWM) ranging from 3.1 m – 3.5 m below deck elevation (estimated based on Photos).



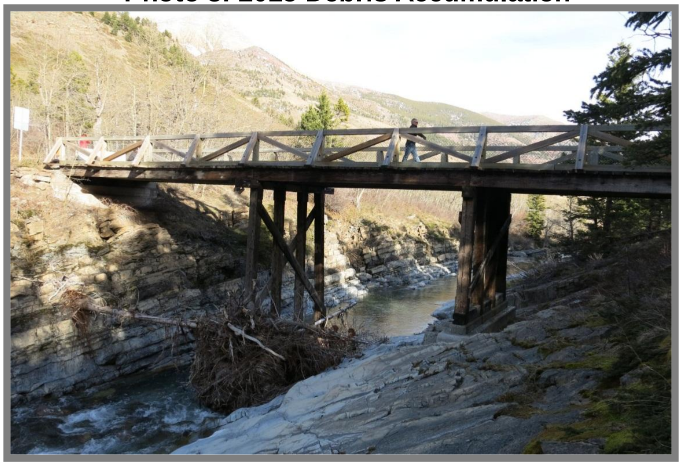
REVISION	(Name) (Date) (Name) (Date) (Name) (Date)	Figure 1.1: Bridge Location	PROJECT No: 2015-3336 DATE: 2015/02/22 SCALE: N/A PROJECTION: N/A

2.2 Recent Flood Events

- Parks Canada amendment #2 dated November 27, 2014, noted that the HWM from the 2013 flood was estimated to be half way up to the second pier.
- Debris accumulation at the bridge opening has been an ongoing issue since the bridge was constructed as shown in several historical reports and in the most up to date site photos. **Photo 2** and **Photo 3** shows the debris accumulation from 1991 and 2015 respectively.

Photo 2: 1991 Flood and Debris Accumulation

Photo 3: 2015 Debris Accumulation



Source: Historical reports provided by PCA.

2.3 Design Criteria

The following design criteria were used in the assessment:

- Design discharge calculated based on the 1:100 year flood event.
- Freeboard requirement of 1 m below the bottom girder/stringer elevation.
- Design velocity to not exceed natural creek velocity.
- Fish passage requirements to meet Alberta Transportation “Bridge Conceptual Design Guidelines” which notes that the mean velocity through the crossing should be less or equal to the mean velocity in the channel at Q_{FPD} (Fish Passage Design Flow).
- Navigability Requirements - a minimum of 1.5 m box clearance for the mean annual flood depth as per the Guideline for Navigable Waters Protection Act (NWPA) applications.
- Rock riprap classification and size based on the “Specifications for Bridge Construction”, Heavy Rock Riprap (Section 10).

3. ENVIRONMENTAL CONSTRAINTS

3.1 Navigability

Blakiston Creek is considered navigable based on the Alberta Transportation Drainage Basins and Navigated Stream map (Alberta Transportation 2014), shown in **Figure 3.1.**

As such an estimation of the navigation clearance box will be completed for the proposed replacement options as outlined in the Alberta Transportation "Bridge Conceptual Design Guidelines" and the Updated Guidelines for Navigable Waters Protection Act (NWPA) Applications under the Navigable Waters Protection Program (NWPP)

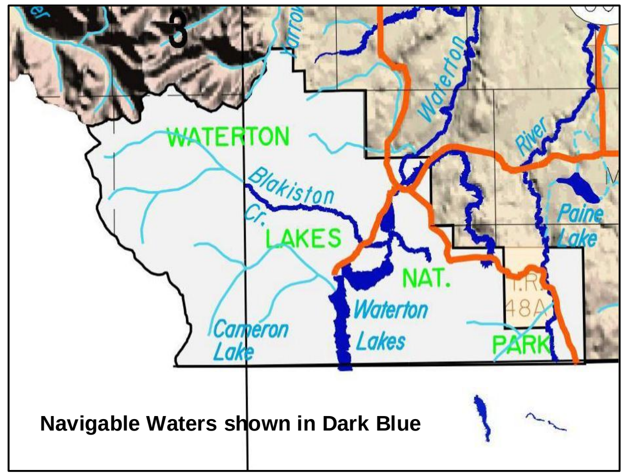


Figure 3.1: Navigable Water Map
Source: Alberta Transportation

3.2 Code of Practice – Creek Classification

Blakiston Creek is understood to be a fish bearing watercourse. A fish passage assessment of the proposed crossing has been completed based on Alberta Transportation's "Bridge Conceptual Design Guidelines", however, given that the replacement option for this site is a clear span (25 m) bridge structure, it is expected that the velocities through the proposed crossing will match the natural creek velocities.

