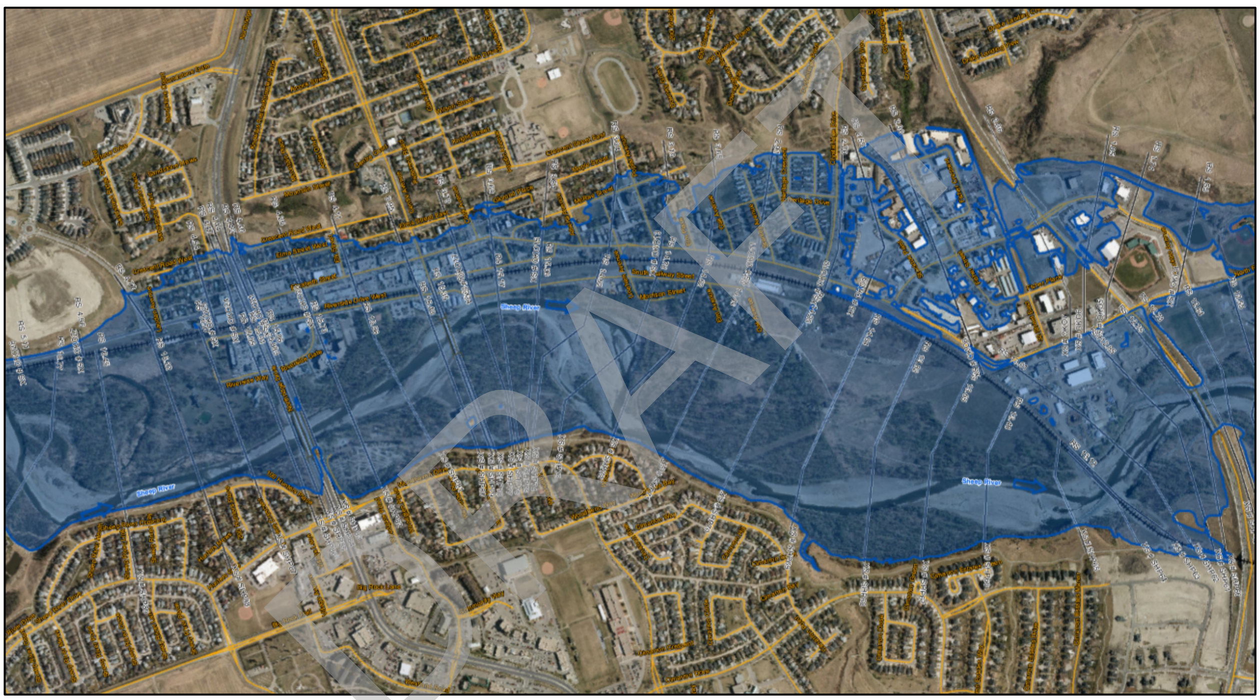
June 2022

Sheep River Flood Hazard Study

Hydraulic Model Creation, Calibration and Inundation Mapping Report



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Report

Hydraulic Model Creation, Calibration and Inundation Mapping Report

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Executive Summary

Alberta Environment and Parks (AEP) commissioned Hatch Ltd. (Hatch) in November 2017 to undertake the Sheep River Hazard Study (the study). The primary purpose of the study is to assess and identify river and flood hazards along the Sheep River, and Threepoint Creek through the MD of Foothills, Turner Valley, Black Diamond, Millarville, and Okotoks. The study is being completed under the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the government of Alberta, the communities mentioned above, and the general public.

The study includes multiple components and deliverables. This report documents the methodology and results of the hydraulic model creation and calibration component, which will support future flood mapping and flood risk assessment. The tasks associated with this component include a description of the flooding history, description of river and valley features, model setup, model calibration, sensitivity analysis and generation of open water flood frequency profiles. This report also documents the methodology and results of the open water flood inundation mapping component, including the inundation maps for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year open water floods.

All river reaches in the study area were integrated into one HEC-RAS model. The model was calibrated for:

- low flow conditions based on water levels and discharges measured in November 2016;
- high flow conditions based on high water marks and high water levels collected by AEP during and after the June 2013 flood and the June 2005 flood; and
- the flow-stage rating curves for the WSC gauging stations in the study area.

The calibrated main channel Manning's n values for high flow conditions are listed in Table ii.

The calibrated model was then used to simulate the open water surface profiles for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year flood events in the study area.

A model sensitivity was evaluated using the 100-year flood simulation results. The results of the sensitivity analysis show that variation of the river channel roughness values has a much higher influence on the simulated flood levels than variation of the floodplain roughness values, and that on average, the 100-year flood levels are estimated to be within a range of ±0.34 m of the simulated values along the Sheep River, and ±0.28 m on Threepoint Creek.

The flood inundation maps were prepared using ArcMap and based on the simulated open water flood levels at the cross sections by subtracting the LiDAR DTM from the water level surface. Flood inundation mapping for the Town of Okotoks was prepared using an independent tributary reach set up within the model, and in many cases the one-dimensional model results were informed with more detailed 2D models. Several special areas were identified for the 13 flood events and manual edits to the water level surface TIN were made.

Based on the simulation results, the main areas to be affected by open water flooding have been identified as follows:

- Low lying areas adjacent to the river in Turner Valley for events equal to or greater than the 100-year flood.
- Black Diamond would begin to experience flooding for events exceeding approximately the 20-year flood.
- Okotoks would experience flooding within the Country Lane estates area for floods exceeding approximately the 20-year event. Northern sections of the town would begin to experience flooding for events equal to or exceeding the 75-year event.
- Most bridges in the area appear to have lower chords elevations which exceed the expected water levels during the 100-year event. However, the Highway 22 bridge through the town of Black Diamond would likely have some water against the lower chord for events equal to or larger than the 10-year flood event.

Acknowledgements

The authors express their special thanks to Kurt Morrison, Peter Bezeau, and Pat Stevenson of Alberta Environment and Parks (AEP), and who provided overall study management, background data, and technical guidance for this study.

The following members of Hatch completed the hydraulic modelling component of this study:

- Joe Groeneveld, Project Manager and technical advisor
- Soheil Zare, Hydraulic modelling
- David Bonin, Hydraulic modelling advisor
- Mark Orton, Hydrology review
- Shayla Murphy, Mapping
- Nadia Langenberg, Mapping
- Rachel Groeneveld, Mapping and Flood Risk Inventory

The study team would also like to thank the following agencies, each of which provided valuable information and assistance in the completion of this portion of the study:

- Municipal District of Foothills No. 31;
- Town of Black Diamond;
- Town of Okotoks;
- Town of Turner Valley;
- Water Survey of Canada; and
- Informatics Branch of Alberta Environment and Parks
- Amec Foster Wheeler (initial investigator, who supplied the surveys and cross sectional data)

Disclaimer

This report has been prepared by Hatch Ltd. ("Hatch") for the sole and exclusive use of Alberta Environment and Parks (the "Client"), for the purpose of assisting the management of the Client in making decisions with respect to the Sheep River Flood Hazard Study (the "Project").

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(b) the report being read as a whole, with sections or parts hereof read or relied upon in context;

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1. Introduction

Alberta Environment and Parks retained Hatch to complete a flood hazard study for a reach of the Sheep River (the Study). The primary purpose of the Study is to assess and identify river and flood hazards along an approximately 60-kilometer-long reach of the Sheep River, and a 35-kilometer-long reach of Threepoint Creek in the Municipal District of Foothills No. 31. This includes the Towns of Black Diamond, Turner Valley, Okotoks and the Hamlet of Millarville. Figure 1-1 shows the extent of the study area and its location within the province of Alberta.

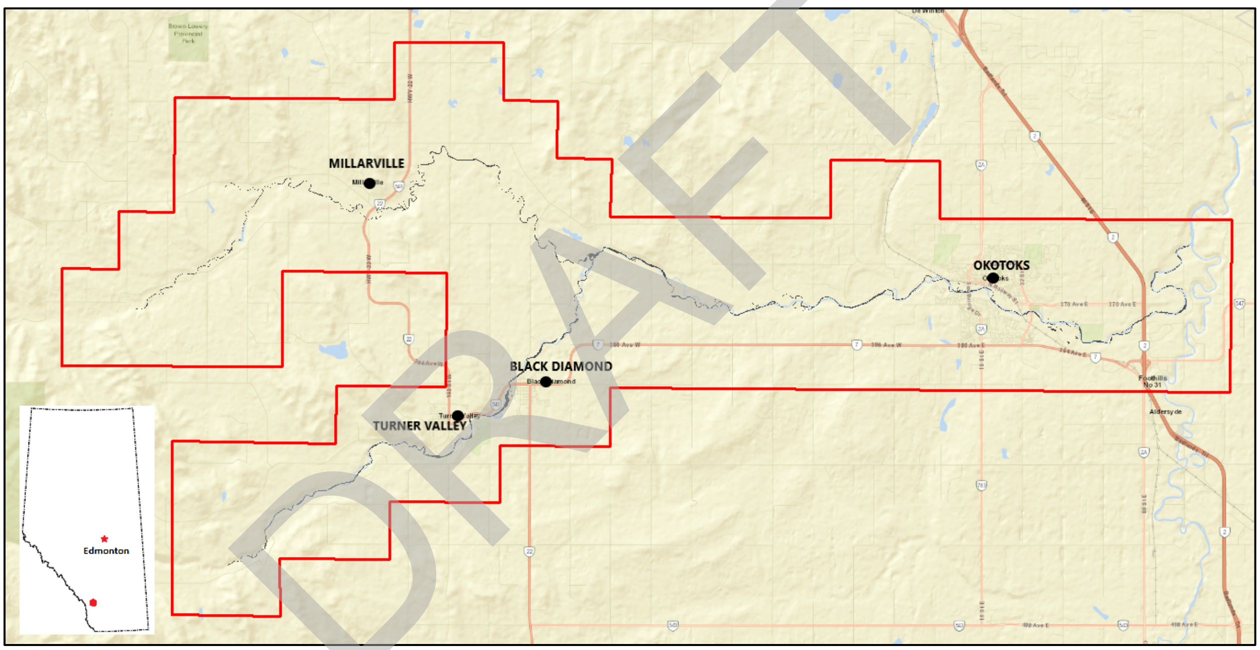

Figure 1-1 – Sheep River Flood Hazard Study Area and the location of the project in the province

Like other flood hazard studies undertaken by the Province, the Sheep River Study includes multiple components and deliverables. The study includes the following components:

- Survey and Base Data Collection Report (Previously completed by AFW)- Volume 1;
- Hydraulic Model Creation, Calibration, and Open Water Flood Inundation Map Production Report - Volume 2;
- Open Water Flood Hazard Identification Report – Volume 3;
- Governing Design Flood Hazard Mapping Report – Volume 4 (not required for this study, since open water flood conditions govern for this reach);

- Flood Risk Assessment and Inventory Report – Volume 5; and
- Channel Stability Investigation Report – Volume 6.

This document represents Volume 2 and provides details of the Sheep River Hazard Study hydraulic model creation and calibration, as well as the preparation of inundation mapping. This work will support the future flood risk assessment components of the study. The tasks associated with this component include a description of the flooding history, description of river and valley features, model setup, model calibration, sensitivity analysis, generation of open water flood frequency profiles, and preparation of inundation mapping.

1.1 Study Objectives

As described by AEP, "the study will be completed under the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the provincial government, local authorities, and the public."

The project was initiated in 2015 by consultant Amec Foster Wheeler (AFW). A portion of the work was completed prior to the contract ending in 2017. Hatch was retained to complete the remainder of the study.

1.2 Study Area & Reach

Figure 1-1 summarizes the study area. As shown, the downstream end of this study reach is the confluence of Highwood River and Sheep River downstream of the Town of Okotoks. The upstream limit of the study reach is located approximately 60 km upstream of the Highwood confluence, just to the west of section 20-19-3-W5M. This is approximately 8 km southwest of Turner Valley. The Threepoint Creek study reach extends from its confluence with the Sheep River, 35 km upstream, to its confluence with Ware Creek (just to the northwest quarter of 23-20-04-W5M).

The 60 km Sheep River study reach includes the key points listed below. The stationing shown is listed in kilometers, as measured from the downstream end of the study reach and extending upstream.

- Confluence with the Highwood River - km 0.0
- Highway 2 Bridge - km 6.98
- Town of Okotoks – between km 11.25 and km 17.45
- Confluence with Threepoint Creek - km 34.52
- Town of Black Diamond - between km 39.90 and km 42.50
- Town of Turner Valley - between km 43.90 and km 48.20

The 35 km Threepoint Creek study reach includes the key points listed below.

- Confluence with the Sheep River - km 0.0
- 192 Street W Bridge Crossing (in the vicinity of the Millarville Race Track) - km 11.36

- Highway 22 Bridge Crossing (in the vicinity of the community of Millarville) - km 20.20
- Confluence with Fisher Creek - km 26.30
- Confluence with Ware Creek and upstream end of study area - km 34.79

2. Flood History

Both the Sheep River and Threepoint Creek have experienced several flood events over the course of their historical record. The flood history of these rivers was compiled by AFW as a part of an earlier scope of work, and Hatch has reviewed and concurs with the summary provided. The structure and information provided by AFW has been primarily retained in this report, with the addition of some small additions/modifications for clarity.

The focus of this study and the flood history review has been on the occurrence and impact of open water flood events. Past experience has shown that ice related flood events are not a significant concern for any of the reaches in this study. This was confirmed during the flood history review.

2.1 Available Data

The flood history for each river reach was compiled by reviewing data from a number of different sources, including:

- The Black Diamond Turner Valley Flood Risk Mapping Study (Klohn-Leonoff, 1992) [ref. 5];
- The Okotoks Flood Risk Mapping Study (Alberta Environment, 1996, revised 2013) [ref. 6];
- Previous engineering flood and erosion evaluations conducted on behalf of the MD of Foothills by Amec Foster Wheeler subsequent to the 2005, 2008, and 2013 floods;
- The MD of Foothills, Town of Okotoks, Town of Turner Valley, and Town of Black Diamond;
- Community Newspaper Archives – Okotoks Western Wheel;
- Local Library – Okotoks; and
- The Alberta Transportation (AT) database. The database was examined for the characteristics of all of the major bridges on Sheep River and Threepoint Creek. The Hydrotechnical Information System (HIS) is AT's primary tool to access the flood observation documents, hydrotechnical file histories and summaries, inspection and survey data, and stream profiles based on digital elevation map (DEM) data.

2.2 Open Water Floods

According to an Alberta Environment 1996 report [Ref. 6], major floods on the Sheep River basin are typically generated when moist air from the southeast moves in and stalls over the western foothills and mountain regions. This can produce very high rainfall intensities in this area, leading to major floods on the Sheep and Threepoint basins.

Flood events have been observed and recorded on the Sheep River and on Threepoint Creek on several different occasions in the recent past. The following sections provide historical flood information on these two watercourses.

There are three active Water Survey Canada (WSC) gauges in the study area as listed in Table 2-1. The locations of these gauges are shown in Figure 2-1.

Table 2-1 – Water Survey Canada Gauges

Gauge	Location	Years
05BL014	Sheep River at Black Diamond	1909 - Present
05BL012	Sheep River at Okotoks,	1908 - Present
05BL013	Threepoint Creek near Millarville	1908 - Present
05BL020	Sheep River Near Aldersyde	1957 - 1965
05BL018	Sheep River at Buck Ranch	1950 - 1969

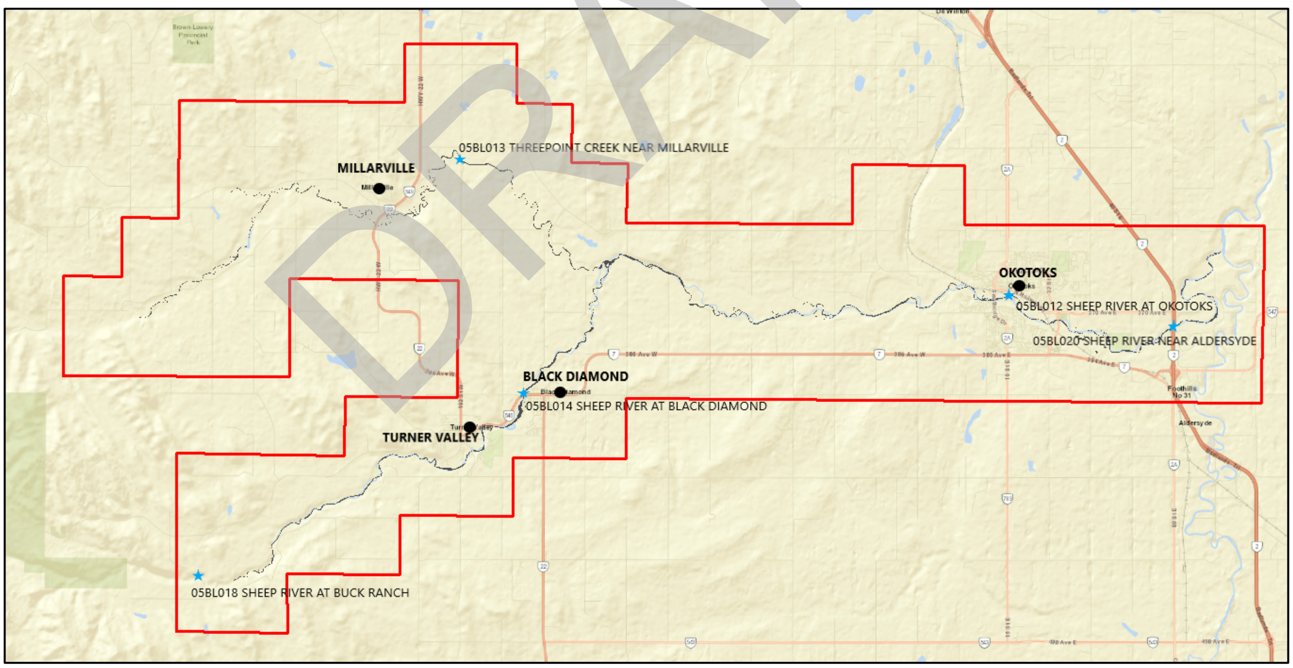

Figure 2-1 – Location of WSC gauges relative to each population centre and the study area

2.2.1 *Sheep River Historic & Observed Floods*

Records have been collected on the Sheep River at Black Diamond and Turner Valley since 1908, when the first gauge was installed. There is no record of severe historic open water flooding in the study area before systematic flood level recording was established in 1908.

2.2.2 *Sheep River Recent & Recorded Floods*

As noted, river flows have been recorded on the Sheep River since as early as 1908. This lengthy record was reviewed, along with Klohn-Leonoff's (1992) report for the Black Diamond and Turner Valley area and the Alberta Environment (1996) report for the Okotoks area to identify the frequency with which large flood flows have occurred. Based on this review, it is clear that communities along the Sheep River have experienced several flood events over the past century.

Figure 2-2 summarizes the annual maximum instantaneous flow recorded for Sheep River at Black Diamond. The figure is a replica of Golder's 2017 report [ref. 17], and shows that there was a 50 year period from 1917 through to 1967 in which the gauge was not operational. Table 2-2 summarizes the ten highest flood events which have occurred on the Sheep River at the Black Diamond WSC gauge (05BL014), based on maximum instantaneous flow data recorded by Environment Canada. The estimated return periods provided in the table for each flood event are based on Golder's 2017 report. Figure 2-3 and Table 2-3 summarize similar information for WSC gauge 05BL012, located on the Sheep River at Okotoks.

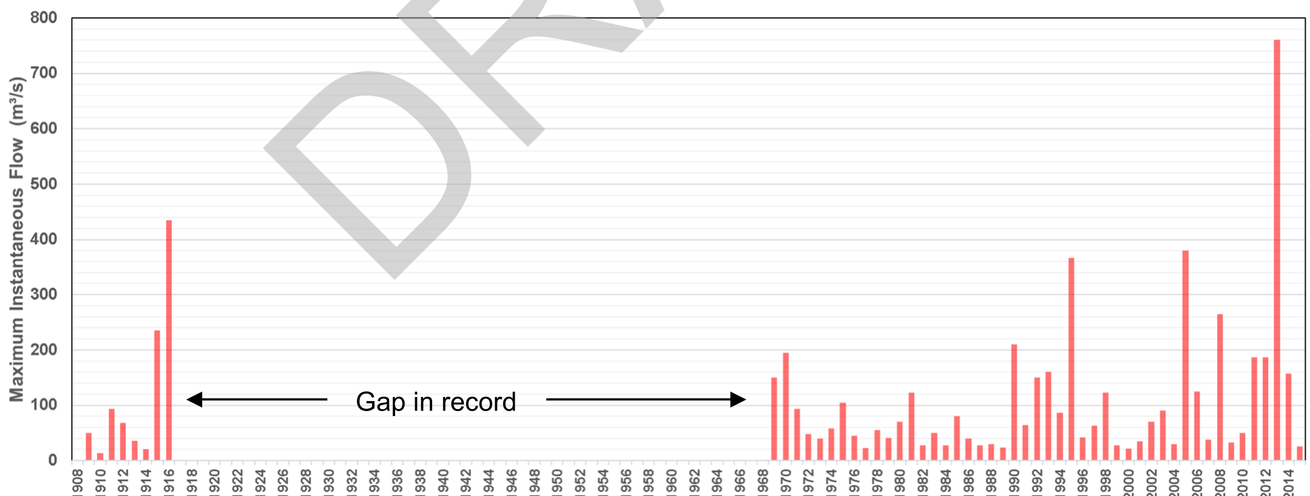

Figure 2-2 – Sheep River at Black Diamond – Maximum Instantaneous Flow (from Golder, 2017)

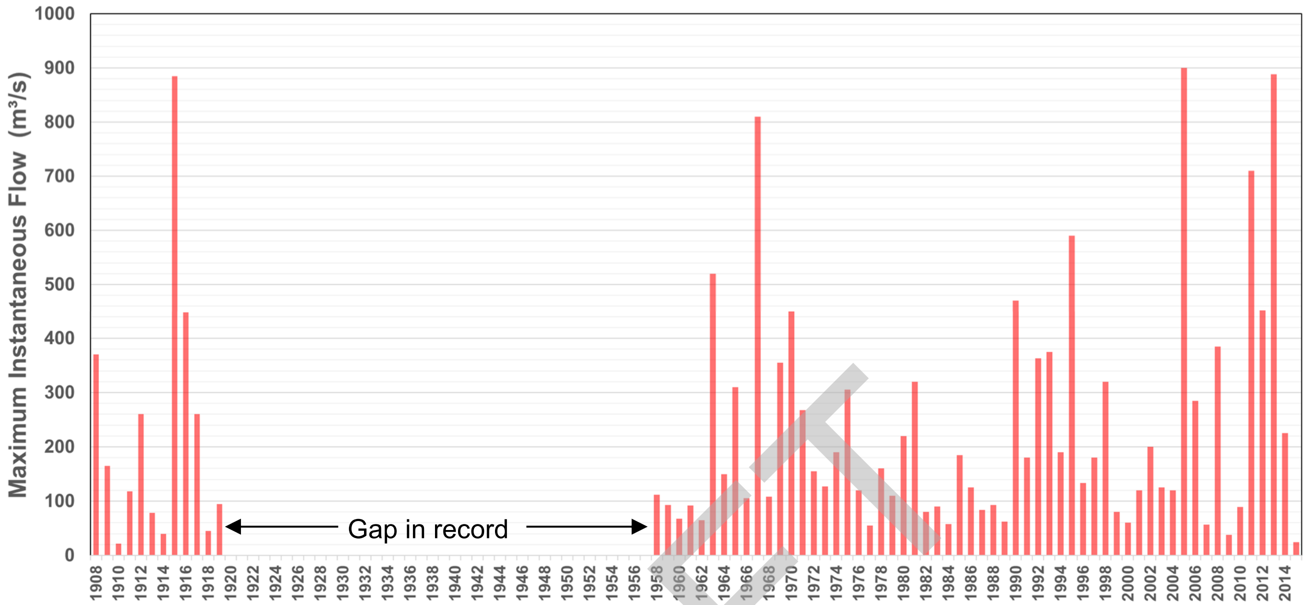

Figure 2-3 – Sheep River at Okotoks – Maximum Instantaneous Flow (from Golder, 2017)

Table 2-2 – Sheep River at Black Diamond: Ten most significant recorded/estimated flows

Year	Maximum Annual Instantaneous Flow (m^3/s)	Estimated Return Period (years)
2013	750	95
1916	431.4 (e1)	30
2005	380	23
1995	366	20
2008	259	11
1915	233.4 (e1)	10
1990	207	8
1970	195	7
2011	185	7
2012	185	7

Notes:
(1) Based on Golder (February 2017).
(2) e1 indicates maximum instantaneous discharge estimated by Golder (February 2017) based on WSC maximum daily discharge value.