4. HYDROLOGY

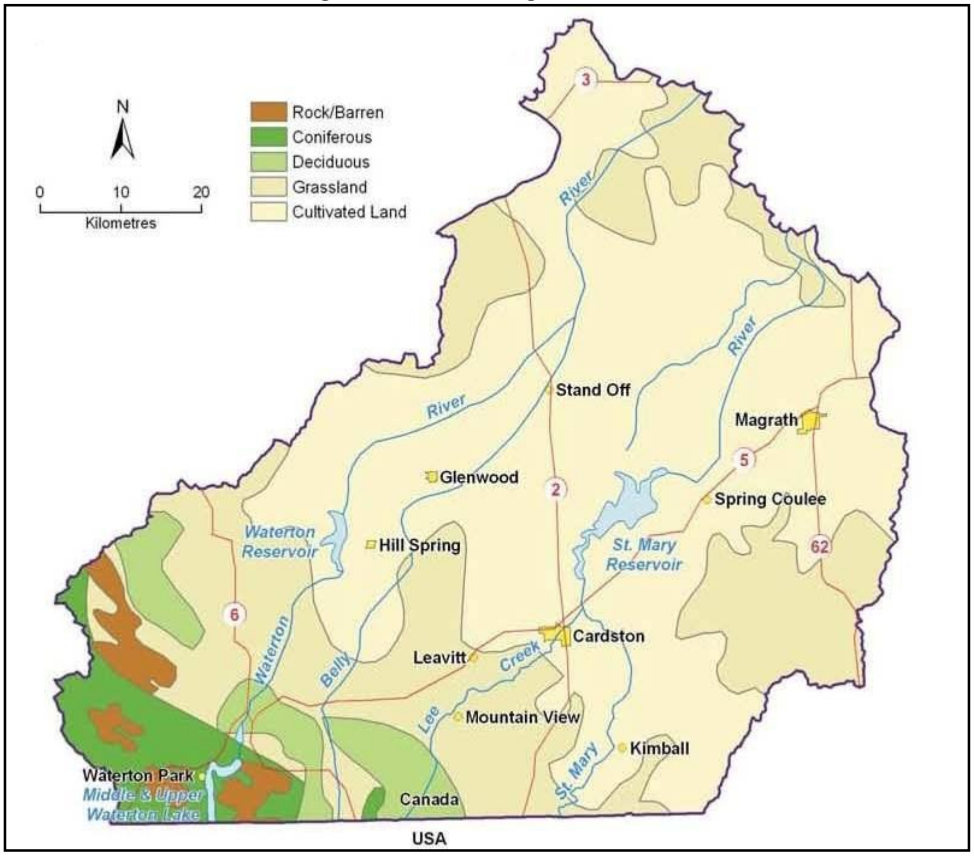
4.1 General

Blakiston Creek flows in a south-easterly direction through the crossing to the confluence with Waterton River. The basin is irregular in shape and consists of undeveloped land (mainly forest and rock and barren lands which are found on high mountain elevations), as shown in **Figure 4.1.**

According to Parks Canada *"Fire, Flood and Avalanche – A Tale of Two Fans*", the origin of Blakiston Creek dates back thousands of years when glacier meltwaters carried materials eroded from the mountain down what are now the Cameron and the Blakiston Creeks and dropped them into the Waterton Lakes. This deposition created what is currently known as the Blakiston fan.

Floods triggered by extensive rain and melting snow have impacted existing structures and the morphology of Blakiston Creek, specifically at the downstream end (fan area) where, according to Parks Canada, the Blakiston Creek shifted in 1995.

Figure 4.1: Existing Land Use



Source: Chapter 4: The Southern Tributaries Sub-Basins – Payne Lake ARD Alberta Transportation

4.2 Drainage Area and Channel Slope

The drainage area tributary to the crossing was estimated to be 128 km^2 based on topographic maps obtained from Global Mapper Software, as shown in **Figure 4.2.**

A survey conducted by Roads West Engineering Ltd. in February 2015 indicated a slope of 0.0114 m/m through the surveyed reach. The surveyed profile is shown in **Figure 4.3** and includes the minimum channel elevation and observed HWMs. The observed historical HWMs were all 2 m or more below the existing bridge deck.

Note that the recent bridge survey is based on a local coordinate system with a base datum of 1000 m.

Figure 4.2: Blakiston Creek Drainage Basin

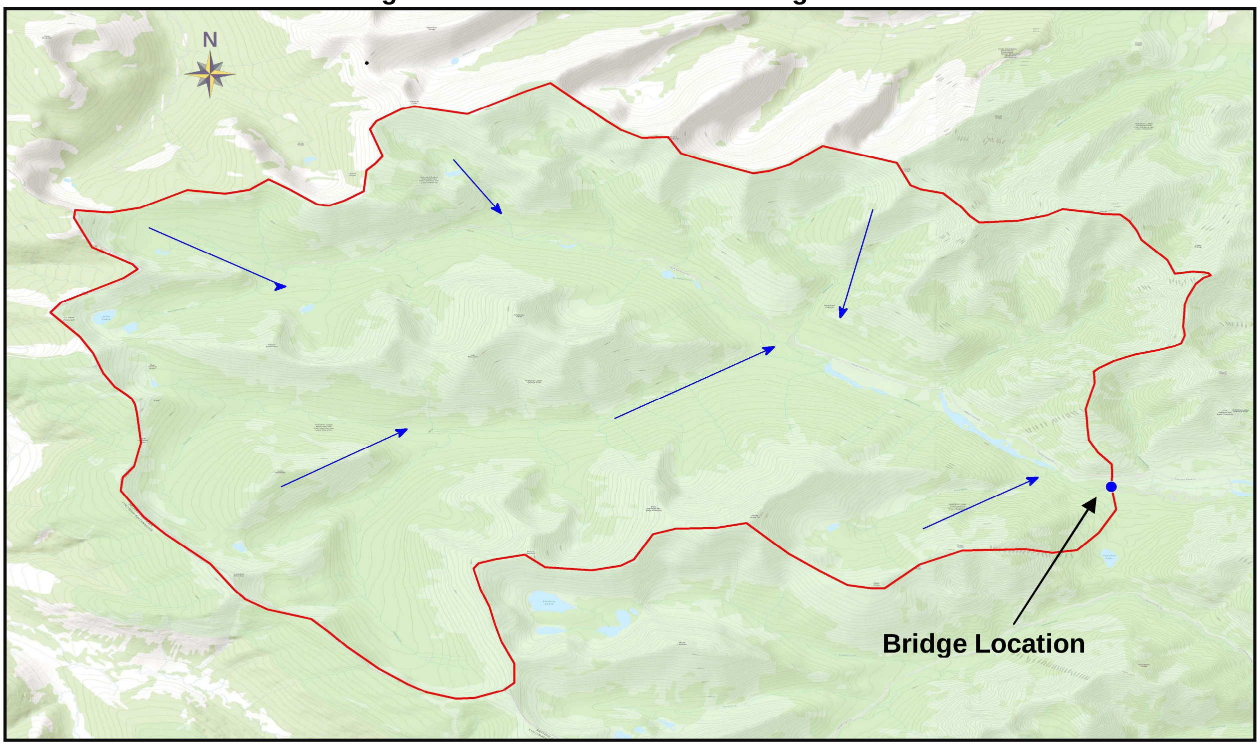
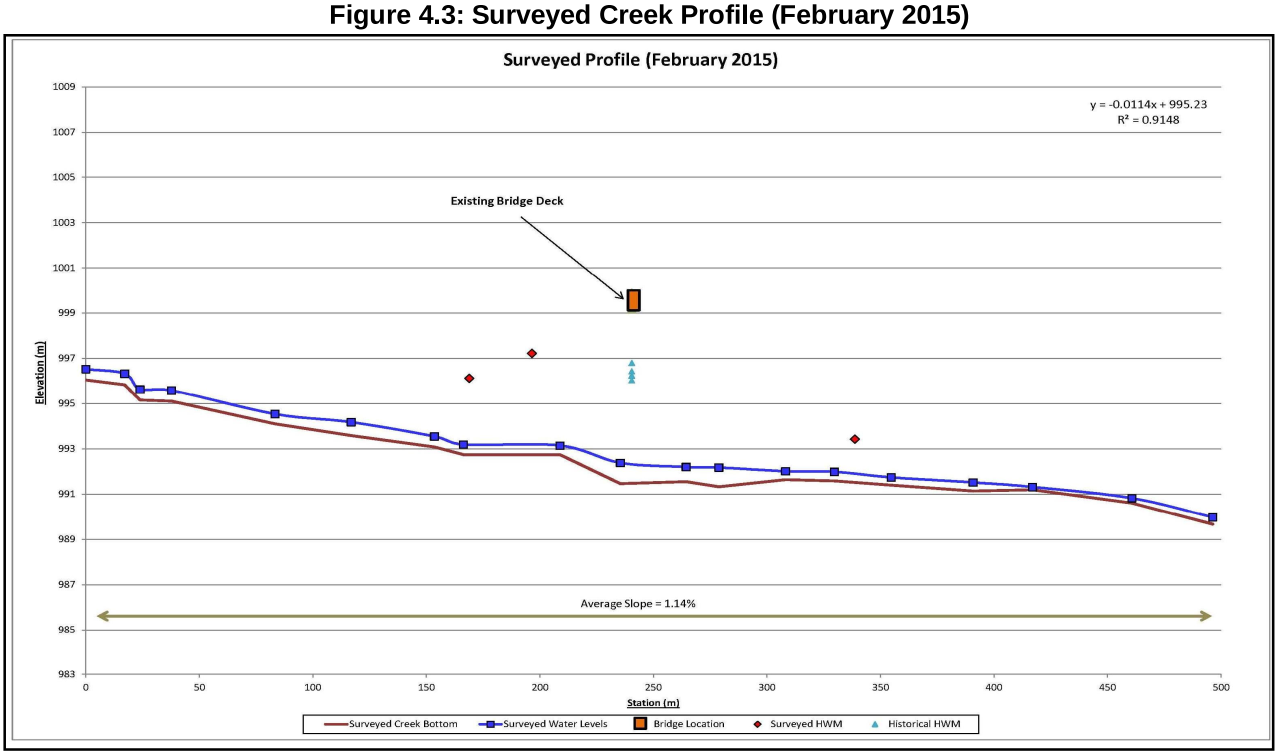


Figure 4.3: Surveyed Creek Profile (February 2015)