Table 2-3 – Sheep River at Okotoks ten most significant recorded/estimated flow

Year	Maximum Annual Extreme (m³/s)	Estimated Return Period (years)
2013	900 (e2)	40
1915	797.5 (e1)	30
2005	771 (e1)	27
1967	724.4 (e1)	23
2011	637.7 (e1)	18
1995	525.2 (e1)	12
1963	507 (e2)	10
1990	423.3 (e1)	8
2012	406.3 (e1)	7
1970	404.5 (e1)	7

Notes:

(1) Based on Golder (February 2017) Sheep River at Okotoks (05BL012) Extended – using flows at Sheep River near Aldersyde (05BL020) from 1958 to 1965 and Sheep River at Black Diamond (05BL014) from 1969 to 2005.

(2) e1 indicates maximum instantaneous discharge estimated by Golder (February 2017) based on WSC maximum daily discharge value.

(3) e2 indicates WSC maximum daily discharge not recorded and maximum instantaneous discharge estimated by Golder (February 2017) based on review of regional streamflow gauges.

(4) Estimated average recurrence interval based on Golder (February 2017).

Significant recent floods have occurred on the Sheep River in 2013, 2005 and 2008. The largest event occurred in 2013, with a peak instantaneous discharge of 900 m3/s.

The second largest flood of the historical record occurred in 1916 – a flood with a recorded mean daily flow of 200 m³/s and a maximum instantaneous discharge of 431.4 m³/s (Table 2-2). Flood damage associated with this event was minimal, likely due to minimal development in the area at the time.

Per the Klohn-Leonoff report [ref. 5], residents of Black Diamond recalled two other events in the 1920's and 1930's that resulted in considerable bank erosion, but little to no damage. According to the same report, using correlation techniques, Alberta Environment estimated that one of the above floods had a peak discharge of approximately 770 m³/s, but notes that the WSC gauges were not active at that time. This flood would be close to a 1 in 100-year event (787 m³/s) based on the Golder hydrology report [ref. 17].

Another significant flood event occurred in 1942, which triggered the evacuation of residents of Turner Valley, but again no damage was reported in Turner Valley. Black Diamond, however, experienced some damage when a farm building was washed away, and an under-construction fish rearing pond destroyed. The magnitude of this flood is unknown, since there was no operating gauge on Sheep River.

Based on the recorded floods (Buck Ranch Gauge - 05BL018), the Black Diamond area experienced large floods in 1963 and 1967 with instantaneous peaks of 340 m^3/s and 303 m^3/s respectively. According to analysis by Alberta Environment, the 1963 flood is equivalent to a peak discharge of 366 m^3/s in Black Diamond. Applying the same proportion, the 1967 peak discharge would be 326 m^3/s. Years 1970 and 1990 also had smaller flood events with 195 m^3/s and 207 m^3/s instantaneous peaks respectively.

2.2.3 Threepoint Creek Historic & Observed Floods

Records have been collected on Threepoint Creek at Millarville since 1908, when the first gauge was installed. Unfortunately, there is no record of severe historic open water flooding in the study area before systematic flood level recording was established in 1908.

2.2.4 Threepoint Creek Recent & Recorded Floods

Figure 2-4 shows the maximum instantaneous flows per year for Threepoint Creek at Millarville. The top ten flood events on Threepoint Creek are listed in Table 2-4. According to the Millarville Residents Flood Association Website [ref. 26], the community has been impacted by floods in 1995, 2005, 2007, 2009, 2011, 2012, 2013, and 2014. It is noted that the years highlighted on this community website mismatch the flow gauge data in some years.

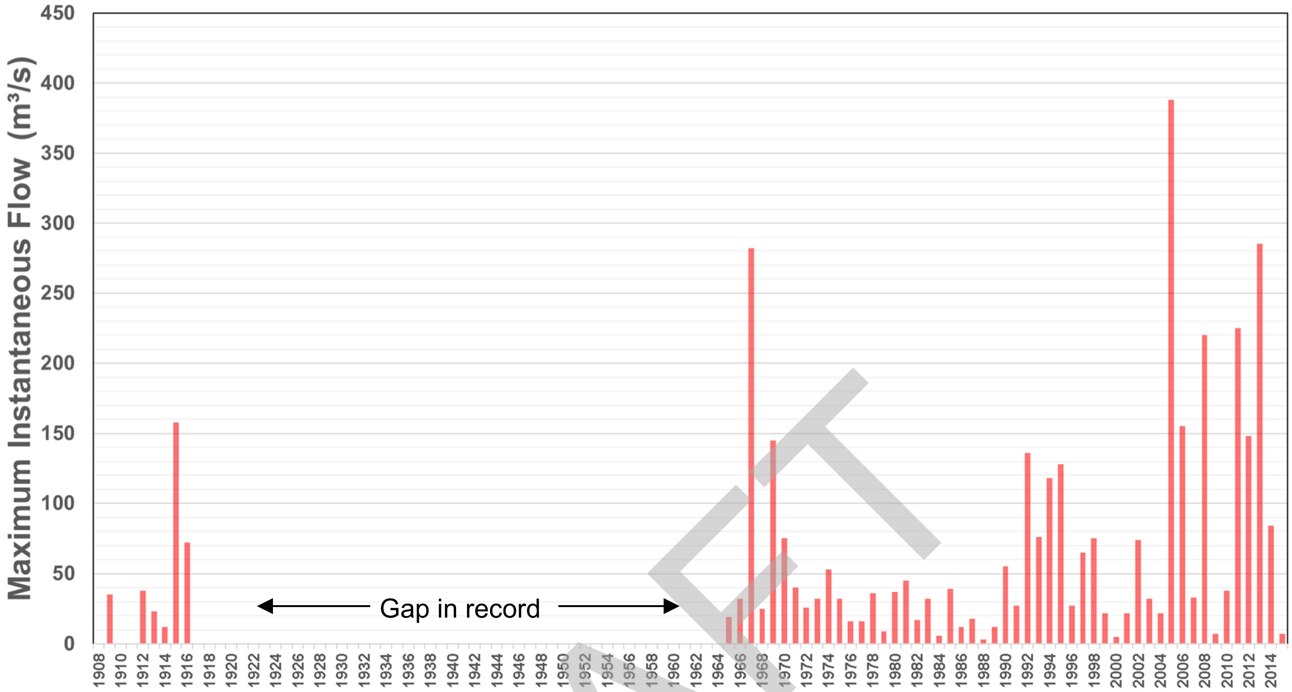

Figure 2-4 – Threepoint Creek at Millarville – Maximum Instantaneous Flow (from Golder, 2017)

Table 2-4 – Threepoint Creek at Millarville: Ten most significant recorded/estimated flows

Year	Maximum Annual Extreme	Estimated return period
2005	389	60
2013	285	30
1967	283	30
2011	226	19
2008	220	18
1915	159	10
2006	157	10
2012	148	9
1969	146	9
1992	138.2	8

2.3 Ice Jam Floods

Based on the Klohn Leonoff report, there are no reports of flooding in any of the either Turner Valley or Black Diamond due to ice jams during either formation or spring break-up. In addition, there was no mention of any historical incidents of ice jam flooding at any stakeholder meetings held with these communities, or the MD, or Okotoks. Therefore, flood vulnerability within these communities appears to be dominated by open water flood events.

2.4 Flood Damage

Appendix A provides a summary of historical flood damages that have been recorded along both the Sheep River and Threepoint Creek. These damage summaries include lists of aerial photographs that were taken during past flood events to document the extent of inundation, the extent of damage experienced at local bridge crossings, and incidences of scour and bank erosion that may have occurred. In these tables, damages are presented separately for the 2013 flood year given that it is the most severe event in recent history.

- Table A1: Sheep River Flood Damages and Repairs for Years Other than 2013 in the MD of Foothills
- Table A2: Sheep River Bridge Flood Damages and Construction Dates for Years Other than 2013
- Table A3: Summary of Sheep River 2013 Flood Damages and Repairs in the MD of Foothills and the Towns of Okotoks, Turner Valley, and Black Diamond
- Table A4: Sheep River 2013 Bridge Flood Damages
- Table A5: Threepoint Creek Flood Damages and Repairs for Years Other than 2013
- Table A6: Threepoint Creek Bridge Flood Damages and Construction Dates for Years Other than 2013
- Table A7: Summary of Threepoint Creek 2013 Flood Damages
- Table A8: Threepoint Creek 2013 Bridge Flood Damages

3. Available Data

Data for this study has been obtained from several sources including AEP, stakeholders, and government websites. This section summarizes the information available and used for this study.

3.1 Hydrology Summary

Golder Associates [ref. 17] has completed a hydrology assessment for the area and the final report of this assessment has been provided to Hatch by AEP. Hatch has reviewed this report and adopted flood values for the hydraulic model based on this recent study.

3.1.1 Hydraulic Model Flow Overview

Figure 3-1 shows the study area, the location of the WSC gauges, the location of the nodes in the Golder hydrology assessment, and the approximate reaches in the hydraulic model where each adopted nodal flow was applied. Table 3-1 shows the flow data, locations, and additional reaches' flow in more detail.

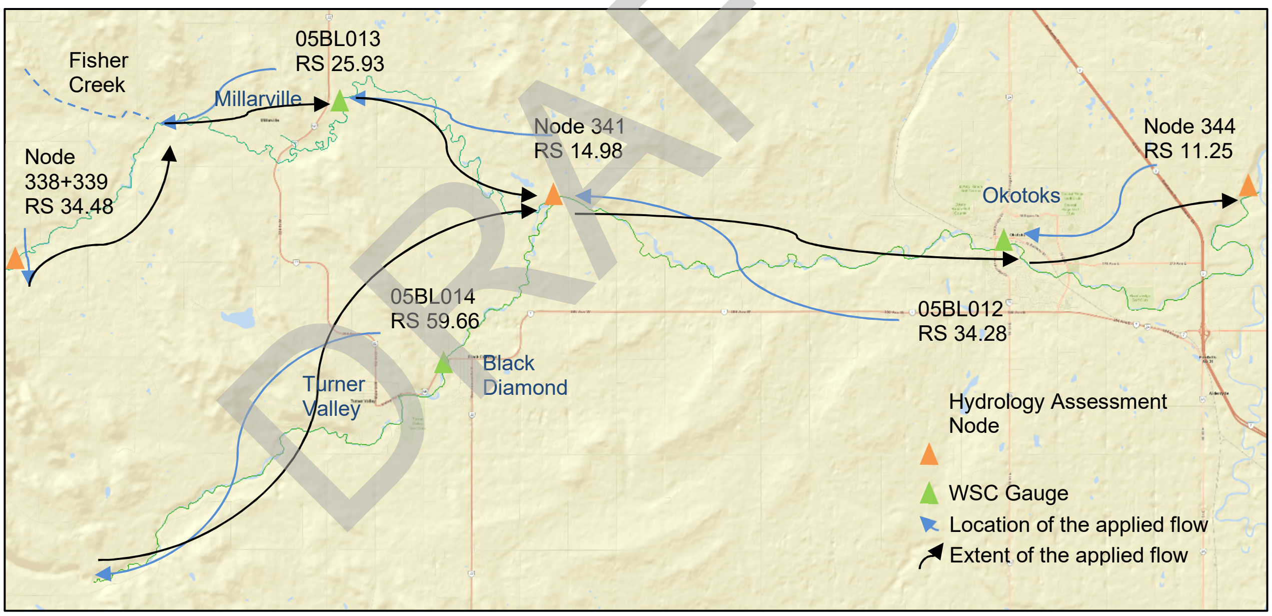

Figure 3-1 – Extent of the study area and location of nodes and WSC gauges

As shown in Figure 3-1 the flows were applied to the reach as follows:

- The Node 344 flow estimates were assumed to apply over the full reach of the Sheep River downstream of the Okotoks community. This is a conservative approach and assumes that all downstream tributary flow in this reach enters the river immediately downstream of the Okotoks WSC gauge.
- The Okotoks gauge flow estimates (05BL012) were assumed to apply on the Sheep River over a reach extending from its confluence with Threepoint Creek down to the

gauge location at the downstream end of Okotoks. Flow estimates in this reach therefore represent the combined flows of the Sheep River and Threepoint Creek upstream at their confluence, as well as any tributary flow entering the river downstream of the confluence.

- The Black Diamond WSC gauge flow estimates (which were estimated based on WSC gauge 05BL014) for the Sheep River were applied over a reach extending from the upstream boundary of the model down to the Threepoint confluence. Flows were assumed to be constant over this full reach, and this was considered to be acceptable given the relatively small tributary area that exists downstream of the WSC gauge.
- On Threepoint Creek, Node 341 flow estimates were applied over a reach extending from a point just downstream of the 05BL013 WSC gauge down to it's confluence with the Sheep River. Flows on this reach therefore represent a combination of the WSC gauged flows and all overland runoff originating from catchment areas located between the gauge and the confluence.
- The WSC gauge 05BL013 flow estimates were applied over for a reach extending from the confluence of Fisher Creek down to the WSC gauge location itself.
- Finally, for Threepoint Creek, upstream of its confluence with Fisher Creek, the flow was set to the combined total of Nodes 338 and 339 (as estimated in the Golder study). These two nodes represent the total inflow that would be expected at the model boundary – inflow that would be contributed by both Threepoint Creek and Ware Creek. Both basins have a very similar basin size, length, and slope, and therefore it is reasonable to assume that peak flows will occur coincidentally on these two sub-catchments.

3.1.2 *Okotoks North of CPR*

The model reach including downtown Okotoks and the north side of the CPR embankment is a key part of the hydraulic model. Although the CPR embankment has protected Okotoks during many recent and past flood events, it has not been designed, built, or maintained as a dyke. Therefore, as directed within the terms of reference, the railway embankment was not considered to be an impervious flood protection structure. When reviewing the results of an early 1D HEC-RAS model run, it was noted that the hydraulic flow regime in this area can be very complex for larger flood magnitudes (for 75-year return period floods or larger). During large flood events, flow near the upstream end of the townsite will begin to run through the town to the north of the CPR embankment, circumventing this structure. To provide additional insight into the complicated flow split that can arise, a two-dimensional model was developed for the Okotoks area. The model was developed using a modified DEM that merged the available bathymetric data with the LiDAR topographic data. The resulting DEM was used to develop a mesh for the HEC-RAS2D model, and the model was run for a variety of flood magnitudes. The results provided additional insight into the expected flow behavior on the north side of the CPR embankment. After a review of these results, and discussion with AEP, it was agreed that the best way to represent hydraulic conditions in this area would be to add a new tributary stream to represent flow on the north side. This stream was dendritic in nature and re-joined the main Sheep River channel just downstream of the town. More information on the hydraulics of this reach is provided in Section 4. This section summarizes flow information adopted for this new reach.

The 2013 flood did not overtop the CPR embankment, however, water was able to enter the downtown area though unblocked culverts and storm outfalls that were hydraulically connected to the river, through a ditch system that is connected to the river to the north of the railway embankment, and also indirectly through seepage that likely occurred through the railway embankment. Thus, there are two sources of flow to the north side of the CPR embankment that must be considered: overtopping flow and seepage/through flow. The latter includes the seepage flow and flow through the culverts and storm outfalls. Considering each of these flow sources:

- Overtopping flow: Overtopping flow was estimated based on the results of the 2D modelling. The model results showed that overtopping would begin at approximately the 75-year flood event, and that overtopping flows would amount to approximately 5% of the total river flow. For the 1000-year event this corresponds to 121.5 m^3/s. The flow was prorated for smaller flood events up to the 75-year event.
- Seepage flow: To calculate seepage flow it was assumed the CPR embankment is a semi-pervious structure with a hydraulic conductivity of 10^{-2} to 10^{-5}. The highest hydraulic gradient expected is for the area where the water level difference between the water in the river and the water in the ditch along the CPR is maximized. Assuming the length of the flow path will be the shortest straight line across the embankment, the expected unit flow using the Dupuit equation would be:

$$q = k \times \frac{(h_1{}^2 - h_2{}^2)}{l}$$

  Application of this equation results in very small flow amounts which could be considered to be insignificant. Assuming a constant flow rate along the full 3,500 m of the CPR embankment, the resulting flow will be in order of 0.01 m^3/s. Increasing the hydraulic connectivity even to that of well sorted sand and gravel would result in a flow of only 1 m^3/s, which is still negligible compared to the magnitude of the overtopping flow.
- Outflow and culvert flow: There are three storm outfalls equipped with flap gates. As a conservative approach, it was assumed the flap gates would not function or would not be in place. The expected flow through these pipes for a river level equivalent to the 1000-year flood level and a dry condition on the other side (worst case scenario) is expected to be about a combined total of 17.1 m^3/s for all three outfalls.

In order to keep the north tributary stream "wet" during all model simulations and maintain a conservative approach, it was assumed that during the 1000-year event the total flow north of the CPR embankment would be the sum of the above components (overtopping flow plus the culvert inflow), which totals 138.6 m^3/s . Flow for other events was calculated similarly. Since these estimated flows were calculated conservatively, and because they represent such a small percentage of the main channel flow, the flow in the Sheep River main channel was maintained at the estimates put forth by Golder (i.e. was not reduced by these amounts) The resulting flow is shown in Table 3-1, rounded to the nearest integer.

3.1.3 Hydraulic Model Flows

Table 3-1 shows the maximum annual instantaneous discharge adopted for different return periods. These flows were applied to the hydraulic model at the locations described in Section 3.1.1. As noted earlier, for 50-year events and smaller, the 2D model indicated that flows in Okotoks to the north of the CPR embankment would be negligible. However, some flow was added as an input to the model for these lower return period scenarios in order to maintain model stability and allow it to run. The results however were not included in any of the inundation mapping series.

Table 3-1 – Annual maximum instantaneous discharge values applied to the model

Estimated Average Recurrence Interval (Years)	Sheep River at Black Diamond (05BL014)	Sheep River at Okotoks (05BL012)	Sheep River at Mouth (Node 344)	Threepoint + Ware Creek (Nodes 338 and 339)	Threepoint Creek at Millarville (05BL013)	Threepoint Creek at Mouth (Node 341)	Okotoks North of CPR
2	61.5	158	166	26.8	39.8	48.7	0.1
5	148	338	355	58.1	98.2	118	0.1
10	240	504	530	88.2	158	192	0.1
20	361	701	737	125.3	235	290	0.1
35	484	886	931	161.2	312	387	0.1
50	576	1020	1070	187.4	368	457	0.1
75	693	1180	1240	221	439	545	4
100	787	1300	1370	246	495	616	14
200	1050	1640	1720	317	650	810	18
350	1310	1950	2050	386	803	1000	52
500	1500	2180	2290	436	914	1140	85
750	1720	2420	2540	496	1040	1300	112
1000	1900	2620	2750	543	1140	1430	139

3.2 DTM Data

Digital terrain model data was provided by AEP. LiDAR information was gathered in 2016 by AEP with a 0.5 m spacing. The horizontal accuracy of the LiDAR information at this resolution is generally within 20 cm and the vertical accuracy for bare earth information is about 10 to 20 cm.

All coordinate information and mapping is in three-degree Transverse Mercator (3TM) plane coordinates based on the Canadian Spatial Reference System 1983 North American Datum (NAD83 [CSRS]); vertical control is referenced to Canadian Geodetic Vertical Datum of 1928 (CGVD28). The DTM data was augmented with survey data to create representative river cross sections as described in section 5.

3.3 Aerial Imagery

The aerial imagery has been provided by AEP. There are two datasets available for the aerial imagery. The most recent dataset was gathered as a part of previous work completed by AFW and was finalized in 2016. AEP also provided an older dataset collected in the 1950's which was used to support other study components..

The most recent dataset (2016) has the following attributes as described in the Survey report for this project [ref. 2]

- Date of Acquisition: April 20, 2016.
- Camera: Vexcel UltraCAM XP.
- Image Resolution: 30cm.
- Image Bands: RGB, RGBI, Bit Depth: 8, No Data Value: 0.
- Format: .ecw, .tiff.
- Projection: Alberta 3TM_Ref_Meridian_114W.
- Horizontal and Vertical Datum: NAD 83 CSRS, CVGD28.

3.4 Survey Data

Channel cross section survey data was collected and prepared by AFW and provided by AEP for use in this study. AFW's survey report has been finalized and is included in volume 1 of this study report. It was combined with the DTM data as part of the hydraulic model creation, as described in Section 5.

3.5 Existing Models

A draft HEC-RAS 1D model was previously prepared by AFW, and this model was provided by AEP for the reach. This draft model formed the starting point for the current analysis. Klohn Leonoff also prepared a HEC-2 model of the reach in 1992. This model was not utilized in the current study however, as it was superceded by the more current AFW model.

3.6 Highwater Marks

AEP provided high water mark (HWM) reports and AFW also collected some data associated with the passage of the 2013 flood. Table 3-2 and Table 3-3 summarize the number of HWM points available from AEP and AFW respectively separated by reach and year.