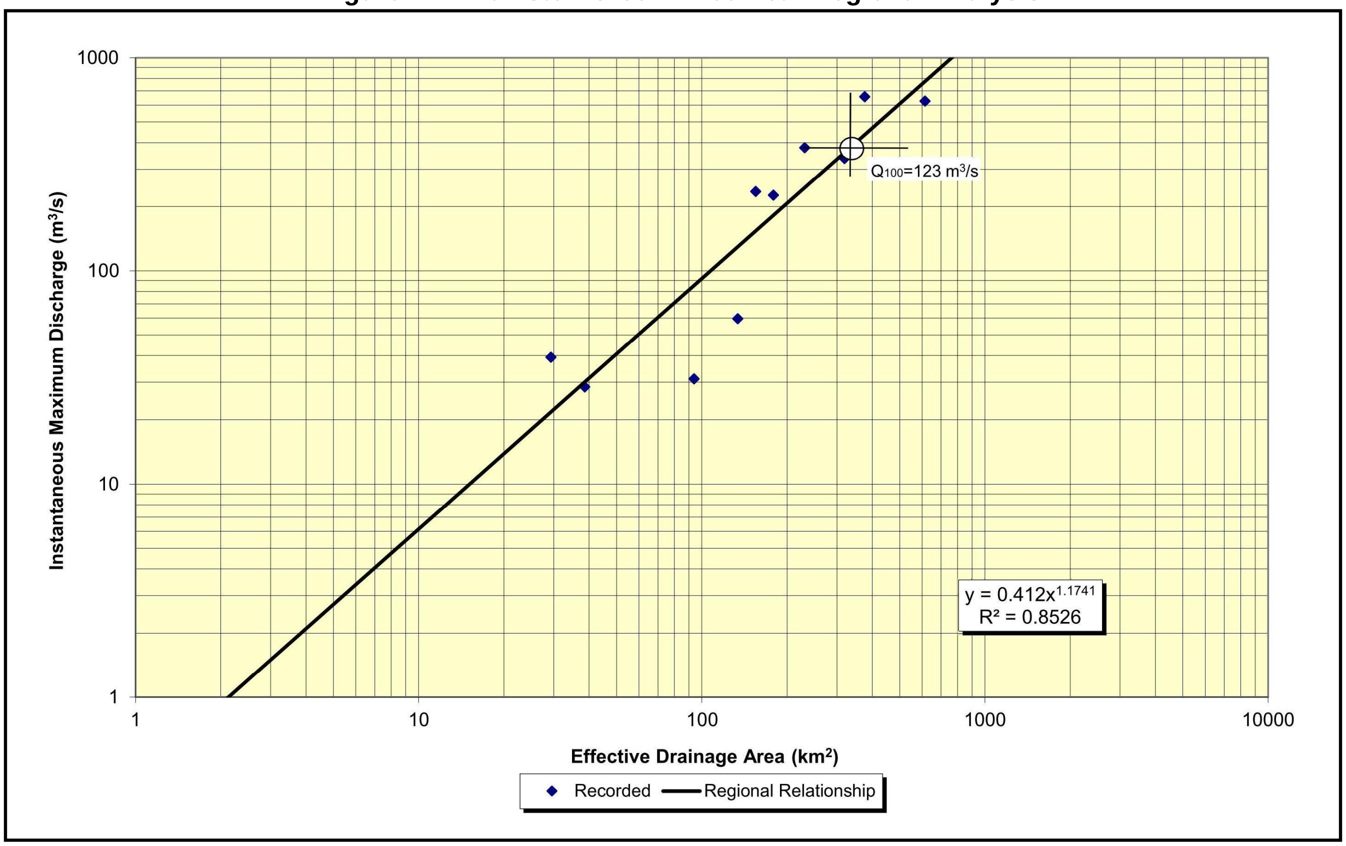
4.3 Regional Analysis

A regional analysis was conducted using Water Survey of Canada gauge data for a number of rivers and creeks including the Pincher Creek, Mill Creek, Castle River, Waterton River, Belly River, Drywood Creek, Foothills Creek, Tough Creek and Lee Creek.

The results are shown in **Figure 4.4**. The analysis resulted in an R^2 value of 0.85 which indicates good data correlation.

For the project basin area of 128 km^2 basin, the peak flow is **123 m^3/s**.

Figure 4.4: Blakiston Creek 1:100 Year Regional Analysis



4.4 Runoff Depth Method

The Basin Runoff Potential method estimates the basin runoff potential based on runoff depth zones which have been defined based on statistical analysis of historic stream flow data for Alberta.

According to Alberta Transportation *"Hydrotechnical Design Guidelines for Stream Crossings",* the basin runoff potential method is recommended in cases when the runoff response at a site may not reach the channel capacity estimate under design conditions due to limitations in the runoff supply in the hydrologic region, or runoff routing effects from the upstream basin and channel.

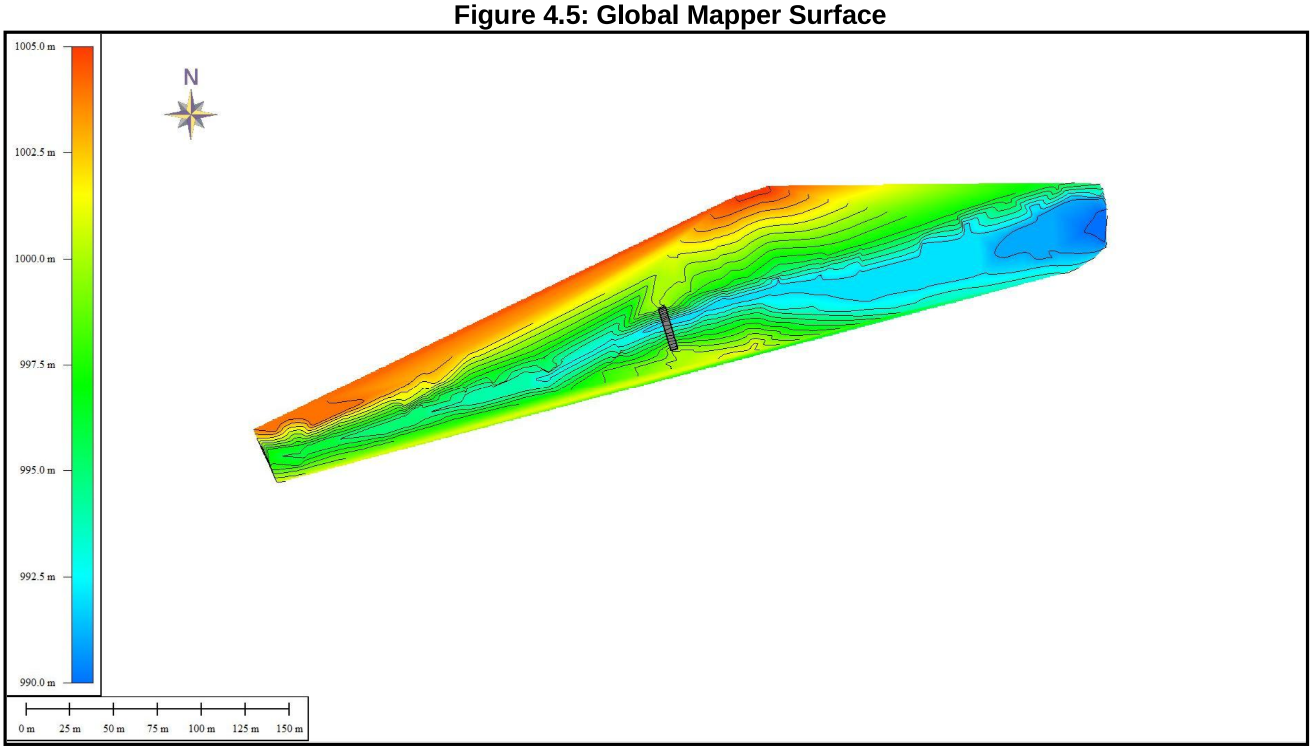
Based on Alberta Transportation's Runoff Depth map, a runoff depth of 150 mm and time to peak of 20 hours were used for the basin along with a drainage area of 128 km^2. The maximum runoff potential was determined to be **267 m^3/s.** Based on past experience, this method tends to result in discharge values that are much higher than other methods.

4.5 Channel Capacity

The Alberta Transportation Channel Capacity calculator was used to estimate the design flow for the Blakiston Creek crossing.

As previously mentioned, a survey was conducted by Roads West Engineering Ltd. in February 2015. The survey extended approximately 250 m upstream and downstream of the existing bridge (500 m total). Global Mapper software was used to create a surface from the surveyed points, as shown in **Figure 4.5.** The surface was used to determine the channel parameters.

Figure 4.5: Global Mapper Surface



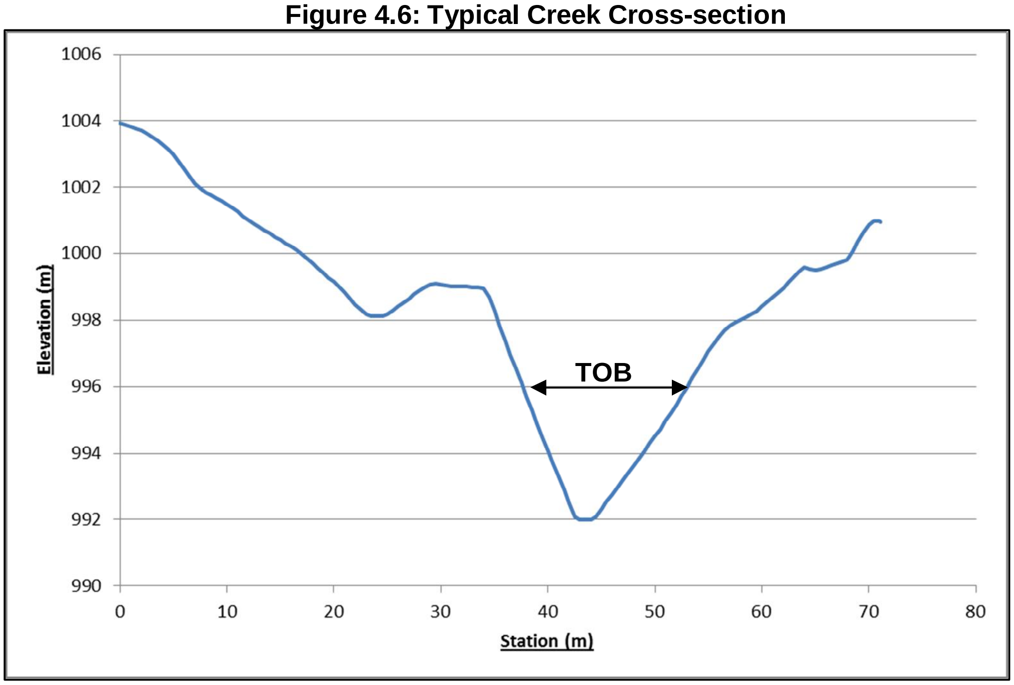
For the preliminary analysis, 18 cross-sections (9 upstream and 9 downstream of the crossing location), were delineated from the surface. A typical cross-section is shown in **Figure 4.6**.

Based on the survey data, the average channel dimensions are as follows:

- Bottom width = 2.0 m
- Top of bank width =16.8 m
- Channel depth = 2.05 m
- Local channel slope = 0.0114 m/m (Survey)

Based on these values and a Manning's n of 0.05 (recommended value by AT based on bottom width and channel slope), the estimated channel capacity at the bankfull stage is **64 m^3/s.** When allowance is made for the floodplain as recommended by AT, the capacity increases to **156 m^3/s.**

Figure 4.6: Typical Creek Cross-section



4.6 Flood Frequency Analysis – Basin Correlation

A search of available Water Survey of Canada (WSC) gauge data revealed that Blakiston Creek is not gauged.

Gauge data from streams located in nearby areas but within a geographically similar drainage area with similar characteristics were included in the analysis. **Table 4.1** describes the gauges near the crossing location.