Table 3-2 – Number of high water mark points gathered by AEP during historical flood events

Year	Sheep River	Threepoint Creek
2013	31	
2011	5	
2008	5	2
2005 (1)	64	22
2005 (2)	45	
1995	30	
1992		27
1990	13	
1981	15	
1963	16	

Table 3-3 – Number of high water mark points gathered by AFW

Year	Sheep River	Threepoint Creek
2013	51	30

3.7 Gauge Data & Rating Curves

AFW previously gathered the gauge data and rating curve information available for this study. This information is summarized below.

Table 3-4 – Gauge data for the study area (adopted from AFW report [ref. 27])

Station No.	Station Name	Years of Record	Current Rating Curve Version and Year It Became Operational	Comments
05BL012	Sheep River at Okotoks	1908 to 1920 1965 to 1968 2006-present	#7 2014	Current rating curve is Version #7, indicating a relatively stable and steady gauge location. Historical curves very close to current curve. Station damaged during 2013 flood and monitoring equipment was not operational during flood peak.
05BL013	Threepoint Creek near Millarville	1908 to 1916 1965-present	#14 2009	Current rating curve is Version #14, indicating relatively dynamic channel conditions. Rating curve lowered 2.185 m due to channel degradation resulting from 2005 flood.
05BL014	Sheep River at Black Diamond	1908 to - 1916 1968-present	#18 2014	Current rating curve is Version #18 curve, indicating relatively dynamic channel conditions. Station destroyed during 2013 flood and 2013 flood peak was not recorded. Station moved downstream of HWY 22 Bridge after 2013 flood. Previous rating curves do not apply to the current location. At the previous location, datum lowered 1 m in 1997, likely due to channel changes resulting from the 1995 flood.

3.8 Flood Photography

AEP provided aerial flood photography for the 2013 (Post flood and near peak), 2005, and 1995 flood events. The spatial extent of coverage varies from year to year:

- The 2013 post flood dataset covers both Threepoint Creek and Sheep River with Turner Valley as the upstream boundary of Sheep River.
- The 2013 near peak dataset only covers the Sheep River
- The 2005 Flood covers both reaches, but under a post flood condition (i.e. off peak)
- The 1995 Flood dataset is also only available for the post-peak period in the Okotoks and Black Diamond Areas

AEP provided 2013 near-peak aerial flood photography on the Sheep River, extending downstream from Turner Valley to the Highwood River confluence, including Black Diamond/Turner Valley and Okotoks (collected 24 June 2013). This flood photography did not extend to Threepoint Creek.

4. River & Valley Features

The following general description has been prepared based on the channel stability review performed as a part of this study, and on previous information contained in Alberta Environment (1996), Klohn-Leonoff (1992), and Golder Associates (2017).

4.1 General Basin and Valley Description

The Sheep River basin's effective drainage area is 1,570 km^2 at its confluence with the Highwood River. Its headwaters originate in the Misty Mountain Range at an elevation of 3,225 m, and the basin extends eastward to the confluence with Highwood River where the mean basin elevation drops to about 983 m. The basin is comprised of two large sub-basins: Threepoint Creek sub-basin and the Upper Sheep River sub-basin. Threepoint Creek, which enters Sheep River 16 km west of Okotoks, is a major tributary that contributes up to half of the flood discharge to Sheep River at the confluence of these two streams.

The Sheep River basin is long and narrow can be divided into three distinct zones: mountain, foothills, and prairie.

- Mountain Zone: High mountain runoff originates primarily from the Upper Sheep River basin. This portion of the basin is defined as being mountainous and consists of bedrock talus slopes, rock slides, and colluvial deposits. It is treed except where soil instability inhibits growth.
- Foothills Zone: The foothill and prairie portions of this zone are composed of cordilleran tills with alluvial and colluvial deposits
- Prairie Zone: The prairie basin is the most downstream portion of the catchment and covers the region downstream of the Sheep River/Threepoint Creek confluence. Much of this basin area has been cleared for grazing or agricultural use, but some of its steeper slopes remain tree covered.

Upstream of Turner Valley, the Sheep River is located within a relatively narrow, incised, stream-cut valley. The valley is approximately 150 m wide at the top and 100 m wide at the bottom, and the average depth is about 20 m. Downstream of Turner Valley, the valley widens significantly. In this reach, the valley has an average width of approximately 1,000 m at the top and is between 150 m and 800 m wide at the bottom. The average valley depth is approximately 25 m. (Klohn-Leonoff (1992))

At the confluence of Threepoint Creek, the valley and floodplain can reach widths of up to 1,600 m, and this valley width can become fully or partially mobilized during floods events, depending on their magnitude. Downstream of the confluence, the river valley remains wide (400 to 1,600 m widths). This channel planform persists down to a point just downstream of the Town of Okotoks, where the valley narrows and the river deepens. The river valley is only about 600 m wide on average in this reach, and the river remains narrow right up to its confluence with the Highwood River.

Threepoint Creek has three tributaries: Upper Threepoint Creek, Ware Creek, and Fisher Creek. All three tributaries represent mountain catchments with narrow valleys. The Threepoint Creek valley downstream of Fisher Creek is very similar to that of Sheep River downstream of Turner Valley.

The fluvial morphology of the river has been generated through downcutting and erosion processes, and as a result the Sheep River has created a number of distinct terraces. These terraces are remnants of established floodplains that were left exposed after the river had changed course or cut through it's underlying deposits to form a new channel and floodplain. From the information available, this process may be continuing, albeit slowly at the present time. There are several terraces evident within this river reach – some fairly continuous, some built-up, and others mature and well pronounced.

Cross section and rating curve comparisons in these same reaches over several decades (1992-2016 and 1992-2016) indicate a dynamic channel environment that has responded to large flow events with lateral bank erosion and channel downcutting in places followed by deposition and aggradation between large flow events.

4.2 Channel Characteristics

The river channel is relatively steep and straight in the upper reaches. The nature of the channel changes downstream of the town of Turner Valley on the Sheep River, and downstream of Millarville on Threepoint Creek. The lower reach is less steep and as a result the river planform is more sinuous, and the meandering river creates a larger valley.

Most of the river channel substrate consists of cobbles to fine sand with frequent deposition of sediments and gravel beds along the river. This results in a very active bed, and dynamic changes can significantly change the active river channel from one flood to another.

4.3 Floodplain Characteristics

Most of the flood plain on the upper reach is vegetated with trees and ranchlands. Moving toward the lower reach, some developments and some farmlands are present as well, however, most of the floodplain on the lower reach is still covered with vegetation including trees, shrubs and grass.

4.4 Bridges, Culverts & Weirs

There are several crossings over the Sheep River and Threepoint Creek located along the study reach. These crossings are summarized in Table 4-1 below.

Table 4-1 – List of crossing for the study reach

River	River Station (km)	Structure	Description	Bottom Chord Elevation (m)
Threepoint Creek	32.38	Bridge	HWY 204	1253.85
Threepoint Creek	19.97	Bridge / Culvert	HWY 22 - Millarville	1186.75
Threepoint Creek	11.12	Bridge	192 St W	1164.07
Threepoint Creek	4.31	Ford	Township Road 210	N/A
Sheep River	46.08	Bridge	Decalta Road	1200.37
Sheep River	42.22	Bridge	HWY 22 - Black Diamond	1176.23
Sheep River	15.89	Bridge	HWY 2A (south-bound)	1055.80
Sheep River	15.88	Bridge	HWY 2A north-bound)	1056.21
Sheep River	15.36	Bridge	Okotoks Pedestrian	1053.14
Sheep River	13.13	Bridge	CPR	1054.70
Sheep River	12.74	Bridge	32 Street	1045.55
Sheep River	7.01	Bridge	HWY 2	1020.63

4.5 Flood Control Structures

Dedicated flood control structures are those that were specifically identified by stakeholders, including the MD of Foothills and the Towns of Okotoks, Black Diamond, and Turner Valley. The dedicated flood control structures are listed in Table 4-2 for Sheep River. There is no dedicated flood control structure for Threepoint Creek.

Table 4-2 – List of dedicated flood control structures for Sheep River

River Station		Description
Start	End	
36.53	37.25	128 Street (E Bank Sheep River) berm constructed at location where channel avulsion occurred during 2013 flood
41.36	41.94	Black Diamond Dike Downstream of HWY 22 Bridge (SE Bank Sheep River)
42.24	42.62	Black Diamond Dike Upstream of HWY 22 Bridge (E Bank Sheep River)
43.66	43.93	Black Diamond Well No. 3 Dike (N Bank Sheep River) constructed to protect groundwater water supply well
45.26	46.03	Turner Valley Dike Downstream of Decalta Road Bridge (Alberta Culture flood protection structure to protect Gas Plant) (NW Bank Sheep River)
46.04	46.13	Turner Valley Dike at Decalta Road Bridge (S Bank Sheep River)
46.08	46.48	Turner Valley Dike Upstream of Decalta Road Bridge (NW Bank Sheep River)

Table 4-3 summarizes two additional flood control structures identified by AFW during the field visit.

Table 4-3 – Other flood control structures

River Station		Description
Start	End	
9.60	10.18	River’s Edge Golf Club Berm (N Bank Sheep River)
10.82	11.80	Riverbend Campground Berm (N Bank Sheep River)

4.6 Other Features

Erosion protection structures, such as riprap bank revetments, were identified based on AFW’s previous work for the MD of Foothills and survey crew observations. These structures are intended to stabilize streambank slopes and their top elevation is typically at or below the top of the bank. Information has been documented for each erosion protection structure, including their start and end points and photographs showing the structure (contained in the Study File for this project). Erosion protection structures are listed in Table 4-4 and Table 4-5. Erosion protection structures are located at areas of high channel instability and protect infrastructure.

Table 4-4 – Sheep River Erosion Control Structures

River Station (km)		Description
Start	End	
7.49	7.91	Country Lane RV (S Bank Sheep River)
12.58	12.93	32 Street Bridge Okotoks (N Bank Sheep River)
14.11	14.65	Okotoks Cimarron Slope (S Bank Sheep River)
14.77	15.36	Okotoks between Centre and Lineham Aves (N Bank Sheep River)
17.11	17.41	CP Rail West side of Okotoks (N Bank Sheep River)
37.02	37.14	128 Street Frishke Residence (W Bank Sheep River)
41.06	41.14	Near Black Diamond Adam's Site (W Bank Sheep River)
42.09	42.15	Near Black Diamond HWY 22 Site (W Bank Sheep River)
42.65	42.86	Near Black Diamond Upstream of Black Diamond Site (W Bank Sheep River)
44.07	44.34	HWY 22 between Black Diamond and Turner Valley (N Bank Sheep River)

Table 4-5 – Threepoint Creek Erosion Control Structures

River Station (km)		Description
Start	End	
5.21	5.47	338 Avenue (S Bank Threepoint Creek)
11.57	12.03	Racetrack/Gaudet (N and E Banks Threepoint Creek)
14.81	14.95	208 Street (N Bank Threepoint Creek)
20.19	20.58	Stack and Third (SW and E Banks Threepoint Creek)
22.03	22.17	Millarville (SW Bank Threepoint Creek)
31.17	31.29	Beauchemin Park (SE Bank Threepoint Creek)

5. Model Construction

The hydraulic model developed for a study reach is the cornerstone of any river hazard study. The goal of this component of the project is the construction of a robust hydraulic model that can be used to assess the impact of different flood events on the area along the study reach.

5.1 HEC-RAS Program

The HEC-RAS program (Version 5.0.3) was used as the software platform for developing the one-dimensional (1D) hydraulic models in the study area. HEC-RAS was developed by the U.S. Army Corps of Engineers to simulate the flow of water through systems of open channels and to compute water surface profiles through single or networked channel reaches. HEC-RAS is capable of simulating steady and unsteady flow conditions. The program can be used to calculate water surface profiles for gradually varied flow. The program is capable of calculating the water surface profiles associated with subcritical, supercritical and mixed flow regimes. In this study, the program is used in steady-state mode. The latest, official version of HEC-RAS 5.03 has the capability to perform one dimensional (1D), two dimensional (2D), and combined 1D and 2D modeling.

5.1.1 Theoretical Aspects

The methodology applied in the program is based on the solution of the one-dimensional (1D) energy equation. Energy loss due to channel friction is calculated by Manning's equation. The computational procedure in the model is the standard step method, which is a finite difference solution of the energy equation. The program solves the energy equation by iteration to attain an energy balance between each successive pair of cross sections and proceeds stepwise along the channel. Therefore, the HEC-RAS program is very suitable for calculating water surface profiles in natural channels where substantial cross section survey data is available.

The 1D and steady flow implementation of the program has the following limitations:

- The simulation is based on a 1D flow assumption, which is not as applicable for flow in rapid expansions and contractions and flow on large floodplains where flow becomes two- and three dimensional (2D or 3D).
- The assumption of steady-state flow in the reach will not account for any possible attenuation effects, and therefore results in a somewhat conservative estimate of water level.
- A rigid channel geometry was assumed. However, there may be dynamic changes that can occur during a flood event. For example, during the 2013 flood the channel changed during the flood, due to the formation of an avulsion and possible scour of sections of the river channel.
- The assumption of a 1D hydrostatic pressure distribution across the stream channel means that super elevation effects cannot be simulated.

- The total energy head is assumed to be the same across the cross section without considering the energy exchange between flows in the channel and its floodplain. Complex 2D flow patterns occur within the floodplains that would be inundated during major flood events. A constant energy head assumption across a cross section may not be reasonable in those cases.

As described below, ineffective flow areas and lateral structures are techniques used in HEC-RAS to deal with the above noted processes. However, the HEC-RAS limitations should be kept in mind when reviewing and interpreting the model results, and a certain margin of error is inherent in the limitations of the program and approach.

5.1.2 General Model Setup

All reaches in the study area are included into one integrated model setup. The model consists of 7 reaches. Table 5-1 provides some information on each of these reaches.

Table 5-1 – Summary of model reaches geometry

River	Reach	Number of Cross Sections	Average Spacing (m)
Threepoint Creek	US Millarville	141	244 m
Sheep River	US Threepoint	108	231 m
Sheep River	DS Threepoint	8	250 m
Sheep River	128 St Overflow	26	110 m
Sheep River	DS 128 Street	95	218 m
Sheep River	DS Okotoks	53	231 m
Okotoks	NorthStream	28	156 m

A preliminary model for the reach was developed by AFW. However this model required considerable modification to address a number of persistent deviations that were evident between the surveyed data and the processed cross sections. This required a complete rebuild of the model by Hatch to eliminate these deviations. In doing so, the following modifications have been made:

- Various cross sections have been extended or reoriented to completely capture the extent of inundation for the full range of flood events. For these extended or re-oriented cross sections, the underwater portion of the cross section (elevation and orientation) has been maintained as per the original bathymetric survey.

- In some instances, it was necessary to add a small number of cross sections to help refine the model. The underwater bathymetry for these cross sections was developed based on interpolation between adjacent cross sections.
- Various approaches were applied to better model flow diversions along the study reach. (e.g. Lateral structures, culverts, etc.)
- The model roughness (Manning's n) was adjusted if needed.
- Bridge coefficients and the simulation approach for estimating bridge losses was adjusted within an acceptable range
- Ineffective flow areas types and extents were adjusted.
- Reaches were modified and adjusted.
- Bank locations were adjusted.
- Model boundary information were adjusted.
- Permeant flow obstructions were added in some locations.
- Contraction and expansion coefficients for cross sections were modified if it was appropriate.

5.2 Geometric Data Base

The model geometry has been generated based on the elevation information, land use information, structures survey and drawings, and flood control structures.

5.2.1 Cross Section Data

The locations of all cross sections included in the model were selected based on the locations of the surveyed cross sections and modelling requirements. These cross sections were based on the river survey data collected in 2016 by AFW, and the 2016 LiDAR data provided by AEP. A limited number of cross sections were added to refine the model in some areas. This was required to help compare model results directly to a surveyed flood elevation, or to help facilitate the eventual production of smooth inundation polygons. These interpolated cross sections were not surveyed, but rather the underwater portion of the cross section is an interpolation of the adjacent surveyed cross sections. The surveyed cross sections have been flagged as being surveyed in the model cross section description, and the surveyed report cross section number added to the description. Interpolated sections have been flagged as being interpolated.

The total number of river cross sections used for modelling the Sheep River and Threepoint Creek study area is 431 (282 for the main reach of the Sheep River, 141 for the Threepoint Creek reach, and 8 cross sections for the 128 street overflow). In addition, a separate reach with 28 cross sections has been introduced to simulate flow within the Town of Okotoks. It should be noted that these cross sections were simply cut directly from the LiDAR topographic data – there was no wetted channel to survey in this urban environment. This reach is shown in Figure 5-1 below as the “Okotoks North Stream”.

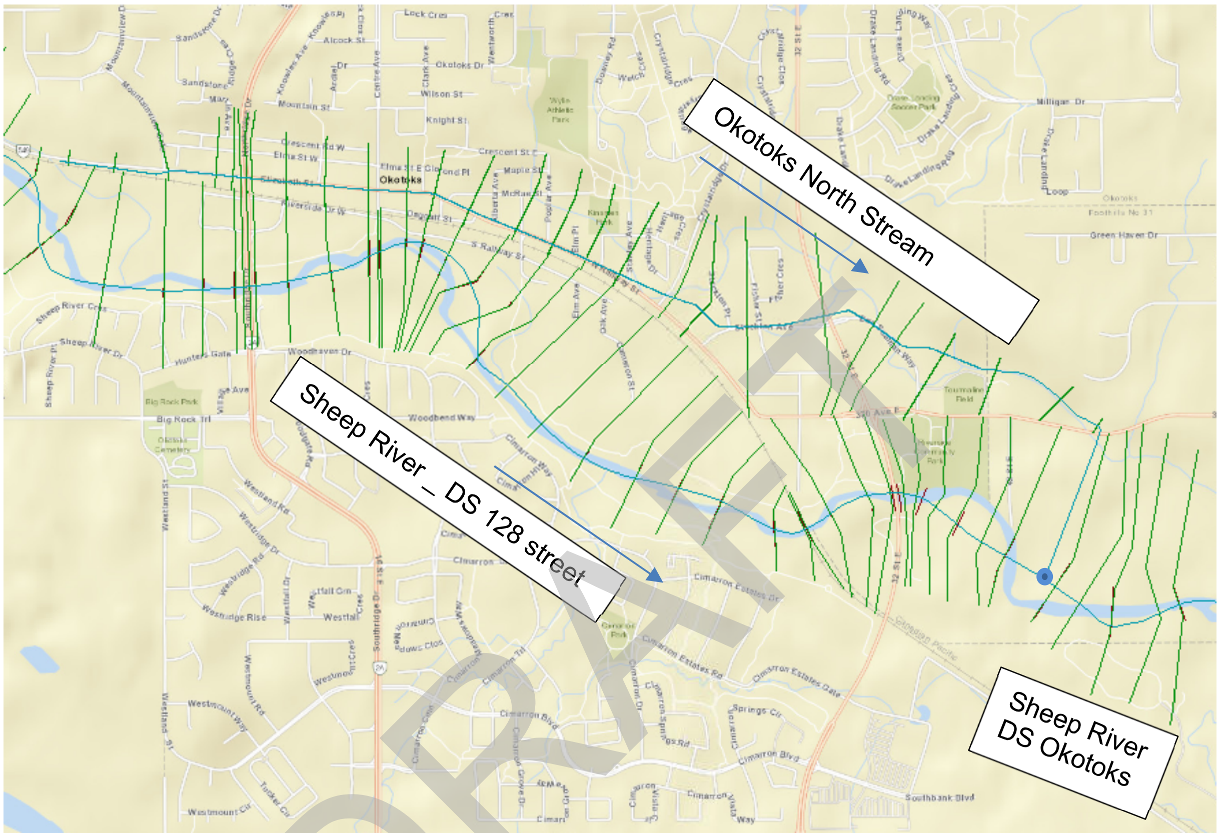

Figure 5-1 – Additional model reach in Okotoks

The model was setup to include two cross sections per bridge/culvert – one immediately upstream and one immediately downstream. The surveyed cross sections were all extended across the left and/or right floodplains using the LiDAR information that is detailed in the AFW report “Survey and Base Data Collection Report (Volume 1)”.

As per the AFW report, the locations of the surveyed cross sections were selected to capture all relevant changes in the river channel and floodplain geometry, channel bed slope, and cross section shape. The chainage of the cross sections was determined from the mapping based on the distance between cross sections, as scaled along the river thalweg. Distances for the left and right overbank areas were determined separately using right and left bank lines.

5.2.2 Bridges, Culverts &Weirs

The bridge geometries used in the HEC-RAS model for the structures listed in Table 4-1 were based on the following data:

- cross section surveys upstream and downstream of the structures by AFW in 2016
- bridge/culvert dimension surveys.
- As built drawings provided by Alberta Transportation

All existing bridges are represented in the HEC-RAS model. They include those which may not affect water levels during floods (e.g., clear span bridges with sufficient freeboard). Energy losses through the bridges include both local and friction losses. Local losses are generally the highest losses and are created by the sudden contraction and expansion caused by the bridge embankment encroachment and the reduction in the cross sectional area due to the presence of bridge piers. The other component is the increase in friction losses caused by the higher velocity flow and increased wetted perimeter of the channel within the bridge opening.

There are various methods available to calculate the energy losses associated with a bridge structure. These include:

- **Energy Equation.** Using this method, the program estimates energy loss through the bridge opening using a simple standard step technique - the identical technique used to assess loss at all other river cross sections. For the bridge opening, the cross section properties are modified to include the additional wetted perimeter and loss in conveyance area associated with the bridge piers and abutments, and then both friction and local expansion and contraction losses are estimated for these modified sections.
- **Momentum Balance.** The second method available estimates overall losses by applying a momentum balance calculation between the upstream and downstream sections of the bridge, taking into account both friction losses and drag forces associated with the bridge piers.
- **Yarnell Equation.** The Yarnell equation is an empirical equation developed to estimate the difference in water level upstream and downstream of a bridge opening. The equation was developed in 1934, based on an evaluation of hydraulic modelling test data. Coefficients can be modified in the equation to represent different numbers, types, and shapes of piers.
- **FHWA WSPRO Method.** The fourth method available also uses the energy equation to estimate overall headloss and is based on techniques embodied within the Federal Highway Administration's Water Surface PROfile (WSPRO) model.

Each method offers advantages and disadvantages, but for this modelling reach, use of the energy equation was selected and used to estimate bridge losses. It has been Hatch's experience in the past that the use of this loss calculation technique is simple, computationally robust, consistent with loss calculation in upstream and downstream reaches, generally matches observed losses very well, and requires fewer data inputs (drag coefficient, pier shape, etc). The Momentum Balance approach can lead to greater uncertainties in loss estimation if the bridge opening geometry is complex or variable in nature, and the Yarnell equation is somewhat dated, and not often applied.