Table 4.1: WSC Gauges

Gauge	Description	Drainage Area (km2)	Years of Available Data
05AA004	PINCHER CREEK AT PINCHER CREEK	155	56
05AA011	MILL CREEK NEAR THE MOUTH	179	29
05AD010	DRYWOOD CREEK NEAR THE MOUTH	231	43
05AD901	FOOTHILLS CREEK NEAR PINCHER CREEK	134	11

A flood frequency analysis was conducted using the maximum instantaneous values for each of the above WSC gauges. Calculations were based on the analysis and comparison of four frequency distributions; Pearson Type III, Log Pearson Type III, Long Normal, and Gumbel.

The best estimate for a 1:100 year return period corresponds to discharges in the range of 71 m^3/s and 167 m^3/s (average of 4 distributions). A summary of the estimated discharges and their corresponded unit flow is shown in **Table 4.2**.

Table 4.2: Flood Frequency Analysis Results

Basin	Drainage Area (km^2)	Q1:100 (m^3/s) (Aveg. 4 Distributions)	Unit Flow ($m^3/s/km^2$)	Blakiston Creek Q (m^3/s)
PINCHER CREEK	155	202	1.30	**167**
MILL CREEK	179	157	0.88	**112**
DRYWOOD CREEK	231	247	1.07	**137**
FOOTHILLS CREEK	134	74	0.55	**71**

The unit flows were used to calculate the discharge at the bridge location. The result of this calculation has been highlighted in red in the above table.

Based on the above analysis, the estimated 1:100 year discharge at the crossing is **122 m^3/s** (average of the four basins).

4.7 Hydrology Summary

The estimated drainage area at the bridge site is 128 km^2. The local channel slope at the crossing is estimated to be 0.0114 m/m, as per the survey completed in February 2015.

The estimates for design discharge are as follows:

- Regional Analysis = 123 m^3/s
- Runoff Depth Method = 267 m^3/s
- Flood Frequency Analysis - Basin Correlation = 122 m^3/s
- Channel Capacity = 64 m^3/s (bankfull), 156 m^3/s (including floodplain allowance)

The design discharges range from 122 m^3/s to 267 m^3/s. A design discharge of **123 m^3/s** is recommended for the design of the replacement structure based on the Regional Analysis. Due to the limited amount of survey data, the design flow from the Regional Analysis was recommended as it is consistent with the flood frequency analysis of others WSC gauges located in the area.

Appendix B provides detailed information of the design discharge calculations.

4.8 Observed HWMs

Table 4.3 summarizes the HWMs observed since 1991. Note that the first four elevations were estimated based on historical photos and Parks Canada site observations. The last three HWMs were identified during the survey.

Table 4.3: Observed HWMs at Existing Bridge Location

Year	Elevation (m)*	Note	Freeboard to Bottom of Bridge (m)
1991	996.1	Historical Photo (At bridge Location)	3.3
1995	996.2	Historical Photo (At bridge location)	3.2
2013	996.8	Historical Photo (At bridge location)	2.6
2015	996.5	Parks Canada (At bridge location)	2.9
2015	996.1	2015 Survey (Upstream of Bridge)	3.3
2015	997.3	2015 Survey (Upstream of Bridge)	2.1
2015	993.4	2015 Survey (Downstream of Bridge)	6.0

Note: Elevations are based on Local Coordinates (1000 m Reference Datum)
Bottom of Existing Bridge Elevation: 999.4

All the above HWMs were accompanied by a large debris accumulation at the bride opening resulting in backwater and high water levels.

5. HYDRAULIC MODELING USING HEC-RAS

This preliminary analysis included the development of a backwater model of the Blakiston Creek to determine the open water flood conditions and velocities. The following section discusses the model development and results.

Survey data was used to create complete cross sections which include the floodplain areas. Nineteen (19) composite cross sections were used to create the Hec-Ras model. Hec-Ras was developed by the U.S. Army Corps of Engineers and is capable of calculating water levels and channel velocities for a range of discharges and a variety of boundary conditions. The model setup includes nine cross sections upstream of the proposed crossing and nine cross sections downstream.

Two scenarios were included in the analysis:

- Three Span Bridge – Existing bridge configuration
- Single Span Bridge (25 m)

The above scenarios have been evaluated for the design discharge of 123 m^3/s and the structures were assumed to be located at the same location as the existing crossing.

The model results are summarized in **Table 5.1.**

Table 5.1: Summary Model Results

Options	Scenario	Minimum Bottom of Girder Elevation (m)*	High Water Level (m)	Freeboard (m)	U/S Velocity (m/s)	D/S Velocity (m/s)	Average Velocity (m/s)
N/A	Natural Channel	N/A	996.1	N/A	3.3	3.8	3.6
1	Three Span Bridge (Existing Configuration 10.2 - 7.3 - 7.5)	999.3	996.3	3.0	3.3	4.5	3.9
2	Single Span Bridge (25 m)	998.4**	996.1	2.3	3.3	3.8	3.6

Note: The elevations are based on Local Coordinates (1000 m Reference Datum)
Model results do not account for the impact of debris which could result in higher water levels and velocities for Option 1
* Surveyed Deck Elevation of 999.9 m
** Assumed a 1.5 m depth of Superstructure

Table 5.1 shows that the single span bridge option does not impact the natural channel velocities and will likely not affect fish passage through the bridge. The water levels or velocities are slightly higher for the three span bridge.

A single span bridge is the most desirable option as it would eliminate the in-stream pier and therefore reduce or eliminate debris built-up at the crossing and potentially eliminate the need for in-stream work, which has a negative effect on fish and fish habitat.

The single span configuration will provide 2.3 m of freeboard above the design water surface elevation and 1.2 m of freeboard above the maximum observed HWM elevation of 997.3 m recorded during the 2015 survey. The 2015 HWM corresponds to a flow of 285 m^3/s based on the channel dimensions.