All bridges within the study area are approximately perpendicular to the main channel flow direction, so that it was not necessary to include any skew in the model.

The initial values of the contraction and expansion coefficients at the bridges were selected to be 0.3 and 0.5, respectively. These are typical values listed in the HEC-RAS user manual.

5.2.3 Flood Control Structures

Flood control structures were included in the HEC-RAS model, and the cross sections include the geometry of all flood control structures noted in Table 4-2 above. Figure 5-2 illustrates an example of a cross section incorporating a flood control structure (dike) within the community of Turner Valley.

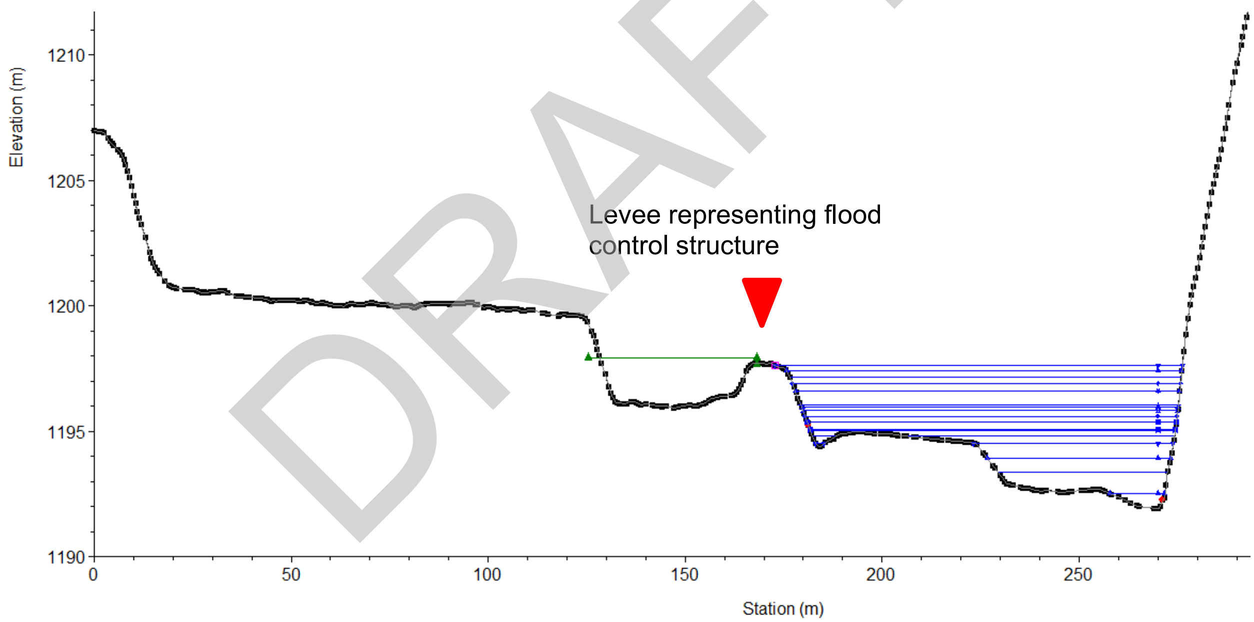

Figure 5-2 – Example of flood control structure in Turner Valley (River Station 45.73)

Only structures that were identified and acknowledged by the stakeholders, were designed as flood control structures, and are regularly maintained were included in this study as being flood control structures. Flood control structures are represented in the HEC-RAS model using one (or a combination) of:

- Levees; and
- Ineffective flow areas.

Method selection was based on professional judgement and suitability of use for the particular cross section. If one method was selected for a particular flood control structure, it was consistently used for the entire length of that flood control structure.

5.2.4 Ineffective Flow Areas

Ineffective flow areas are established in the HEC-RAS model at locations that contain water that is not actively being conveyed. Regions of ineffective flow can be caused by natural obstructions in the floodplain such as sections of the valley wall projecting into the floodplain or by man-made structures such as bridge approach abutments and roadway embankments. Ineffective flow areas also occur in low-lying land adjacent to the channel that is subject to back flooding due to connection to the channel or due to a water body such as a pond. In this study, the following two types of ineffective flow areas were used, as defined in the HEC-RAS user's manual:

- Normal Ineffective Areas – A left station and elevation and a right station and elevation are defined. If the water surface is below the established ineffective elevations, the areas to the left of the left station and to the right of the right station are considered ineffective. Once the water surface goes above either of the established elevations, then that specific area is no longer considered ineffective and the area will convey water in the downstream direction.
- Permanent Blocked Ineffective Flow Area – An elevation, a left station, and a right station is set for each ineffective block. The blocked ineffective flow area is set to permanent. Once the water surface goes above the elevation of the blocked ineffective flow area, the blocked area remains ineffective, but flow is allowed to go over top of the ineffective flow area.

5.2.5 Levees

Levees were used in the model to contain the flow within the main channel or floodplain until the levee is overtopped. Levees are required at man-made structures such as dikes or roads. The areas on the land side of these structures would convey discharge once these structures are overtopped but not before overtopping. The use of a levee within the HEC-RAS program allows the model to replicate this mechanism.

Levees were also used to artificially separate flows in the area around both Okotoks and Millarville. 2D model simulations were first undertaken in both areas to gather additional insight into the flow patterns and flow quantities that may overtop these levees. For Okotoks, these overtopping flows were then introduced as inflows to a separate 1D model reach located within the townsite (as explained in section 5.2.1). For Millarville, 2D model simulations showed Highway 549 would be effective at preventing water from crossing over the highway and flooding areas to the south over most of it's length. Some overtopping was evident in the runs at the location of the intersection of Highway 549 and Highway 22. The

1D model was modified to reflect this, and local backwater effects in this area were added as manual edits in the mapping series.

5.2.6 *Other Features*

Lateral structures have also been added to refine flow movement through the Threepoint Creek and Sheep River confluence area and the 128 street overflow. The addition of these lateral structures helps to control the transfer of water in between the main river reaches on both water bodies, and provide a better match with recorded water levels in these areas and to 2D model results.

5.3 Model Calibration

Model calibration is key to developing a stable model that accurately replicates flow patterns and water levels on the study reach. Model calibration was accomplished by comparing simulated results to observed conditions and by adjusting model parameters within accepted ranges until simulated results matched observed conditions as closely as possible.

5.3.1 *Methodology*

The Manning's n roughness values, ineffective flow areas, and the bridge contraction/expansion coefficients were the primary model parameters used to calibrate the HEC-RAS model. The initial selection of Manning's n values for the reach was made taking into consideration river bed/bank materials, vegetation cover, site information collected during the field inspection, and our past experience in setting up hydraulic models on river reaches like the Sheep River and Threepoint Creek.

In many rivers, the Manning's n value may vary somewhat with depth. For example, in well entrenched and stable river channels, the channel roughness may decrease with increased river depth or flood flow. In a river with a very high sediment load, the opposite may occur as bed form sizes and shapes begin to change and grow with increased flow velocities. This suggests that different roughness values could ideally be considered to represent low flow and high flow conditions. However, the primary purpose of this study is the simulation of flood passage events, and therefore the objective of the hydraulic model calibration was to generate a single geometry file which would be suitable for simulating the full range of flows, but with an emphasis on matching water levels during flood events. Since the focus of this study was on flood passage, this model should be used cautiously if being applied to study low flow conditions in the river.

Model calibration was conducted using observed flow and water level information available for both low flow and high flow conditions, and available WSC gauging station rating curves to determine appropriate roughness values across a wide range of flows.

The model calibration process involved multiple iterations in which selected model parameters were systematically adjusted, and simulated profiles were compared to observed high water marks (for high flow calibration), surveyed water levels (for low flow calibration), and gauging station rating curve data. The objective of the model calibration was to achieve a consistently good match between simulated water levels and the high water marks, surveyed water levels and gauged water levels.

The 2013 flood event was selected as the calibration event for the Sheep River. The 2013 flood represents the largest flood event in recent history on this river, and there are a number of good HWM's collected by AEP during this event that can be used for comparison. For Threepoint Creek, the 2005 high water marks collected by AEP were used for calibration. The 2005 event represents the largest flood event in recent history for Threepoint Creek. After calibrating the model to these events, it was also used to simulate other flow events to validate the performance of the model.

5.3.2 *Low Flow Calibration*

The low flow calibration was undertaken based on data collected by AFW during the channel cross section surveys in late October to Late November 2015. AFW collected water level and edge of water information during the site survey. Flows in the river system were very low at this time. Based on the date of data collection and available WSC gauge data, the following flows were estimated during the survey data collection period for different locations in the study reach (Table 5-2).

Table 5-2 – Flow information during the survey data collection

Reach Name	River	Discharge (m^3/s)
Threepoint Creek below Ware Creek	Threepoint	0.16
Threepoint Creek between Ware and Fisher Creeks	Threepoint	0.16
Threepoint Creek below Fisher Creek	Threepoint	0.22
Above and Below HWY 22	Threepoint	0.22
Below Millarville Reservoir Tributary	Threepoint	0.22
Below Pothole Creek (to confluence with Sheep River)	Threepoint	0.22
Above Threepoint Creek Confluence	Sheep	2.55
Below Threepoint Creek Confluence	Sheep	2.63
Below 128 Street Overflow	Sheep	2.63
Below Okotoks	Sheep	2.63

For the low flow calibration, Hatch set up the model with the information summarized above and simulated the corresponding water surface profile. The simulated profile was then compared against surveyed levels at a number of key locations. Table 5-3 and Figure 5-3 summarize the results of this comparison.

Table 5-3 – Low Flow Calibration Results

Reach	RS (km)	WL Survey (m)	Simulated WSE (m)	Difference (m)	Location Description
Sheep River	50.21	1218.13	1218.01	0.12	U/S of Turner Valley
Sheep River	42.21	1171.66	1171.68	-0.02	05BL014
Sheep River	24.54	1085.74	1085.78	-0.04	U/S of Okotoks
Sheep River	15.24	1048.62	1048.45	0.17	05BL012
Sheep River	2.55	994.56	994.62	-0.06	U/S of Highwood River Confluence
Threepoint	25.93	1209.60	1209.56	0.04	U/S of Millarville
Threepoint	17.31	1176.46	1176.22	0.24	D/S of Millarville
Threepoint	11.09	1157.80	1157.40	0.40	05BL013
Threepoint	6.44	1144.39	1144.35	0.04	U/S of Sheep River Confluence

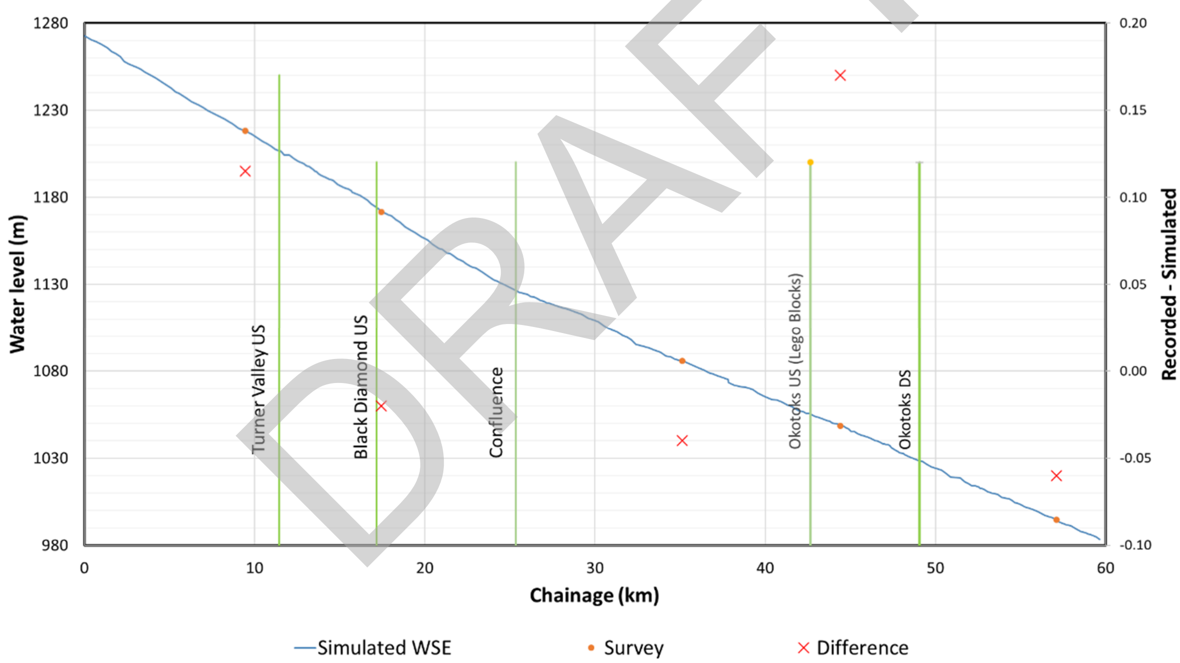

Figure 5-3 – Water surface profile and the calibration result for low flow – Sheep River

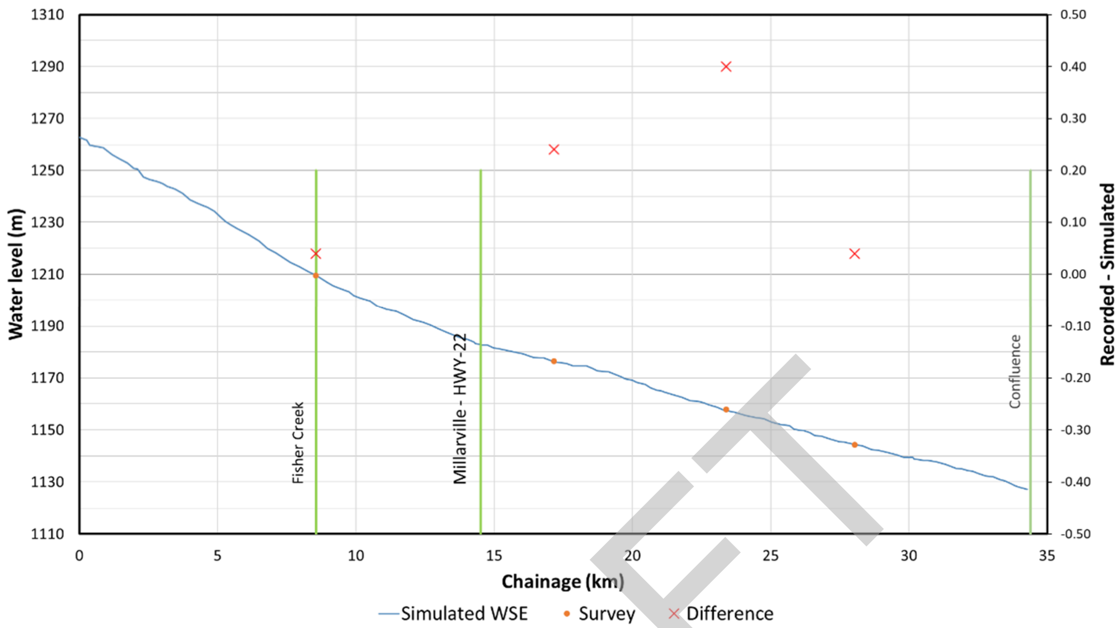

Figure 5-4 – Water surface profile and the calibration result for low flow – Threepoint Creek

5.3.3 High Flow Calibration

For the high flow calibration, the model was used to simulate passage of two of the largest flood events in recent history: the 2013 event and the 2005 event. Highwater marks were collected during each flood event, as described in Section 3.6 above.

The results are shown in Table 5-4 and Figure 5-5 for the 2013 Sheep River calibration. As noted in the table, some HWM measurements showed a significant deviation from the simulated water level, most notably at points 2013-SP-1a, 2013-SP-5.5a, 2013-SP-7a, 2013-SP-14a, and 2013-SP-16-a. Review of aerial photographs in the area revealed that log jams occurred often during this flood event, and likely created temporary backwater effects that couldn't be reproduced with the model. In other instances, the channel path seemed to change appreciably pre to post flood, indicating significant erosion or scour had likely taken place. Taking these things in to consideration, the average absolute difference between the simulated and reported water levels is approximately 0.29 m, with individual differences ranging from 0.02 m to +0.6 m

Table 5-4 – High water marks for Sheep River – calibration with 2013 flood

Name	HWM	Simulated	Difference	Comment
2013-SP-1-a	1211.15	1210.62	0.53	Log Jam Effect
2013-SP-2-a	1199.82	1200.35	-0.54	
2013-SP-3-a	1199.68	1199.62	0.06	
2013-SP-5-a	1194.06	1193.76	0.30	
2013-SP-5-b	1194.00	1193.66	0.34	
2013-SP-5.5-a	1189.96	1189.13	0.83	Due to D/S Log Jam Effect
2013-SP-7-a	1186.24	1184.86	1.38	Log Jam Effect
2013-SP-8-a	1176.06	1176.65	-0.59	
2013-SP-9-a	1175.49	1175.34	0.14	
2013-SP-10-a	1167.63	1167.00	0.63	
2013-SP-11-a	1163.76	1163.78	-0.02	
2013-SP-14-a	1134.26	1132.99	1.27	The topography changed significantly in the area
2013-SP-16-a	1109.72	1109.25	0.47	Invalid Reading
2013-SP-18-a	1090.76	1090.44	0.32	
2013-OKO-2-c	1058.02	1058.38	-0.36	
2013-OKO-2-b	1057.67	1058.14	-0.47	
2013-OKO-2-a	1057.91	1058.14	-0.23	
2013-OKO-2B-a	1055.54	1055.30	0.24	
2013-OKO-3-a	1054.86	1054.75	0.11	
2013-OKO-3-b	1054.23	1054.09	0.14	
2013-OKO-4-a	1053.60	1053.04	0.57	
2013-OKO-5-a	1052.34	1052.24	0.10	
2013-OKO-5-b	1052.11	1052.07	0.05	
2013-OKO-6-a	1049.99	1049.89	0.10	
2013-OKO-7.1-a	1041.50	1041.73	-0.23	
2013-OKO-7.1-b	1042.89	1043.05	-0.16	
2013-OKO-10-a	1017.29	1017.62	-0.33	
2013-OKO-10-b	1016.74	1017.17	-0.43	

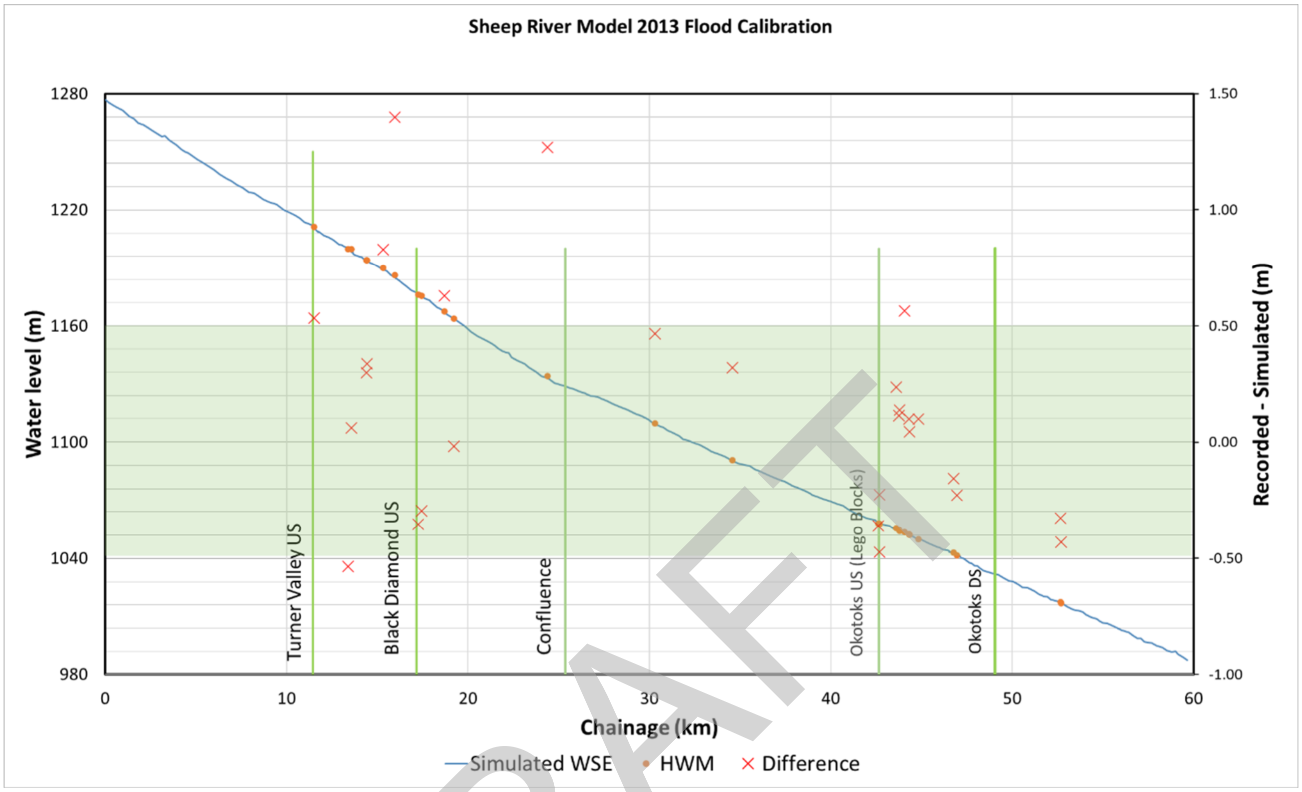

Figure 5-5 – Sheep River calibration results – 2013 flood

The results are shown in Table 5-5 for the 2005 Threepoint Creek calibration. As noted in the table, some HMM gauges showed a significant deviation from the simulated water level, most notably at points 2005-3PT-6 points, and 2005-3PT10-a. Datum errors at each of these HMM markers are the likely cause for such large discrepancies. Taking these things in to consideration, the average absolute difference between the simulated and reported water levels is approximately 0.32 m, with individual differences ranging from 0.01 m to +1 m