The single span bridge configuration was also analysed based on a maximum flow of 156 m^3/s (channel capacity tool), which resulted in an increase of 0.4 m above the design HWL; however, still providing 1.9 m of freeboard below the proposed bottom of girder elevation.

The HEC-RAS model results produced an average velocity of 3.6 m/s through the crossing. Class **III** rock riprap will be required to protect against erosion as per AT "Design Guidelines for Bridge Size Culverts".

Figure 5.1 and Figure 5.2 illustrate the model profile and cross-section for the single span option respectively.

Appendix C shows detailed HEC-RAS results for the replacement options considered.

Figure 5.1: Profile of the Proposed Bridge (Single Span Configuration)

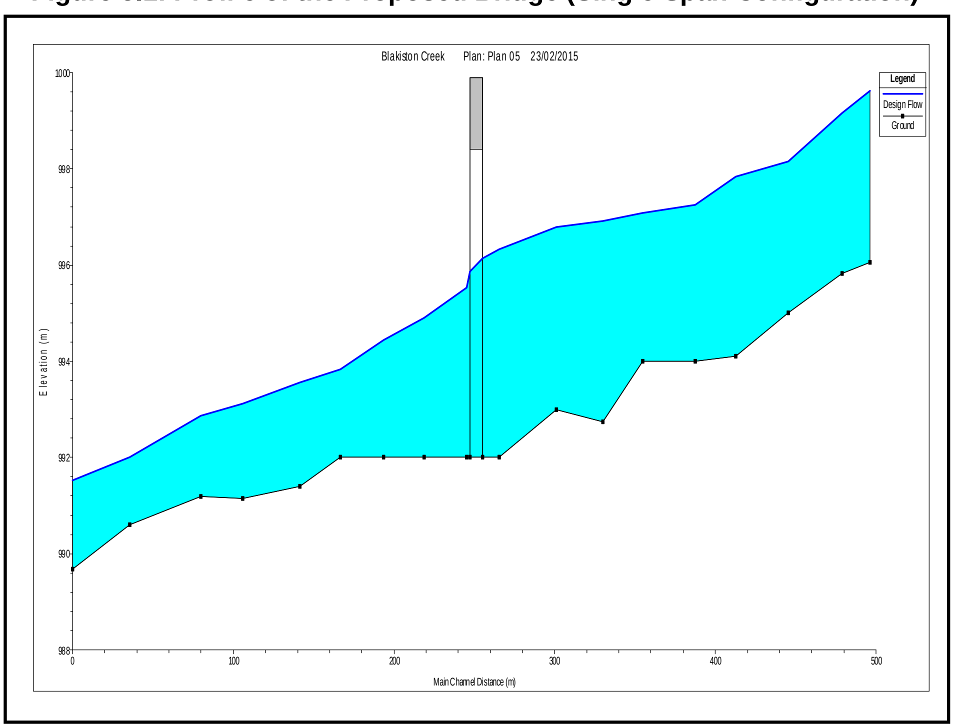
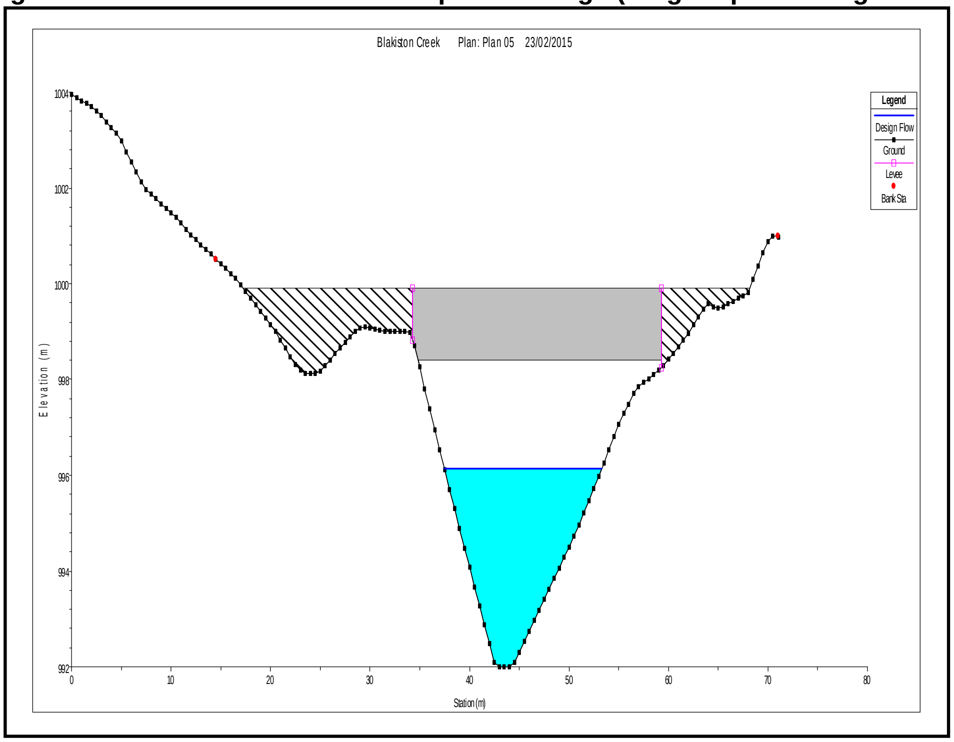


Figure 5.1: Cross-section of the Proposed Bridge (Single Span Configuration)



5.1 Fish Passage Assessment

According to the Alberta Transportation "Bridge Conceptual Design Guidelines", a fish passage design flow (Q_{FPD}) is required for the assessment of fish passage at bridge/culvert structures. The main purpose for assessing fish passage is to ensure that the mean velocity throughout the bridge is less than or equal to the mean velocity in the channel at Q_{FPD}.

Q_{FPD} is calculated based on the following equations:

- Estimated depth of flow (Y_{FPD}) = 0.8 – 34.5S; minimum Y_{FPD} = 0.2 m; S= Channel Slope
- Fish passage design flow (Q_{FPD}) at Y_{FPD} is ten calculated by using AT's Channel Capacity Tool.

Based on the above, Q_{FPD} was calculated to be 3.4 m^3/s based on the estimated depth of flow (Y_{FPD}) of 0.41 m. This flow is presumed to be exceeded 5% of the time. Fish passage was assessed using the HEC-RAS backwater model.

Table 5.2 summarizes the estimated velocities through the proposed crossing configurations.

Table 5.2: Summary of Estimated Velocities

Yfdp (m)	0.41 m
Qfdp (m3/s)	3.4 m^3/s
	Average Velocity (m)
Natural Channel	**1.1**
Three Span Bridge (Existing Configuration 10.2 - 7.3 - 7.5)	1.1
Single Span Bridge (25 m)	1.1

As shown in Table 5.2, the velocities for the above configurations are equal to the natural channel velocities at $Q_{FDP;}$ therefore, fish passage should not be a concern.

5.2 Navigable Water Requirements

As previously mentioned, Blakiston Creek is considered navigable based on the Alberta Transportation Navigable Water map.

According to AT's "Bridge Conceptual Design Guide", the current practice is to use a reference water level (Y2) based on the mean annual flood (Q2) to assess navigation impact of a crossing structure. The estimation of Q2 can be completed by using nearby WSC gauges (depending on the number of records) or an empirical equation (based on creek slopes) as noted in the Bridge Conceptual Design Guide.

Since Blakiston Creek is not gauged, the calculation of Q2 was based on the empirical equation Q2 = Q/10 (for slopes higher than 0.01 m/m) as described in the Bridge Conceptual Design Guidelines and resulted in a discharge of 12.3 m^3/s. The reference water depth (Y2) was estimated to be 0.85 m.

Table 5.3 summarizes the minimum navigability clearance available for the proposed bridge configuration.

Table 5.3: Navigable Water Analysis

	Proposed Bridge (25 m Single Span)
Bottom Girder Elevation (m)*	998.4
Reference Water Level (m)*	993.3**
Minimum Clearance Provided Above Y2 (m) *	5.1

** Elevations based on Local Coordinates*
*** Calculated based on a Surveyed Creek bottom elevation of 992.384 m.*

Based on results, the proposed bridge configuration (25 m single span) meets navigability requirements. The bridge minimum clearance is higher than the required clearance envelope of 1.5 m high, as noted in the Guidelines for Navigable Waters Protection Act (NWPA) Applications.

6. SUMMARY

Based on the above analysis, AE has made the following observations, conclusions, and recommendations:

- The Canyon Church Camp Bridge was constructed in 1982 and is located approximately 12 km from the Townsite of Waterton on the Red Rock Parkway, over Blakiston Creek. The existing structure is a 3 m –span bridge with an in-stream pier that has been impacted by debris build up.

- The existing three-span bridge has experienced structural damages during high flows due to repeated debris accumulation at the pier.

- The recommended design discharge to be used for the preliminary design of the replacement structure is 123 m^3/s based on the Regional Analysis.

- Based on the HEC-RAS model results, the three span bridge results in slightly higher levels and velocities compared to the single span option. The single span bridge is the most desirable replacement structure as it reduces the potential for debris jams and provides adequate freeboard above the design high-water level.

- The HEC-RAS model results show velocities through the crossing of 3.3 m/s upstream and 3.8 m/s downstream for the proposed single span bridge. Class III rock riprap is required at the crossing to protect against erosion.

- **Table 6.1** summarizes the preliminary design parameters for the proposed bridge structure.

Table 6.1: Summary of Design Parameters

Parameters (25 m Single Span Bridge)	Values
Design Flow (m^3/s)	123 m^3/s
Surveyed Deck Elevation (m)	999.9 m
Minimum Bottom of Girder Elevation (m)	998. 4 m
Computed High Water Elevation (m)	996.1 m
Freeboard (m)	2.3 m
Computed Average Velocity (m/s)	3.6 m/s
Erosion Protection	Class III Rock Riprap

- The design was also checked against higher flows and was found to provide adequate freeboard.
  - ✓ A flow of 156 m3/s increases the HWL by 0.4 m.
  - ✓ There is 1.2 m of freeboard above the 2015 HWM (the highest observed at this crossing), which corresponds to a discharge of approximately 285 m^3/s.
  - ✓ Flows much higher than the design discharge can be accommodate due to the configuration of the crossing.

- A 25 m single span bridge is the recommended replacement structure for this crossing.

- The proposed structure does not impact the natural channel; therefore, fish passage is not concern for this option.

- In terms of navigability, the proposed bridge configuration (25 m single span) meets navigability requirements, a minimum of 1.5 m of clearance, as noted in the Guidelines for Navigable Waters Protection Act (NWPA) Applications.

- Confirm the Creek classification and restricted activity period.

- Conduct a more detailed survey prior to detailed design and construction to confirm the creek dimensions and site conditions.