Table 5-5 – High water marks for Threepoint Creek – calibration with 2005 flood

Name	HWM	Simulated	Difference	Comment
2005-3PT-2-a	1162.26	1162.18	0.08	
2005-3PT-2-b	1162.56	1162.33	0.23	
2005-3PT-6-a	1198.97	1204.04	-5.07	Measured point is below the terrain
2005-3PT-6-b	1199.12	1204.48	-5.36	Measured point is below the terrain
2005-3PT-6-c	1199.13	1204.49	-5.36	Measured point is below the terrain
2005-3PT-6-d	1198.9	1204.58	-5.68	Measured point is below the terrain
2005-3PT-6-e	1198.89	1204.53	-5.64	Measured point is below the terrain
2005-3PT-6-f	1199.05	1204.00	-4.95	Measured point is below the terrain
2005-3PT-7-a	1205.73	1205.51	0.22	
2005-3PT-7-b	1205.62	1205.50	0.12	
2005-3PT-4-c	1185.56	1185.90	-0.34	
2005-3PT-4-d	1184.85	1185.92	-1.07	
2005-3PT-4-a	1185.39	1185.56	-0.17	
2005-3PT-4-b	1185.38	1185.07	0.31	
2005-3PT-1-a	1142.88	1142.56	0.32	
2005-3PT-9-a	1235.47	1235.99	-0.52	
2005-3PT-10-a	1243.67	1244.58	-0.91	Measured point is below the terrain
2005-3PT-11-a	1246.18	1246.19	-0.01	
2005-3PT-11-b	1246.23	1246.19	0.04	
2005-3PT-11-c	1246.31	1246.19	0.12	
2005-3PT-12-a	1252.96	1253.90	-0.94	
2005-3PT-14-a	1274.04	No Value	No Value	U/S of the study reach

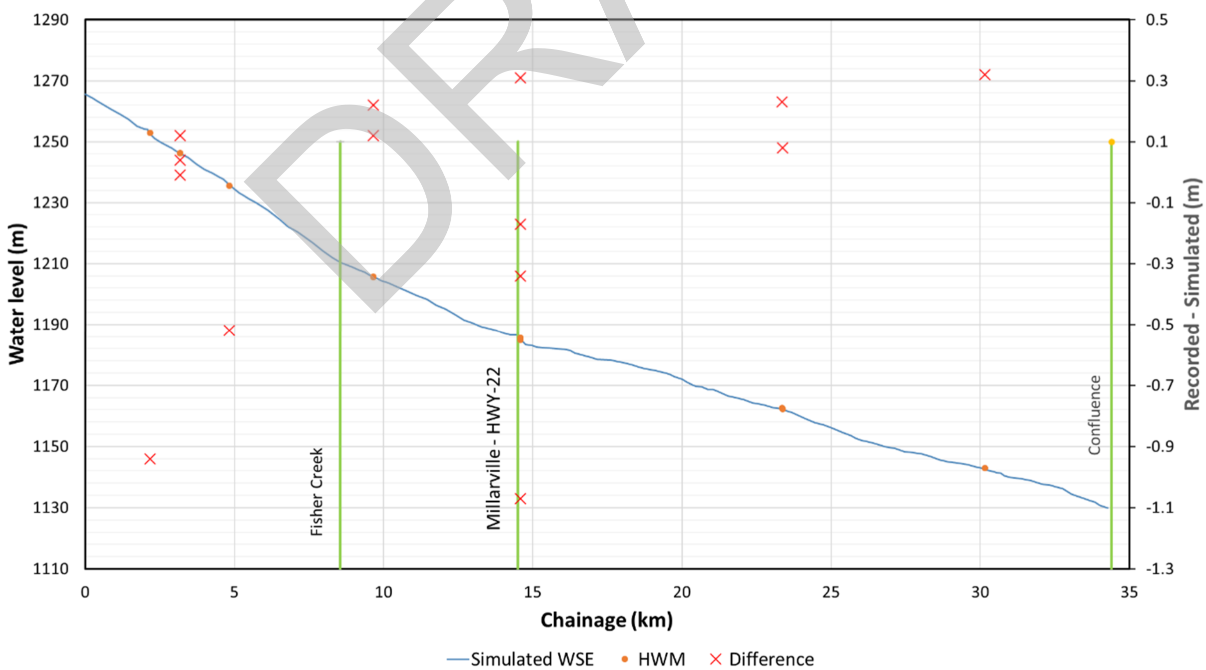

Figure 5-6 – Threepoint Creek calibration results – 2005 flood

5.3.4 Gauge Data & Rating Curves

The data available at the WSC gauging stations summarized in Table 5-6 were also used to support the model calibration. As described in Section 3.7, there are three WSC gauges in the study area. The corresponding HEC-RAS river stations associated with each WSC gauge were determined and are summarized in Table 5-6. The HEC-RAS model was then run for a range of flows, and the simulated results were compared against the observed rating curve at each gauge location. The results are shown in Figure 5-7 to Figure 5-9.

Table 5-6 – List of WSC gauges and corresponding river stations

WSC Gauge	Description	Corresponding River Station in the model
05BL012	Sheep River at Okotoks	15.24 Sheep River Reach
05BL013	Threepoint Creek near Millarville	11.09 Threepoint Creek Reach
05BL014	Sheep River at Black Diamond	42.21 Sheep River Reach

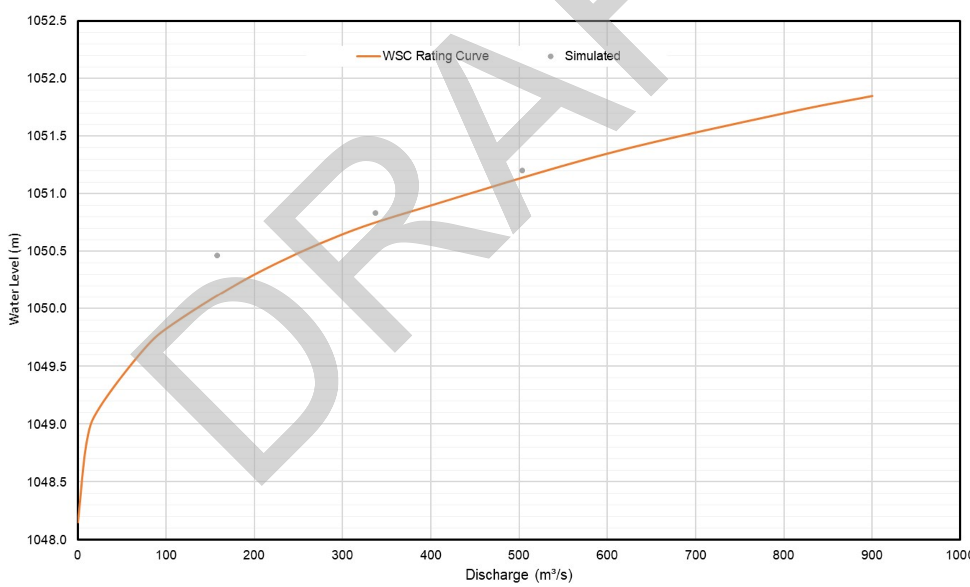

Figure 5-7 – Simulated flow vs. WSC rating curve at 05BL012 location

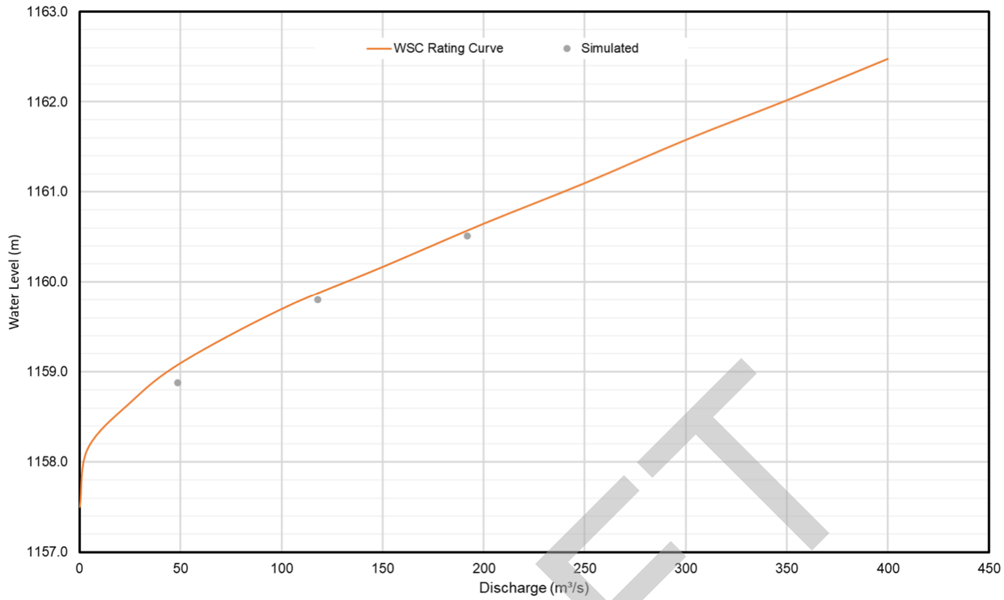

Figure 5-8 – Simulated flow vs. WSC rating curve at 05BL013 location

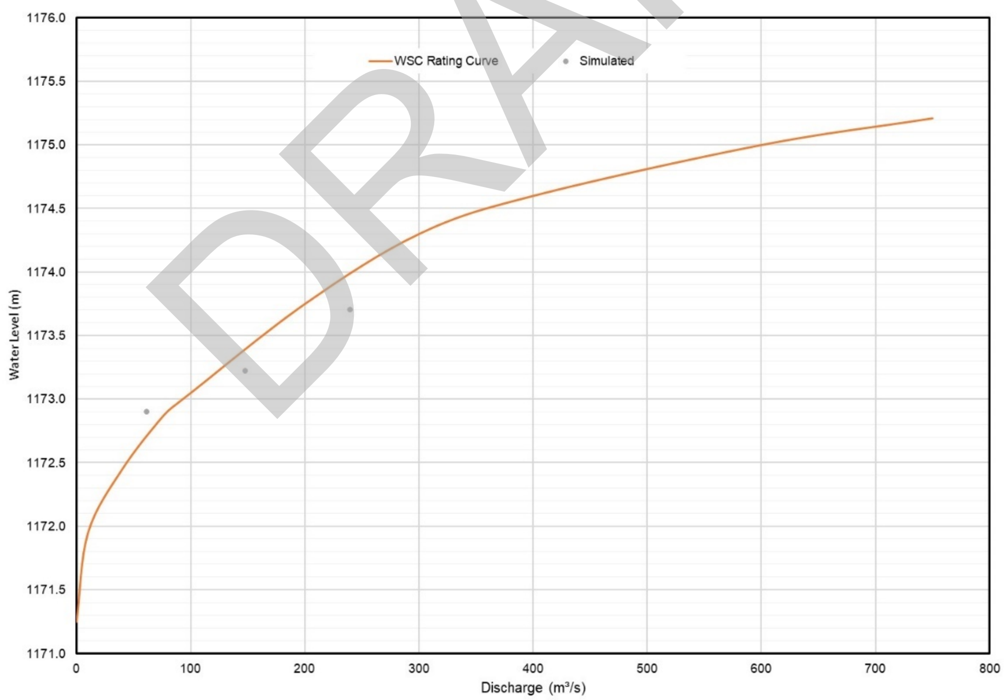

Figure 5-9 – Simulated flow vs. WSC rating curve at 05BL014 location

5.3.5 Summary of Calibration Results

The above sections describe the methodology and results of the model calibration. As noted, the main purpose of this study is the identification of river and flood hazards. Therefore, the priority for the model calibration was on replicating high flow events, and the model was then checked for the low flow events. The sections below briefly summarize the calibration.

5.3.5.1 Sheep River Calibration

Water level measurements on the Sheep River were available for the June 2013 open water flood event, and the model was calibrated to match these water levels. Earlier AEP HWMs from the 1981, 1990, 1992 and 1995 events were not utilized for calibration due to the significant channel changes that have likely occurred since these events occurred. The previous channel and floodplain geometry would not be well represented by the 2015/2016 LiDAR and survey, on which the model is based.

In the model, both the roughness (Manning's n values) and ineffective flow areas were methodically adjusted for cross sections on the Sheep River reach to best match observed water levels. Ineffective flow areas were selected and adjusted as a part of the calibration exercise to best replicate the flow dependent mobilization of additional channel networks evident on the braided main channel. These model parameters were then fixed for all flow events, and the model was used to simulate lower flow events and the results checked to ensure the match between computed and observed water levels remained acceptable. As a final step, the model was run to simulate the entire portfolio of flood events in this study (1:2-year up to a 1:1000-year flood event) to ensure there were no inconsistencies in these profiles.

The boundary condition for the model for this calibration run was set based on observed water levels at the downstream end of the reach, at the Sheep River's confluence with the Highwood River.

The final calibrated model was able to match the observed water levels during the 2013 flood event reasonably well, with a mean difference between simulated and observed levels of 0.29 m. Individual differences ranged from 0.06 up to 0.6 m. The mean difference between simulated and observed levels for the low flow event was 0.03 m. Individual differences ranged from -0.06 m up to +0.17 m.

5.3.5.2 Threepoint Creek Calibration

Water level measurements on Threepoint Creek were available for both the June 2013 open water flood event, and the 2005 flood event. The model was calibrated to match the 2005 water levels since this event represented the highest flows and levels experienced on Threepoint Creek in recent years (i.e. higher than the 2013 flows).

In the model, both the roughness (Manning's n values) and ineffective flow areas were again methodically adjusted for cross sections on the Threepoint Creek reach to best match observed water levels. Ineffective flow areas were selected and adjusted as a part of the calibration exercise to best replicate the flow dependent mobilization of additional channel networks evident on the braided main channel. As a final step, the model was run to simulate the entire portfolio of flood events in this study (1:2-year up to a 1:1000-year flood event) to ensure there were no inconsistencies in these profiles.

The final calibrated model was able to match the observed water levels during the 2005 flood event reasonably well, with a mean difference between simulated and observed levels of 0.32 m. Individual differences ranged from -0.3 m up to 1.0 m. The mean difference between simulated and observed levels for the low flow event was 0.18 m. Individual differences ranged from -0.4 m up to +0.4 m.

5.3.5.3 *Potential Sources of Error*

Consideration was given to the potential sources of error that could result in differences between the model and the observed HWMs for these events, and these include:

- Discharges are only known at the streamflow monitoring gauge reaches and are estimated at others. Therefore, discharges may have varied locally from those used in the calibration run.
- Complex 2D flow patterns can occur within the floodplains along the study reach that would be inundated during major flood events. Therefore, a constant energy head assumption across a cross section may not be reasonable. This may result in HWMs varying considerably from the results in the 1D HEC-RAS model.
- These streams are very dynamic with significant channel changes that can occur due to sediment and debris erosion and deposition processes, or through short-circuiting of channel thalwegs. This may result in a transient geometric condition over the course of a flood event, as the cross section erodes or sediment deposits. The current channel geometry used for all calibration scenarios, which could be significantly different from the historic channel geometry that was actually in place when the measurement was taken.
- Numerous engineering flood protection works were constructed after the 2013 flood and these are reflected in the channel geometry used for all calibration scenarios. Hence the historic channel conditions may not be completely reflected by the model.
- There are errors inherent in the HWM documentation process. For example, HWMs are often defined by debris that is hung up on fences or on vegetation. Sometimes

the branches of vegetation are pushed down during floods and may spring back up after the flood. Conversely, debris may have dropped in elevation following the flood.

- It was noted that these floods can carry significant debris, and this debris can temporarily jam at constriction points in the river. The resulting debris jam can lead to local staging not captured by the model.

5.4 Model Parameters & Options

5.4.1 Manning Roughness Values

5.4.1.1 Channel Roughness

The final calibrated river channel Manning n values are summarized in Table 5-7 below for the Sheep River and Threepoint Creek reaches.

Table 5-7 – Main Channel Manning roughness summary

Stream	Calibrated Manning's n Value
Sheep River below Okotoks	0.032 – 0.039
Sheep River above Okotoks	0.030 – 0.042
Threepoint Creek	0.033 – 0.042

5.4.1.2 Overbank Roughness

The final calibrated overbank Manning n values are summarized in Table 5-8 below for the Sheep River and Threepoint Creek reaches.

Table 5-8 – Overbank Manning roughness summary

Stream	Calibrated Manning's n Value
Urban Areas	0.07 – 0.08
Grassland	0.05
Dense Vegetation	0.12
Treelines	0.12

5.4.2 Expansion & Contraction Coefficients

Transition losses associated with changes in the shape of river cross sections (or effective flow areas) are computed in the HEC-RAS program by multiplying the absolute difference in velocity heads between cross sections by a coefficient. This coefficient is termed either expansion or contraction coefficient depending on what type of transition loss is being computed.

Because the expansion or contraction of flow was gradual in nature along the study reach, contraction and expansion coefficients of 0.1 and 0.3 respectively were used in the model for all gradual cross section transitions. For more abrupt transitions at bridge crossings, a contraction coefficient of 0.3 and an expansion coefficient of 0.5 was used to account for greater energy losses expected due to the more abrupt change in waterway opening at bridge openings.

5.4.3 Obstructions & Ineffective Flow Areas

Ineffective flow areas are established in the HEC RAS model at locations that contain water that is not actively being conveyed. As noted earlier (see Section 5.3), regions of ineffective flow can be caused by natural obstructions in the floodplain such as sections of the valley wall projecting into the floodplain, or by man-made structures such as bridge approach abutments. To represent this, the following types of ineffective flow were used in the model:

- Topographically low areas in which standing water may exist: Permanent ineffective flow areas were specified to block off low-lying areas that do not effectively convey flow.
- Topographically low areas that can be activated: Non-permanent ineffective flow areas were specified to block off low-lying areas that become active once the water level exceeds a given elevation.
- Bridge decks and embankments: Permanent ineffective flow areas were specified to block off flow through and in the vicinity of bridge embankments.

Small residential buildings and houses are not specified as building blockages, because their effects on the hydraulic conditions in the overbank areas are already represented by the composite or apparent Manning's value for residential areas.

5.4.4 Flow Splits, Islands & Diversions

There are two basic methods for modelling flow splits within HEC-RAS:

(1) By using a lateral structure, in which flow exiting the main river channel is controlled using a weir equation. This would be the case, for example, if water escapes from a channel by passing over an elevated section of land, or through a control structure. The lateral structure method is often used if there is a man-made structure, such as a road or railway embankment, that is overtopped.

(2) By using a junction in HEC-RAS at the beginning and end of the split flow, and the energy equation is then solved so that the energy head is the same for the main channel and split flow channel at the upstream and downstream junctions. An example

of the junction method would be the bifurcation of flow that can occur around a large island.

The developed HEC-RAS model includes two regions with a flow split on the Sheep River, which are described below.

- Okotoks split flow – There is a potential for overtopping to occur of the CP Rail line near the western end of the community. This area is circled in red in Figure 5-10 below. Downstream of the overflow location, the flood water flows in an easterly direction through the industrial areas of the town before rejoining the Sheep River downstream of the CPR Bridge.
- 128 Street split flow – The avulsion that occurred on the Sheep River at 128 Street during the 2013 flood is documented in Amec Foster Wheeler (July 2015). During the 2013 flood, the main channel of Sheep River west of 128 Street was blocked with debris, causing the river to breach its east bank (right bank looking downstream) and divert a portion of flow through the South Rock gravel pit. Although a significant portion of the floodwaters flowed overland through this opening, some of the discharge returned back to the main channel immediately downstream of the breach. The remaining overland flow travelled northeast through the gravel pit and across 128 Street (and further eastward across 112 Street) prior to returning to the main channel of Sheep River. Subsequent to the 2013 flood, as part of interim mitigation measures, the flow was restored back to the main channel and the east bank was armoured where the avulsion initiated. A lateral structure was therefore used to represent this flow split. The lateral structure comprised the berm that was built subsequent to the 2013 flood and adjacent areas.
- Threepoint Creek Confluence - No flow splits were used on Threepoint Creek.

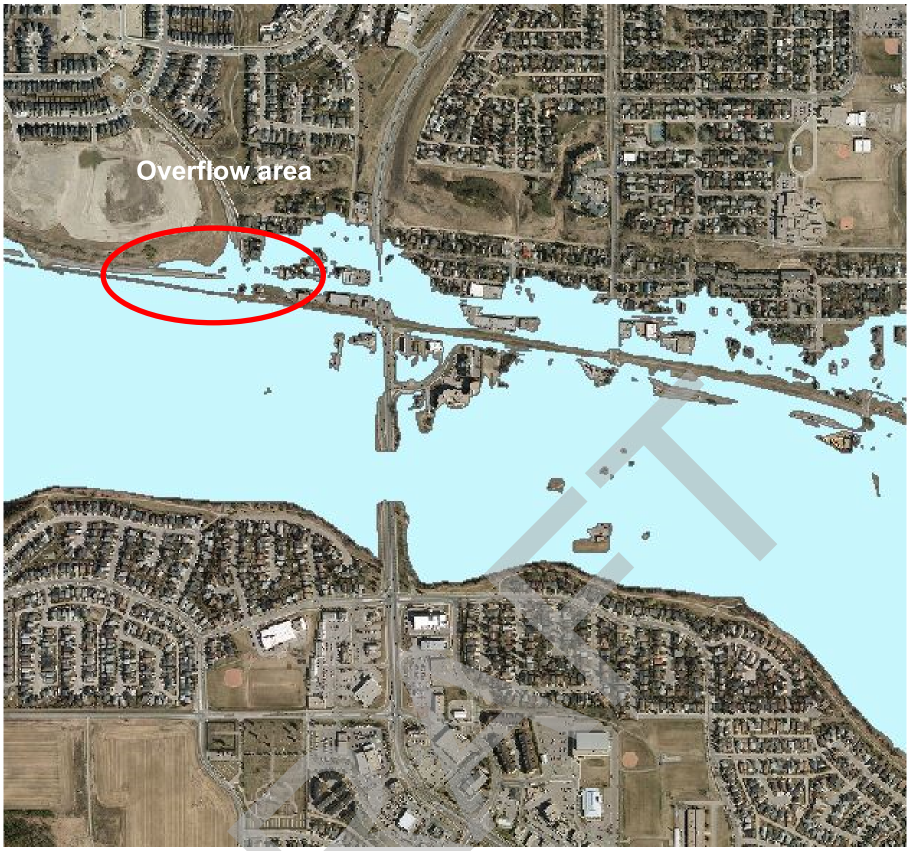

Figure 5-10 – Okotoks Split Flow

5.5 Open Water Flood Frequency Profiles

Surface water profiles were then simulated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events using the calibrated HEC-RAS model. The estimated peak discharges for these flood events were determined in the hydrology analysis presented in Table 3-1. Care was taken to ensure that the computed water surface profiles and the computed energy grade lines were all consistent, and did not inadvertently cross for any flood events

Figure 5-11 to Figure 5-13 show the open water flood frequency profiles for the Sheep River. **Figure 5-14** shows the same information for the Threepoint Creek. These profiles are provided in a tabular format in Appendix C.

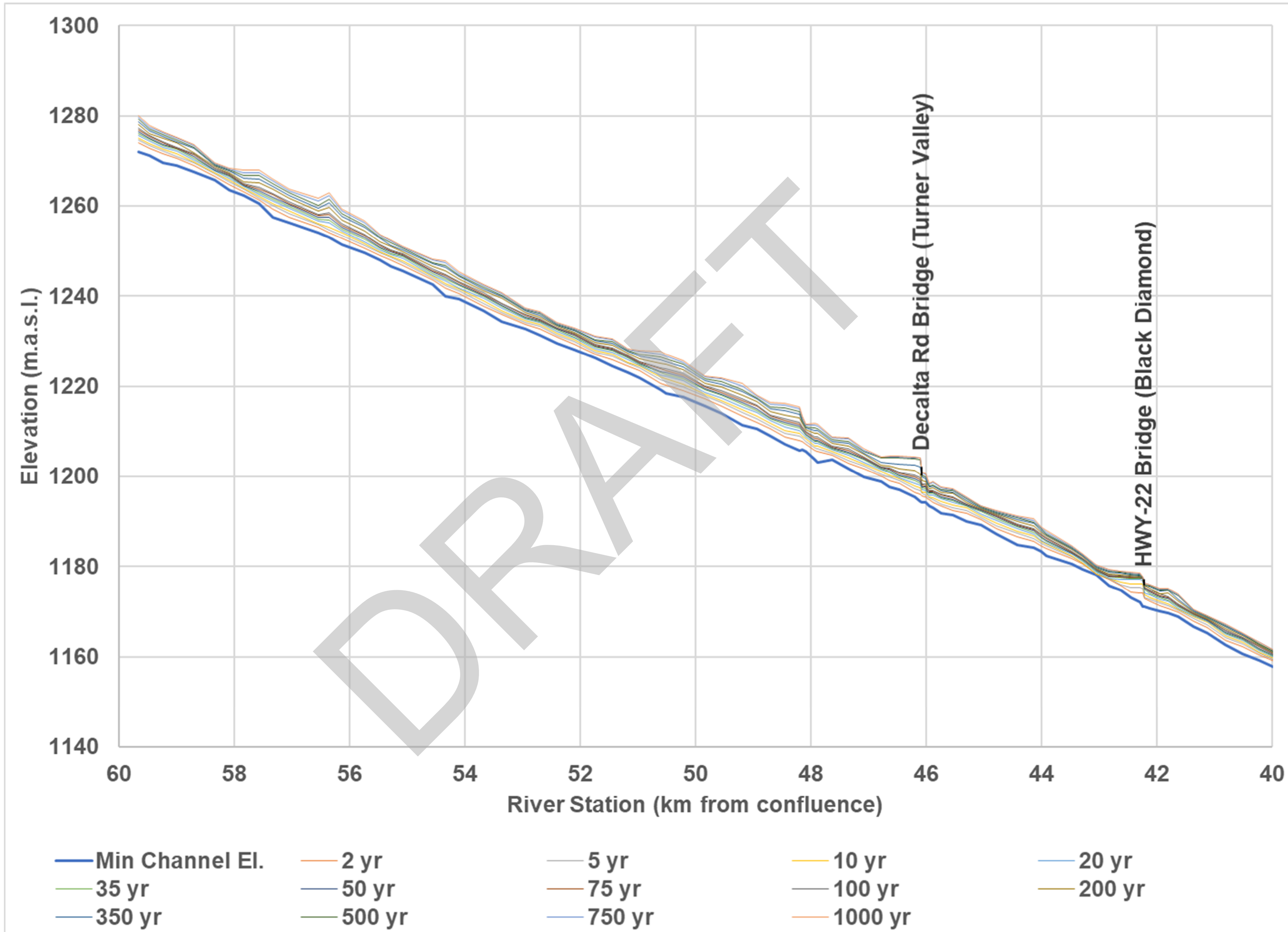

Figure 5-11 – Sheep River Water Level Profile (All frequencies)

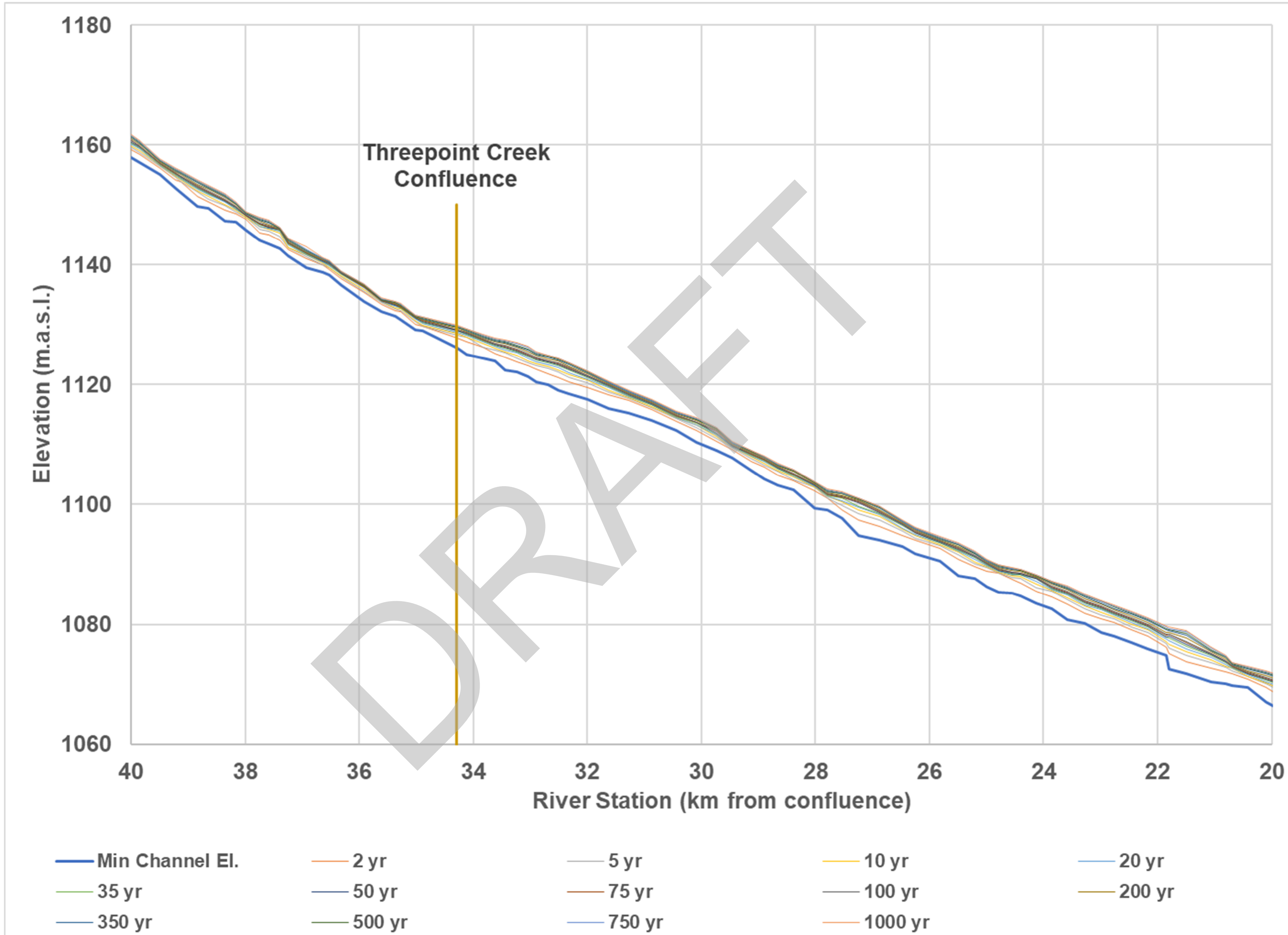

Figure 5-12 – Sheep River Water Level Profile (All frequencies)

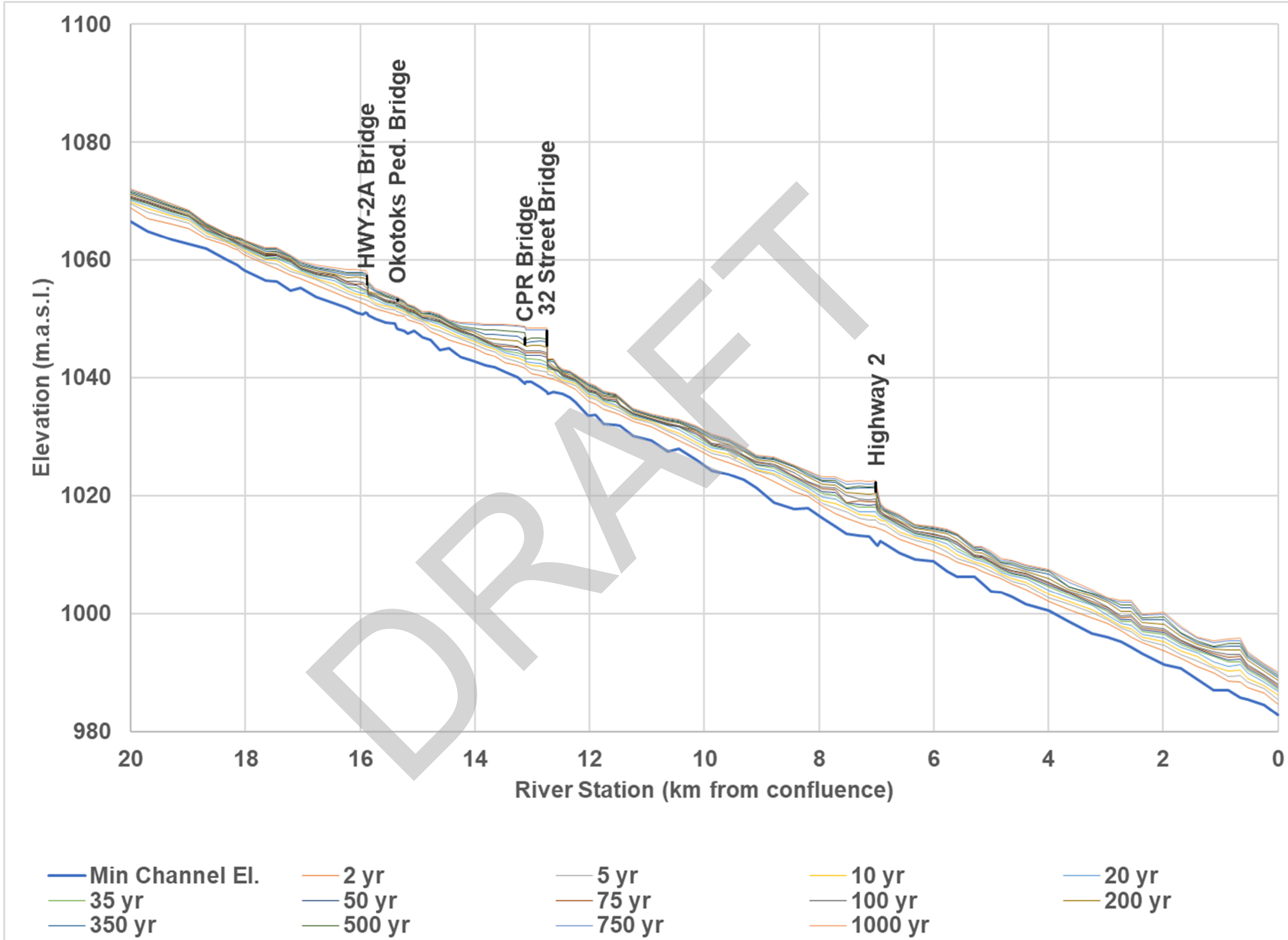

Figure 5-13 – Sheep River Water Level Profile (All frequencies)

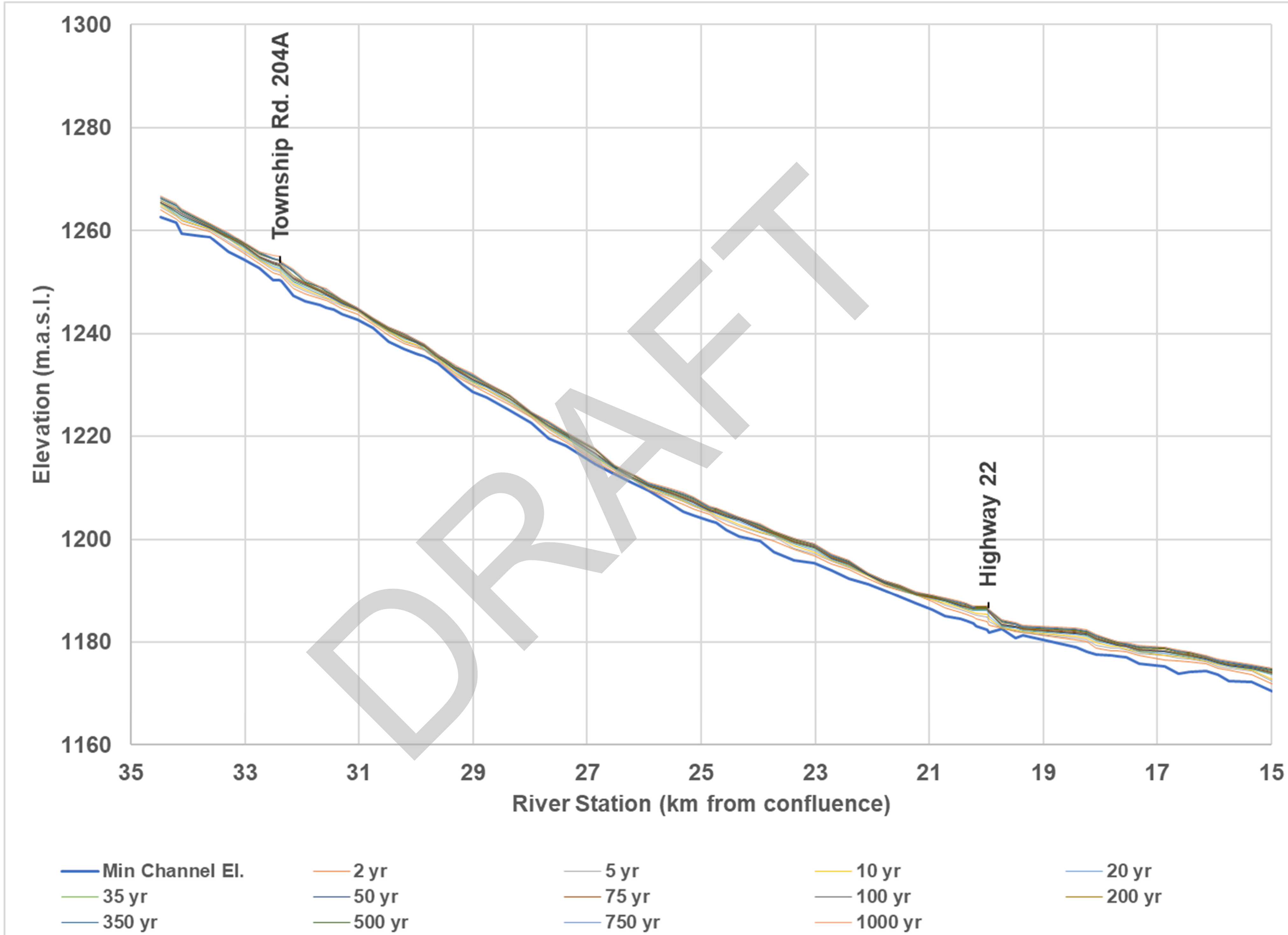

Figure 5-14 – Threepoint Creek Water Level Profile (All frequencies)

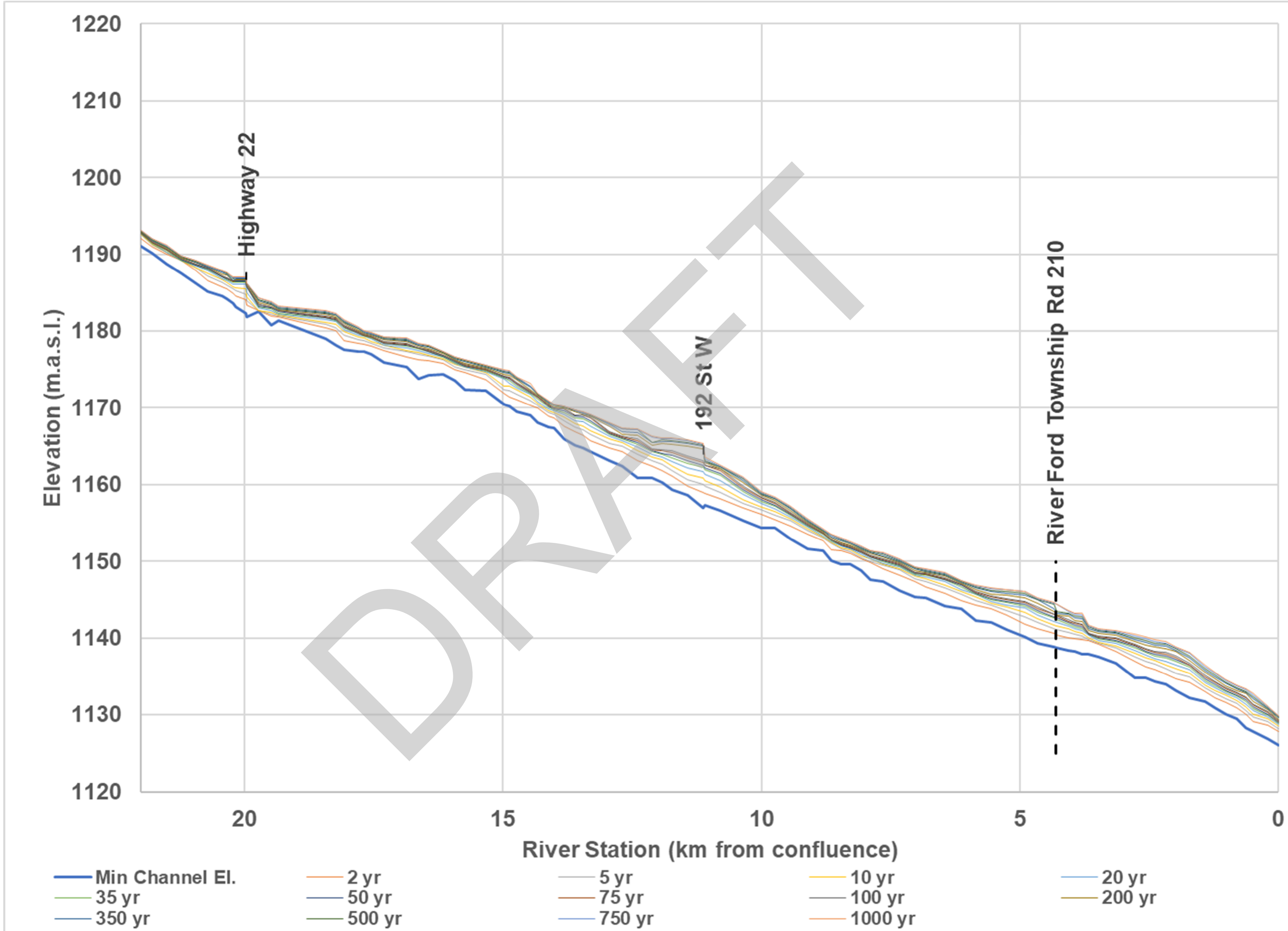

Figure 5-15 – Threepoint Creek Water Level Profile (All frequencies)

5.6 Model Sensitivity

Sensitivity analyses were conducted to evaluate the effects of modified model parameters on the simulated 100-yr flood water levels. The model was tested for it's sensitivity to changes in the selected Manning's n values for the channels and floodplains. The calibrated parameters were first decreased and then increased by 10 percent and the resultant water levels were compared to the base case levels. The results of the sensitivity analyses were used to help quantify the level of uncertainty associated with the simulated 100-yr flood levels on both Sheep River and Threepoint Creek. The sensitivity analysis results are summarized below.

Table 5-9 – Summary of Sensitivity Analysis Results

Reach	Decreased Manning's n by 10%		Increased Manning's n by 10%	
	Maximum WL Change (m)	Average WL Change (m)	Maximum WL Change (m)	Average WL Change (m)
Threepoint Creek	-0.24	-0.07	0.19	0.07
Sheep River	-0.33	-0.07	0.39	0.08

The downstream boundary condition in the HEC-RAS model was selected based on water levels that were estimated for at the Sheep River/Highwood River confluence in a previous study. This was considered to be a fixed parameter for this study, and therefore the model's sensitivity to the downstream boundary condition was not assessed.

6. Flood Inundation Maps

6.1 Methodology

The flood inundation maps were prepared based on the following information:

- Simulated water levels at individual cross sections for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events;
- Locations and extents of individual cross sections;
- LiDAR DTM; and
- Information about permanent flood control structures.

Directly inundated areas were plotted on each map, and this includes any areas that may be hydraulically connected to the main river channel via ditches, open culverts, or through bridge structures. In addition to delineating direct inundation areas, the following special inundation areas were identified for each flood event:

- Scenario 1 – Single Overtopping Point: At locations where inundated areas are connected to the main channel at a single overtopping point (spill point), the inundation extent was re-evaluated using a constant water level which is equal to that at the spill point.
- Scenario 2 – Multiple Overtopping Points: If there are multiple overtopping points related to a single overflow area, the inundation extent was based on the hydraulic gradient in the main channel between the overtopping points. The inundation extent upstream of the most upstream overtopping point and downstream of the most downstream overtopping point, were evaluated using the estimated water level at these bounding spill points.
- Scenario 3 – Single Overtopping Point Causing Overtopping Downstream: Under Scenario 1, if the area behind the single overtopping location would be (after some time) completely inundated and pooled with a constant surface water elevation similar to the water level at the spill point, this may cause a second overtopping further downstream and flow back into the main channel, because at that point the water level behind the embankment may be higher than that in the main channel. In this case, the inundation extent was re-evaluated using a linear interpolation between the water level at the upstream spill point and the ground elevation at the downstream re-entry point.
- Scenario 4 – Potential Flood Inundation due to Flood Control Structure Failure: In areas where permanent flood control structures have been identified and are not overtopped, the protected areas are shown as potentially flooded. The inundation extent is determined by assuming that the flood control structure is ineffective.

6.1.1 Direct Flood Inundation Areas

The following general procedure was used in ArcGIS to develop the inundation extent for the 13 open water flood events:

1) Assign water levels at each section for all flood events to the cross section polyline features as attributes. The result is one polyline feature that includes the simulated water levels for all flood events.
2) Create a continuous water level surface using a Triangulated Irregular Network (TIN) between cross sections.
3) Manually adjust the water level surface TIN in special areas
4) Convert the adjusted TIN into a water level raster with the same resolution and cell alignment as the DTM raster.
5) Subtract the water level raster from the DTM.

6) Assign “NoData” to dry cells (with water depths smaller than 0.01 m).

7) Convert the wet area into a polygon dataset. Features not directly connected to the main river channels are flagged (Scenario 1).

As noted in step 3 above, in some areas, and for some return periods, it was necessary to manually adjust the automatically computed inundation extents. The manual edits performed are briefly summarized below.

- The generated inundation polygons were reviewed, and all polygons that appeared to be the result of isolated flooding (i.e. flooding that was not due to some form of hydraulic connection to the main river channel) was deleted.
- In general, inundation mapping near the mouths of relatively large tributaries was included based on the simulated water levels at the locations of the tributary mouths. This applies to the tributary area joining Threepoint Creek immediately upstream, and to the north of the Highway 22 bridge crossing (the Millarville reservoir area), and to the confluence of Threepoint Creek with Fisher Creek.
- For low return period floods like the 2-Year event, manual edits were required to connect discontinuous inundation areas that were generated along the main channel. The LiDAR DEM used to delineate inundation includes the water surface observed on the day of the LiDAR survey. In some areas, the LiDAR DEM was therefore actually above the computed water surface in the main channel, and this resulted in some gaps in the projected inundation limits for the main channel. In these areas, the inundation extent for the next larger flood event (i.e. 5-year flood) with a continuous inundation without gaps was used, and aerial photographs were also used to identify the main channel location.
- On Threepoint Creek, at the intersection of Hwy 549 and Hwy 22, it was noted that there was a single overtopping point (I,e, Scenario 1) that would lead to the backwater flooding of the pond (and other overland areas) located to the north between Hwy 549 and Millarville Landing. In this area, water levels were assigned to this area based on levels computed in the main river channel just at the point that floodwaters began to overtop Hwy 549.
- On the Sheep River, at station RS 37.74 km, the 1D model appeared to overpredict water levels when compared to the more detailed 2D simulations. The 2D model results showed that even for very large events, up to and including the 1000-Year flood, river flows would continue to be contained within the natural river banks in this area. Therefore small manual edits were required to reflect this on the mapping series.
- On the Sheep River, at the confluence of the Sheep River and Threepoint Creek, the it was noted that there was a single overtopping point (i.e. Scenario 1) that would

lead to the backwater flooding of some areas of land located to the west of Highway 22. Water levels were assigned to this area based on levels computed in the main river channel at cross section RS 33.83 km.

- On the Sheep River, just below the confluence of the Sheep River and Threepoint Creek, the it was noted that there was another single overtopping point (i.e. Scenario 1) that would lead to the backwater flooding of some areas of land located to the east of Highway 22. Water levels were assigned to this area based on levels computed in the main river channel at cross sections RS 33.62 and RS 33.44 km.
- On the Sheep River, with the town of Okotoks, the 2D model results have shown that for flood events equal to or larger than the 75-year return period, water will begin to flow through the community, entering through an upstream ditch, travelling through the community, and exiting below the 32 Street bridge. The water levels in this area were assigned based on the one-dimensional HEC-RAS model results, but manual edits were required to connect some directly flooded areas. These hydraulic connections were made based on the 2D modelling results.

6.1.2 *Inundation Due to Potential Flood Control Structure Failure*

Inundation due to a potential flood control structure failure was also mapped. The nature of flooding expected behind a flood control structure will depend on the water level predicted for an event relative to the ground elevation at the base of the structure, and the crest elevation of the structure. Areas were mapped as representing potential inundation due to a flood control structure failure if the flood water level in the main river channel was higher than the natural ground or the toe of the control structure as shown in Figure 6-1, but lower than the crest of the structure. If the main river channel water level exceeded the crest elevation of the flood control structure, then the flooding was considered to be direct inundation, and was not attributed to a flood control structure failure.

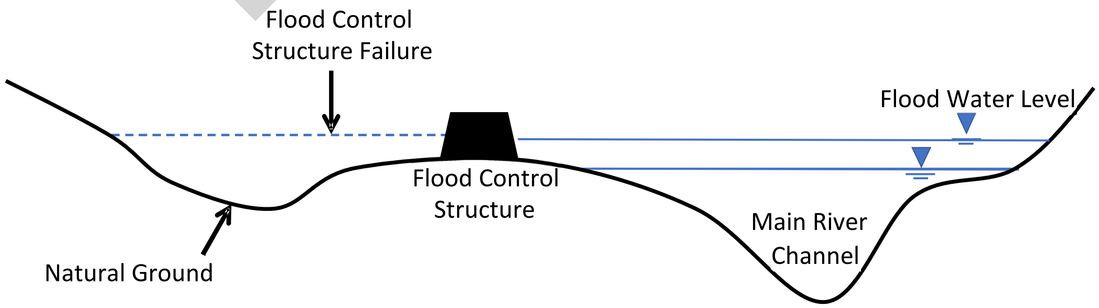

Figure 6-1: Illustration of Flood Control Structure Failure Inundation

6.2 Flood Impacts

6.2.1 Flooding of Residential Areas

Sheep River Upstream of the Threepoint Creek Confluence

Direct flooding would begin for some residences in the community of Turner Valley for floods with a return period of 100-Years or greater. At this magnitude of flood, water levels are expected to begin overtopping the crest of the flood control structures currently in place. Water levels would begin to exceed the natural ground elevation at the base of the flood control structure for floods with a return period of 20-Years or greater.

Direct residential flooding would begin for events exceeding the 20-Year return period in Black Diamond, as water levels would begin to overtop a low point on the intersection of 5th St SW and 3 Ave SW. Water levels would begin to exceed the natural ground elevation at the base of the flood control structure for floods with a return period of 10-Years for greater.

Sheep River Downstream of the Threepoint Creek Confluence

The largest community in this reach of the Sheep River is that of Okotoks. Direct residential flooding would begin in the community of Okotoks for events due with return periods equal to or greater than 75-Years. Flood water would begin to enter the community through a ditch located near the upstream end of the community, would travel through the community to the north of the railway embankment, and would re-enter the river downstream of the 32 St bridge.

Threepoint Creek

Residential flooding would begin for events exceeding the 20-Year return period for residents in the Millarville area that are located to the south of Highway 549.

6.2.2 Flooding of Commercial & Industrial Areas

Sheep River Upstream of the Threepoint Creek Confluence

Commercial areas in Black Diamond will be directly inundated for floods with a return period of 35-Years or greater.

Sheep River Downstream of the Threepoint Creek Confluence

Commercial areas of downtown Okotoks will be directly inundated for floods with a return period of 75-Years or greater. The Okotoks Eco Centre will be inundated for floods with a return period of 75-Years or greater. The Okotoks Lions Campground will be inundated for floods with a return period of 5-Years or greater.

Country Lane Estates will be directly inundated for floods with a return period of 20-Years or greater.

Threepoint Creek

The Millarville Racing & Agricultural Society will be directly inundated for floods with a return period of approximately 200-Years or greater.

The Parc Beauchemin Campground will be directly inundated for floods with a return period of 5-Years and greater.

Threepoint Creek Confluence

The Devries Bros Sand & Gravel Ltd yard will be directly inundated for floods with return periods greater than 2-Years. Flood waters are conveyed to the main yard over the right bank flood plain of the Sheep River, and through a small channel that is located on the right bank of the river.

6.2.3 Flooding of Bridges & Culverts

A bridge is considered to be affected by flooding when water reaches its low chord.

Table 6-1 presents a summary of the simulated open water flood levels, 100-year flow velocities and clearances for the 100-year flood for bridges on both the Sheep River and Threepoint Creek.

Table 6-1 – Flooding Effects at Bridges

River	River Station	Structure	Description	Bottom Chord Elevation	2-Year	5-Year	10-Year	20-Year	35-Year	50-Year	75-Year	100-Year	200-Year	350-Year	500-Year	750-Year	1000-Year	Above Bottom Chord Elevation
Threepoint Creek	32.38	Bridge	HWY 204	1253.85	1251.41	1251.88	1252.26	1252.65	1252.97	1253.18	1253.44	1253.57	1254.12	1254.18	1254.21	1254.22	1255.01	>100-Year
Threepoint Creek	19.965	Bridge / Culvert	HWY 22 - Millarville	1186.75	1184.07	1184.82	1185.48	1186.08	1186.36	1186.5	1186.53	1186.58	1186.71	1186.82	1186.89	1186.96	1187.02	>200-Year
Threepoint Creek	11.12	Bridge	192 St W	1164.07	1159.02	1160.05	1160.86	1161.67	1162.24	1162.55	1162.87	1163.07	1164.68	1164.99	1165.14	1165.28	1165.36	>100-Year
Threepoint Creek	4.31	Ford	Township Road 210	N/A	1140.6	1141.18	1141.67	1142.18	1142.6	1142.76	1143.05	1143.16	1143.44	1143.79	1144.37	1144.57	1144.62	N/A
Sheep River	46.078	Bridge	Decalta Road	1200.37	1196.03	1196.82	1197.44	1198.12	1198.58	1198.96	1199.41	1199.75	1200.61	1202.07	1203.84	1204.05	1204.21	>100-Year
Sheep River	42.221	Bridge	HWY 22 - Black Diamond	1176.23	1173.34	1174.01	1174.57	1175.36	1175.72	1176.3	1176.56	1176.72	1177.17	1177.43	1177.61	1177.78	1177.91	>50-Year
Sheep River	15.89	Bridge	HWY 2A	1055.8	1052.49	1053.29	1053.91	1054.34	1054.72	1054.99	1055.39	1055.9	1056.89	1057.29	1057.59	1057.77	1058.2	>75-Year
Sheep River	15.88	Bridge	HWY 2A	1056.21	1052.31	1053.14	1053.79	1054.17	1054.51	1054.8	1055.17	1055.52	1056.56	1056.93	1057.24	1057.36	1057.81	>100-Year
Sheep River	15.36	Bridge	Okotoks Pedestrian	1053.14	1050.65	1051.32	1051.67	1051.99	1052.22	1052.41	1052.68	1052.81	1053.2	1053.25	1053.45	1053.64	1053.79	>100-Year
Sheep River	13.13	Bridge	CPR	1054.7	1041.62	1042.32	1042.81	1043.32	1043.73	1044.06	1044.46	1044.75	1045.53	1046.35	1047.73	1048.64	1048.81	>1000-Year
Sheep River	12.741	Bridge	32 Street	1045.55	1040.1	1040.94	1041.65	1042.05	1042.57	1043.46	1043.92	1044.26	1045.26	1046.08	1046.63	1048.09	1048.38	>200-Year
Sheep River	7.005	Bridge	HWY 2	1020.63	1014.82	1015.88	1016.62	1017.33	1017.98	1018.42	1018.93	1019.31	1020.24	1021.24	1021.47	1021.99	1022.43	> 200-Year

7. Conclusions

7.1 Model Calibration

The HEC-RAS model was set up to represent hydraulic conditions on an approximately 60 kilometer long reach of the Sheep River, and a 35 kilometer long reach of Threepoint Creek in the Municipal District of Foothills No. 31. This reach includes the Towns of Black Diamond, Turner Valley, Okotoks and the Hamlet of Millarville. The model was calibrated based on the available low flow, high flow, and rating curve data. The calibrated HEC-RAS model can be reliably used in this study for simulating various flood events with return periods ranging from 2 to 1,000-years.

The river channel Manning's n roughness coefficient and ineffective flow areas were the main parameters used in calibrating the HEC-RAS model. The calibrated channel Manning's n value for the high flow condition ranges from 0.030 to 0.042 along the Sheep River study reach, and ranges from 0.033 to 0.042 along Threepoint Creek. These Manning's n values are within the typical range of roughness values for similar rivers (Chow 1959).

7.2 Model Sensitivity

Model sensitivity was evaluated using the 100-year flood simulation results. The sensitivity analysis showed that a 10 percent increase in the calibrated roughness coefficient could lead an average increase of 0.08 m in water level on Sheep River, with a maximum increase of up to 0.39 m in some areas. A 10 percent increase in the calibrated roughness coefficient could lead an average increase of 0.07 m in water level on Threepoint Creek, with a maximum increase of up to 0.19 m in some regions.

A 10 percent decrease in the calibrated roughness coefficient could lead to an average decrease in water level of 0.07 m on Sheep River, with a maximum decrease of up to 0.33 m in some regions. A 10 percent decrease in the calibrated roughness coefficient could lead an average decrease in water level of 0.07 m on Threepoint Creek, with a maximum decrease of up to 0.24 m in some regions.

7.3 Flood Profiles

Using the calibrated HEC-RAS model, surface water profiles were simulated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events. Care was taken to ensure that the computed water surface profiles and the computed energy grade lines were all consistent, and did not inadvertently cross for any flood events.

7.4 Flood Damages

Based on the simulation results, the main areas to be affected by open water flooding have been identified as follows:

- Low lying areas adjacent to the river in Turner Valley for events equal to or greater than the 100-year flood.
- Black Diamond would begin to experience flooding for events exceeding approximately the 20-year flood.
- Okotoks would experience flooding within the Country Lane estates area for floods exceeding approximately the 20-year event. Northern sections of the town would begin to experience flooding for events equal to or exceeding the 75-year event.
- Most bridges in the area appear to have lower chords elevations which exceed the expected water levels during the 100-year event. However, the Highway 22 bridge through the town of Black Diamond would likely have some water against the lower chord for events equal to or larger than the 10-year flood event.

8. References

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Appendix A
Documented Flood Damage

Table A1 Sheep River Flood Damages and Repairs for Years Other than 2013 in the MD of Foothills

Roll Number	Legal Land	River Reach	Comments
2029240080 2029240090 2029240100 2029240050	SE 24-20-29 W4	SR2	2005 flood damage reviewed in 2007 at Country Lane RV Park. Erosion protection constructed in 2007 and 2014.
2029240080	SE 24-20-29 W4	SR2	2008 flood concerns reported and assessed. No work done at that time, but works done after 2013 as part of the above noted Country Lane RV Flood Recovery Erosion Control (FREC) Erosion Protection Project.
2029235000	NW 23-20-29 W4	SR3	2008 flood concerns reported and assessed at Riverbend Campground and numerous occasions in the 1990s. Numerous works constructed over the years by the landowner.
2002267530	NE 26-20-2 W5	SR5	2008 flood concerns reported and assessed. Property was bought out by the MD after 2013 flood. Property located in 128 Street floodplain.

Table A2 Sheep River Bridge Flood Damages and Construction Dates for Years Other than 2013

Description	AT Bridge File No.	Legal Land	River Reach	Comments
HWY 2 Bridges	74031 N & S	NW 19-20-28-W4	SR2	1955 bridge complete 1965 scour on south head slope, repaired in 1967, 1973 1979 north head slope repairs 1986 second bridge completed 2005 erosion at U/S SW bank
32 St. Bridge (Okotoks)	79152	NW 22-20-29-W4	SR3	Constructed in 2010
CP Rail Bridge (Okotoks)	84093	NW 22-20-29-W4	SR3	N/A
Okotoks Pedestrian Bridge	81203	SW 28-20-29-W4	SR3	N/A
HWY 2A Bridges (Okotoks)	01145 N & S	SE 29-20-29-W4	SR3	1916 S bank scoured, N approach washed out 1916 S pile protection wall constructed 1923 N approach washed out and protected 1929 N approach nearly lost 1997 Scour at nose of Pier 3, bank erosion at abutments
HWY 22 Bridge (Black Diamond)	82075 & 02487	NW 8-20-2-W5	SR7	1908 bridge constructed 1932 W abutment destroyed in flood and replaced 1934 bridge reconstructed 1942 E U/S bank eroded 1962 bridge reconstructed 1975 E bridge seat settled and scoured 1978 construction of flood control dyke 1982 E head slope restored 1992, 1994, 2005 drift removed from piers
Decalta Road Bridge (Turner Valley)	71004	NW 6-20-2-W5	SR7	1990 new bridge constructed 2005 large drift pile on S pier removed

Table A3 Summary of Sheep River 2013 Flood Damages and Repairs in the MD of Foothills and the Towns of Okotoks, Turner Valley, and Black Diamond

Town name or Roll Number or Street name if Located in MD of Foothills	Legal Land	River Reach	Comments
2029240080 2029240090 2029240100 2029240050	SE 24-20-29 W4	SR2	Country Lane RV, significant flooding of the development and bank erosion (420 m on N bank) – FREC erosion protection completed 2014.
2029230000	S 23-20-29 W4	SR2	River's Edge Golf Club subject to significant flooding – private dike (580 m on N bank) was constructed after the flood
2029227510 2029235000	NE 22-20-29 W4 NW 23-20-29 W4	SR3	Riverbend Campground was subject to significant flooding – private dike (980 m on N bank) was constructed after the flood.
Okotoks	NE 21-20-29 W4	SR3	CP Rail Bridge (150 m on S bank) – erosion protection
Okotoks	SW 28-20-29 W4	SR3	Okotoks between Centre and Lineham Avenues (580 m on N bank) – erosion protection
Okotoks	NW 29-20-29 W4	SR3	CP Rail West side of Okotoks (300 m on N bank) – erosion protection. Note the comment contained in **Appendix A** (Section A3) in which the Western Wheel states "CP Rail Dyke helped prevent worse flooding in Okotoks. Emergency repairs the night of the flood were undertaken to prevent tracks west of town from washing out, and prevent flood waters breaking through into downtown via SR 549." (10 July 2013)
112 St.	E 26-20-2 W5 W 25-20-2 W5	SR5	Between 370 Avenue and 356 Avenue – gravel road completely washed out
128 St.	E 27-20-2 W5 W 26-20-2 W5	SR6	Between 370 Avenue and 359 Avenue – gravel road completely washed out
144 St.	E 28-20-2 W5 W 27-20-2 W5	SR6	Between 370 Avenue and 356 Avenue – gravel road completely washed out
2002272510	SW 27-20-2 W5	SR6	128 Street Frishke Residence (120 m on W bank) – FREC erosion protection completed 2014
2002272500	SW 27-20-2 W5	SR6	128 Street (60 m on E bank) – Reconstructed bank and erosion protection constructed at site where avulsion occurred, completed 2014
2002177500 2002170010	E 17-20-2 W5	SR7	Near Black Diamond Site (80 m on W bank) – FREC erosion protection completed 2014 to protect MD resident, approximately 1 km downstream of HWY 22 Bridge
Black Diamond	SE 17-20-2 W5	SR7	Black Diamond Downstream of HWY 22 Bridge (370 m on SE bank) – town dike

Town name or Roll Number or Street name if Located in MD of Foothills	Legal Land	River Reach	Comments
2002172500	SW 17-20-2 W5	SR7	Near Black Diamond HWY 22 Site (60 m on W bank) – FREC erosion protection completed in 2014 to protect 1160 Drive W 60 m downstream of HWY 22 Bridge
Black Diamond	NE 8-20-2 W5	SR7	Black Diamond Upstream of HWY 22 Bridge (420 m on E bank) – town dike
2002085010 2002085040	NW 8-20-2 W5	SR7	Near Black Diamond Upstream of Black Diamond Site (210 m on W bank) – FREC erosion protection completed in 2014 to protect an MD of Foothills resident approximately 400 m upstream of the HWY 22 Bridge
2002082540	SW 8-20-2 W5	SR7	Black Diamond Well #3 (270 m on N bank) – town dike completed 2016
Turner Valley	SE 7-20-2 W5	SR7	HWY 22 washed out between Black Diamond and Turner Valley (270 m on N bank) – erosion protection completed 2013
Turner Valley	N 6-20-2 W5	SR7	Turner Valley Downstream of Decalta Road Bridge (Alberta Culture Berm) (770 m on NW bank) – provincial dike
Turner Valley	NW 6-20-2 W5	SR7	Turner Valley Decalta Road Bridge (90 m on S bank) – town dike
Turner Valley	NW 6-20-2 W5	SR7	Turner Valley Upstream of Decalta Road Bridge (400 m on NW bank) – town dike

Table A4 Sheep River 2013 Bridge Flood Damages

Description	AT Bridge File No.	Legal Land	River Reach	Comments
HWY 2 Bridges	74031 N & S	NW 19-20-28-W4	SR2	No/minor damages
32 Street Bridge (Okotoks)	79152	NW 22-20-29-W4	SR3	No/minor damages
CP Rail Bridge (Okotoks)	84093	NW 22-20-29-W4	SR3	No info
Okotoks Pedestrian Bridge	81203	SW 28-20-29-W4	SR3	Bridge access washed out
HWY 2A Bridges (Okotoks)	01145 N & S	SE 29-20-29-W4	SR3	No/minor damages
HWY 22 Bridge (Black Diamond)	82075 & 02487	NW 8-20-2-W5	SR7	The east approach of HWY 22 was intentionally breached to alleviate flooding and protect the bridge structure. Section A4 of **Appendix A** is a PowerPoint presentation that contains further information.
Decalta Rd Bridge (Turner Valley)	71004	NW 6-20-2-W5	SR7	North approach washed out

Table A5 Threepoint Creek Flood Damages and Repairs for Years Other than 2013

Roll Number	Legal Land	River Reach	Comments
2002335020 2002337510	N 33-20-2 W5	TR1	2005/08 – Flood concerns reported and assessed. No works constructed.
2102082520	SW 8-21-2 W5	TR2	2008 – Flood concerns reported and assessed. No works constructed.
2102075000	NW 7-21-02 W5	TR3	2003 – Oil pipeline crossing repair immediately downstream of 192 Street bridge. Riprap added to north and south bank.
2103127500	NE 12-21-3 W5	TR3	2005 – Flood concerns reported and assessed. No works constructed.
2103032560	SW 3-21-3 W5	TR5	2008 – Flood concerns reported and assessed. No works constructed at time, but done after 2013 as part of the Millarville FREC erosion protection project.
2103047510 2103047520 2103047530	NE 4-21-3 W5	TR5	2008 – Flood concerns reported and assessed. No works constructed.

Table A6 Threepoint Creek Bridge Flood Damages and Construction Dates for Years Other than 2013

Description	AT Bridge File No.	Legal Land	River Reach	Comments
192 Street W Bridge	2144	NW 7-21-2-W5	TR3	1907 bridge constructed 1932 bridge reconstructed 1943 S abutment converted to pier, approach span added 1957 S pier repaired 1963 S approach washed out 1964 S bank scour filled with rock 1964 timber protection wall replaced with rock 1965 bridge reconstructed 1969 Class 2 rock added to S pier 1980 truss strengthened 1989 W corbels at N pier replaced 1990 bridge reconstructed 1993 N head slope scour repaired with Class 2 rock
HWY 22 Bridge (near Millarville)	13149	SE 3-21-3-W5	TR4	1929 bridge constructed 1942 2 pile approach spans added 1956 bridge reconstructed 1964 S abutment scour hole filled and drift removed 1969 S abutment washed out, water over N approach 1969 S protected guide bank built with Class 2 rock 1990 minor U/S erosion 1999 bridge twinned 2005 flooding over N and S banks, flow along SR 549
2338 Drive Bridge	71578	SW 25-20-4-W5	TR7	1965 bridge constructed 1967 damage to right head slope 1990 bank erosion on left U/S bank 2005 sag along wheel guards - to be replaced in 2008

Table A7 Summary of Threepoint Creek 2013 Flood Damages

Town Name or Roll No. or Street Name if Located in the MD of Foothills	Legal Land	River Reach	Comments
2102050000	SE 5-21-2 W5	TR2	338 Avenue (260 m on S bank) – FREC erosion protection completed 2014
2103127500 2103127560 2103127550	NE 12-21-3 W5	TR3	Racetrack/Gaudet (460 m on N and E banks) – FREC erosion protection completed 2014
2103122500	SW 12-21-3 W5	TR4	208 Street (140 m on N bank) – FREC erosion protection completed 2015
2103025210	W 2-21-3 W5	TR4	Millarville Reservoir (150 m on SE end of Reservoir) – emergency Discover Recovery Program dike repairs and Alberta Community Resilience Program embankment repair
2103030000 2103030050	SE 3-21-3 W5	TR4	Stack and Third (390 m on SW and E banks) – FREC erosion protection completed 2014
2103035010 2103032540 2103032500 2103032510	W 3-21-3 W5	TR5	Millarville (140 m on SW bank) – FREC erosion protection completed 2014
2004257520 2004257540	NE 25-20-4 W5	TR7	Beauchemin Park (350 m on SE bank) – FREC erosion protection completed 2016

Table A8 Threepoint Creek 2013 Bridge Flood Damages

Description	AT Bridge File No.	Legal Land	River Reach	Comments
192 Street W Bridge	2144	NW 7-21-2-W5	TR3	Minor guide bank damages
HWY 22 Bridge (near Millarville)	13149	SE 3-21-3-W5	TR4	No/minor damages
2338 Drive Bridge	71578	SW 25-20-4-W5	TR7	West bank washed out abutment damaged

Appendix B
Open Water Flood Frequency Profiles (Tabular Format)

Reach			W.S. Elev (m)												
Threepoint Creek	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Millarville	34.48	1262.61	1264.06	1264.58	1264.98	1265.28	1265.38	1265.42	1265.43	1265.47	1265.83	1266.13	1266.39	1266.62	1266.80
US Millarville	34.21	1261.47	1262.33	1262.76	1263.01	1263.24	1263.53	1263.72	1263.96	1264.08	1264.43	1264.74	1264.94	1265.16	1265.32
US Millarville	34.11	1259.44	1261.32	1261.85	1262.13	1262.52	1262.83	1263.03	1263.28	1263.42	1263.68	1263.78	1263.93	1264.07	1264.23
US Millarville	33.62	1258.73	1259.71	1260.10	1260.32	1260.43	1260.52	1260.57	1260.61	1260.65	1260.87	1261.11	1261.18	1261.30	1261.36
US Millarville	33.30	1255.94	1257.38	1257.83	1258.31	1258.41	1258.54	1258.63	1258.74	1258.84	1258.97	1259.15	1259.27	1259.42	1259.52
US Millarville	33.04	1254.46	1255.70	1256.12	1256.42	1256.69	1256.92	1257.07	1257.25	1257.30	1257.47	1257.58	1257.67	1257.79	1257.88
US Millarville	32.75	1252.75	1253.58	1254.01	1254.29	1254.49	1254.66	1254.76	1254.86	1255.01	1255.28	1255.56	1255.71	1255.84	1255.93
US Millarville	32.51	1250.37	1251.78	1252.23	1252.58	1253.00	1253.30	1253.51	1253.77	1253.92	1254.36	1254.49	1254.58	1254.69	1255.10
US Millarville	32.39	1250.42	1251.41	1251.88	1252.26	1252.65	1252.97	1253.18	1253.44	1253.57	1254.12	1254.18	1254.21	1254.22	1255.01
US Millarville	32.36	1250.18	1251.04	1251.50	1251.83	1252.17	1252.42	1252.59	1252.80	1252.95	1253.37	1253.47	1253.66	1253.72	1253.85
US Millarville	32.16	1247.39	1248.78	1249.28	1249.61	1249.95	1250.26	1250.47	1250.71	1250.87	1251.25	1251.91	1252.10	1252.37	1252.49
US Millarville	31.95	1246.32	1247.61	1248.13	1248.51	1248.87	1249.20	1249.42	1249.65	1249.80	1249.88	1250.01	1250.08	1250.42	1250.54
US Millarville	31.68	1245.60	1246.72	1247.16	1247.48	1247.76	1248.01	1248.16	1248.24	1248.32	1248.66	1248.91	1249.08	1249.08	1249.14
US Millarville	31.58	1245.09	1246.35	1246.75	1247.03	1247.25	1247.45	1247.56	1247.69	1247.79	1247.96	1248.15	1248.27	1248.59	1248.67
US Millarville	31.45	1244.59	1245.77	1246.10	1246.37	1246.60	1246.71	1246.81	1246.94	1247.01	1247.19	1247.37	1247.48	1247.62	1247.63
US Millarville	31.30	1243.81	1244.81	1245.31	1245.56	1245.69	1245.91	1245.99	1246.07	1246.14	1246.28	1246.42	1246.51	1246.58	1246.65
US Millarville	31.03	1242.70	1243.79	1244.23	1244.43	1244.57	1244.57	1244.62	1244.68	1244.71	1244.81	1244.89	1244.94	1245.00	1245.04
US Millarville	30.75	1241.11	1241.78	1242.16	1242.22	1242.27	1242.55	1242.60	1242.64	1242.70	1242.78	1242.85	1242.91	1242.97	1243.02
US Millarville	30.49	1238.52	1239.70	1240.14	1240.38	1240.49	1240.63	1240.68	1240.81	1240.82	1240.99	1241.08	1241.16	1241.25	1241.31
US Millarville	30.21	1237.09	1238.00	1238.35	1238.69	1238.89	1239.09	1239.26	1239.34	1239.55	1239.72	1239.91	1239.99	1240.06	1240.12
US Millarville	30.00	1236.17	1237.29	1237.69	1237.97	1238.20	1238.27	1238.31	1238.36	1238.41	1238.54	1238.65	1238.73	1238.81	1238.87
US Millarville	29.85	1235.56	1236.79	1236.83	1236.97	1237.09	1237.43	1237.58	1237.63	1237.68	1237.78	1237.85	1237.9.0	1237.96	1238.00
US Millarville	29.61	1234.16	1234.77	1234.93	1235.06	1235.18	1235.25	1235.34	1235.42	1235.48	1235.61	1235.74	1235.87	1235.90	1236.01
US Millarville	29.31	1231.30	1231.93	1232.18	1232.39	1232.69	1232.89	1232.98	1233.09	1233.15	1233.35	1233.45	1233.47	1233.72	1233.72
US Millarville	29.19	1230.10	1230.97	1231.27	1231.49	1231.72	1231.94	1232.08	1232.25	1232.38	1232.65	1232.78	1232.93	1232.96	1233.04
US Millarville	29.00	1228.70	1229.83	1230.11	1230.37	1230.64	1230.84	1230.99	1231.13	1231.19	1231.49	1231.73	1231.79	1232.05	1232.12
US Millarville	28.77	1227.52	1228.55	1228.96	1229.21	1229.47	1229.70	1229.79	1229.90	1229.98	1230.08	1230.23	1230.34	1230.37	1230.51
US Millarville	28.36	1225.14	1226.07	1226.49	1226.70	1226.90	1227.22	1227.33	1227.42	1227.48	1227.74	1227.91	1228.00	1228.14	1228.15
US Millarville	27.98	1222.67	1223.67	1223.87	1224.01	1224.15	1224.26	1224.30	1224.41	1224.47	1224.49	1224.57	1224.65	1224.73	1224.80
US Millarville	27.68	1219.62	1220.79	1221.34	1221.58	1221.74	1221.88	1222.00	1222.09	1222.15	1222.47	1222.62	1222.73	1222.85	1222.94
US Millarville	27.37	1218.07	1218.93	1219.27	1219.52	1219.78	1219.98	1220.05	1220.22	1220.33	1220.34	1220.52	1220.65	1220.77	1220.87
US Millarville	26.86	1214.52	1215.21	1215.53	1215.80	1216.05	1216.28	1216.54	1216.67	1216.78	1217.29	1217.43	1217.52	1217.63	1217.70
US Millarville	26.51	1212.71	1213.00	1213.29	1213.52	1213.77	1213.86	1213.94	1214.01	1214.05	1214.06	1214.14	1214.28	1214.41	1214.44
US Millarville	26.20	1210.93	1211.59	1211.59	1211.62	1211.64	1211.79	1211.84	1211.94	1211.99	1212.27	1212.42	1212.44	1212.57	1212.61
US Millarville	25.93	1209.44	1209.68	1209.68	1209.90	1210.13	1210.26	1210.37	1210.46	1210.56	1210.59	1210.71	1210.80	1210.89	1210.96

Reach			W.S. Elev (m)												
Threepoint Creek	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Millarville	25.52	1206.76	1207.68	1208.12	1208.29	1208.58	1208.74	1208.85	1208.95	1209.03	1209.19	1209.38	1209.50	1209.63	1209.74
US Millarville	25.32	1205.39	1206.77	1207.31	1207.45	1207.67	1207.83	1207.94	1208.06	1208.16	1208.40	1208.62	1208.77	1208.93	1209.05
US Millarville	25.13	1204.64	1205.84	1206.35	1206.59	1206.83	1207.06	1207.18	1207.31	1207.41	1207.65	1207.86	1208.00	1208.16	1208.28
US Millarville	24.85	1203.53	1204.75	1205.10	1205.28	1205.44	1205.52	1205.60	1205.69	1205.76	1205.94	1206.09	1206.19	1206.28	1206.35
US Millarville	24.73	1203.16	1203.99	1204.36	1204.66	1204.94	1205.14	1205.24	1205.36	1205.45	1205.66	1205.80	1205.90	1206.01	1206.09
US Millarville	24.56	1201.71	1202.79	1203.48	1203.87	1204.24	1204.36	1204.45	1204.55	1204.63	1204.81	1205.01	1205.09	1205.18	1205.26
US Millarville	24.33	1200.62	1201.88	1202.42	1202.94	1203.35	1203.67	1203.76	1203.88	1203.94	1204.06	1204.16	1204.23	1204.30	1204.35
US Millarville	23.97	1199.59	1200.58	1201.28	1201.44	1201.79	1202.02	1202.03	1202.15	1202.24	1202.46	1202.64	1202.75	1202.86	1202.95
US Millarville	23.72	1197.59	1199.57	1200.51	1200.70	1200.78	1200.84	1201.03	1201.12	1201.17	1201.31	1201.43	1201.52	1201.62	1201.68
US Millarville	23.37	1195.92	1198.14	1198.29	1198.77	1199.18	1199.33	1199.46	1199.54	1199.63	1199.83	1199.93	1200.02	1200.11	1200.19
US Millarville	23.02	1195.41	1196.86	1197.19	1197.58	1197.94	1198.27	1198.35	1198.58	1198.64	1198.77	1198.99	1199.07	1199.13	1199.17
US Millarville	22.71	1194.04	1195.18	1195.68	1195.98	1196.10	1196.25	1196.36	1196.46	1196.55	1196.71	1196.85	1196.95	1197.05	1197.14
US Millarville	22.41	1192.35	1194.08	1194.42	1194.71	1194.86	1195.02	1195.13	1195.24	1195.33	1195.50	1195.65	1195.75	1195.85	1195.91
US Millarville	22.07	1191.27	1192.40	1192.92	1192.98	1193.04	1193.10	1193.13	1193.17	1193.19	1193.27	1193.33	1193.38	1193.43	1193.48
US Millarville	21.78	1190.10	1191.00	1191.15	1191.33	1191.41	1191.45	1191.51	1191.58	1191.63	1191.75	1191.85	1191.92	1192.00	1192.05
US Millarville	21.51	1188.74	1190.00	1190.20	1190.21	1190.30	1190.49	1190.56	1190.61	1190.67	1190.81	1190.93	1191.01	1191.09	1191.15
US Millarville	21.23	1187.49	1189.18	1189.23	1189.23	1189.23	1189.23	1189.28	1189.38	1189.43	1189.52	1189.61	1189.67	1189.74	1189.79
US Millarville	20.95	1186.27	1187.84	1188.20	1188.22	1188.46	1188.58	1188.64	1188.70	1188.74	1188.89	1188.99	1189.06	1189.14	1189.20
US Millarville	20.72	1185.15	1186.62	1187.22	1187.55	1187.84	1188.00	1188.10	1188.19	1188.24	1188.32	1188.40	1188.46	1188.51	1188.54
US Millarville	20.44	1184.53	1185.79	1186.35	1186.67	1186.85	1187.02	1187.07	1187.15	1187.21	1187.43	1187.59	1187.72	1187.77	1187.83
US Millarville	20.34	1184.18	1185.51	1186.01	1186.29	1186.53	1186.66	1186.78	1186.89	1186.98	1187.29	1187.43	1187.57	1187.59	1187.63
US Millarville	20.22	1183.57	1184.97	1185.50	1185.75	1186.05	1186.35	1186.48	1186.50	1186.55	1186.63	1186.61	1186.76	1186.93	1187.03
US Millarville	20.17	1183.15	1184.60	1185.25	1185.66	1186.08	1186.37	1186.50	1186.53	1186.58	1186.71	1186.82	1186.89	1186.97	1187.02
US Millarville	19.98	1182.35	1184.07	1184.82	1185.48	1186.08	1186.36	1186.50	1186.53	1186.58	1186.71	1186.82	1186.89	1186.96	1187.02
US Millarville	19.95	1181.88	1183.34	1184.03	1184.50	1184.98	1185.74	1185.76	1185.86	1185.92	1186.15	1186.20	1186.23	1186.24	1186.27
US Millarville	19.73	1182.52	1182.69	1182.69	1182.69	1182.97	1183.19	1183.30	1183.44	1183.54	1183.79	1184.01	1184.14	1184.28	1184.37
US Millarville	19.49	1180.81	1181.96	1182.25	1182.47	1182.70	1182.91	1183.00	1183.11	1183.19	1183.39	1183.55	1183.63	1183.72	1183.80
US Millarville	19.35	1181.31	1181.82	1181.94	1182.06	1182.21	1182.33	1182.57	1182.63	1182.69	1182.82	1182.92	1183.06	1183.19	1183.28
US Millarville	18.43	1178.94	1180.42	1180.88	1181.14	1181.46	1181.67	1181.77	1181.89	1181.97	1182.17	1182.35	1182.47	1182.59	1182.68
US Millarville	18.23	1178.14	1180.01	1180.47	1180.85	1181.19	1181.41	1181.50	1181.60	1181.68	1181.86	1182.02	1182.13	1182.24	1182.33
US Millarville	18.07	1177.60	1178.81	1179.45	1179.89	1180.23	1180.47	1180.58	1180.71	1180.79	1180.99	1181.15	1181.25	1181.37	1181.45
US Millarville	17.80	1177.34	1178.37	1178.88	1179.26	1179.52	1179.65	1179.75	1179.86	1179.94	1180.11	1180.25	1180.34	1180.44	1180.51
US Millarville	17.68	1177.32	1178.33	1178.79	1179.13	1179.33	1179.35	1179.42	1179.50	1179.56	1179.71	1179.84	1179.91	1180.00	1180.07
US Millarville	17.54	1176.98	1178.09	1178.40	1178.70	1178.97	1179.12	1179.18	1179.26	1179.33	1179.48	1179.61	1179.67	1179.76	1179.84
US Millarville	17.31	1175.89	1177.44	1177.83	1178.16	1178.21	1178.35	1178.45	1178.57	1178.65	1178.84	1179.00	1179.10	1179.21	1179.29
US Millarville	16.87	1175.35	1176.61	1177.35	1177.48	1177.83	1178.05	1178.17	1178.29	1178.39	1178.60	1178.77	1178.87	1178.98	1179.06

Reach			W.S. Elev (m)												
Threepoint Creek	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Millarville	16.63	1173.80	1176.33	1176.96	1177.25	1177.49	1177.67	1177.76	1177.80	1177.85	1178.00	1178.16	1178.25	1178.33	1178.41
US Millarville	16.44	1174.30	1176.21	1176.70	1176.92	1177.14	1177.30	1177.39	1177.49	1177.56	1177.74	1177.90	1178.00	1178.11	1178.20
US Millarville	16.15	1174.41	1175.77	1176.23	1176.40	1176.58	1176.66	1176.75	1176.83	1176.89	1177.09	1177.18	1177.24	1177.33	1177.39
US Millarville	15.93	1173.60	1174.96	1175.27	1175.65	1175.82	1175.96	1176.02	1176.10	1176.15	1176.22	1176.39	1176.50	1176.59	1176.66
US Millarville	15.74	1172.42	1174.57	1174.94	1175.28	1175.28	1175.41	1175.50	1175.60	1175.67	1175.85	1176.01	1176.12	1176.22	1176.30
US Millarville	15.34	1172.23	1173.68	1174.32	1174.58	1174.68	1174.82	1174.92	1175.02	1175.10	1175.26	1175.37	1175.45	1175.54	1175.61
US Millarville	14.98	1170.52	1171.87	1172.36	1172.86	1173.74	1173.90	1173.99	1174.09	1174.16	1174.39	1174.60	1174.73	1174.87	1174.99
US Millarville	14.88	1170.26	1171.44	1172.25	1172.84	1173.25	1173.56	1173.73	1173.93	1174.07	1174.28	1174.47	1174.59	1174.73	1174.86
US Millarville	14.74	1169.53	1171.08	1171.80	1172.31	1172.63	1172.89	1173.07	1173.17	1173.27	1173.67	1173.84	1173.95	1173.99	1173.99
US Millarville	14.47	1168.99	1170.34	1171.00	1171.40	1171.77	1171.93	1171.99	1172.15	1172.26	1172.38	1172.72	1172.81	1172.81	1173.15
US Millarville	14.33	1168.12	1169.95	1170.38	1170.61	1170.80	1171.17	1171.38	1171.44	1171.58	1171.69	1171.77	1171.83	1171.88	1171.92
US Millarville	14.11	1167.47	1168.95	1169.43	1169.68	1169.91	1170.09	1170.21	1170.34	1170.43	1170.64	1170.72	1170.79	1170.87	1170.92
US Millarville	14.02	1167.43	1168.65	1169.16	1169.39	1169.58	1169.78	1169.88	1169.99	1170.03	1170.12	1170.30	1170.36	1170.43	1170.47
US Millarville	13.82	1165.94	1167.64	1168.34	1168.78	1169.18	1169.46	1169.64	1169.82	1169.92	1169.98	1170.08	1170.14	1170.21	1170.27
US Millarville	13.60	1165.08	1166.87	1167.51	1167.93	1168.34	1168.67	1168.87	1168.99	1169.09	1169.55	1169.66	1169.71	1169.77	1169.81
US Millarville	13.45	1164.75	1166.44	1167.14	1167.66	1168.22	1168.61	1168.84	1168.99	1169.03	1169.22	1169.31	1169.38	1169.45	1169.50
US Millarville	13.30	1164.30	1165.76	1166.53	1167.06	1167.60	1168.06	1168.35	1168.68	1168.85	1168.88	1169.00	1169.08	1169.14	1169.20
US Millarville	12.94	1163.09	1164.78	1165.43	1165.91	1166.29	1166.57	1166.72	1166.79	1166.87	1167.68	1167.84	1167.93	1168.02	1168.08
US Millarville	12.69	1162.40	1164.25	1164.99	1165.55	1165.74	1165.96	1166.08	1166.17	1166.27	1166.61	1166.95	1167.24	1167.28	1167.39
US Millarville	12.40	1160.87	1163.10	1163.91	1164.43	1164.90	1165.28	1165.52	1165.78	1165.99	1166.43	1166.83	1167.14	1167.15	1167.26
US Millarville	12.12	1160.88	1162.39	1163.18	1163.63	1164.01	1164.29	1164.46	1164.59	1164.68	1165.17	1165.45	1165.45	1166.15	1166.38
US Millarville	11.91	1160.31	1161.81	1162.64	1163.19	1163.59	1163.92	1164.12	1164.37	1164.56	1165.32	1165.61	1165.79	1165.96	1166.08
US Millarville	11.72	1159.34	1161.16	1161.81	1162.39	1162.98	1163.50	1163.81	1164.15	1164.39	1165.27	1165.56	1165.75	1165.91	1166.04
US Millarville	11.42	1158.63	1159.81	1160.67	1161.40	1162.16	1162.75	1163.07	1163.44	1163.72	1165.07	1165.38	1165.55	1165.72	1165.85
US Millarville	11.13	1156.91	1159.02	1160.05	1160.86	1161.67	1162.24	1162.55	1162.87	1163.07	1164.68	1164.99	1165.14	1165.28	1165.36
US Millarville	11.09	1157.27	1158.84	1159.75	1160.50	1161.34	1161.91	1162.21	1162.48	1162.58	1162.84	1163.00	1163.13	1163.37	1163.54
US Millarville	10.79	1156.66	1158.19	1159.01	1159.67	1160.55	1161.17	1161.50	1161.84	1162.00	1162.11	1162.28	1162.35	1162.44	1162.51
US Millarville	10.36	1155.34	1157.01	1157.60	1158.06	1158.73	1159.10	1159.33	1159.60	1159.82	1160.31	1160.57	1160.72	1160.85	1160.96
US Millarville	10.01	1154.32	1156.18	1156.73	1157.11	1157.52	1157.84	1158.05	1158.25	1158.35	1158.59	1158.73	1158.86	1159.02	1159.14
US Millarville	9.73	1154.33	1155.47	1156.05	1156.46	1156.84	1157.16	1157.35	1157.55	1157.68	1157.86	1158.11	1158.18	1158.31	1158.41
US Millarville	9.44	1152.97	1154.64	1155.34	1155.57	1155.83	1156.02	1156.12	1156.23	1156.32	1156.62	1156.79	1156.98	1157.08	1157.15
US Millarville	9.11	1151.61	1153.57	1154.05	1154.26	1154.46	1154.61	1154.72	1154.83	1154.90	1155.01	1155.19	1155.32	1155.43	1155.52
US Millarville	8.81	1151.38	1152.65	1153.00	1153.18	1153.35	1153.50	1153.59	1153.70	1153.80	1153.87	1153.98	1154.06	1154.15	1154.23
US Millarville	8.65	1150.05	1151.53	1152.39	1152.51	1152.63	1152.69	1152.76	1152.80	1152.82	1153.03	1153.20	1153.36	1153.46	1153.54
US Millarville	8.46	1149.57	1151.37	1151.62	1151.76	1151.93	1152.06	1152.15	1152.25	1152.32	1152.52	1152.68	1152.82	1152.94	1153.03
US Millarville	8.28	1149.67	1151.00	1151.30	1151.47	1151.64	1151.71	1151.79	1151.88	1151.96	1152.14	1152.30	1152.40	1152.52	1152.61

Reach			W.S. Elev (m)												
Threepoint Creek	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Millarville	8.06	1148.80	1150.31	1150.47	1150.71	1150.95	1151.10	1151.20	1151.32	1151.41	1151.50	1151.65	1151.74	1151.85	1151.93
US Millarville	7.89	1147.57	1149.81	1150.03	1150.28	1150.35	1150.52	1150.61	1150.73	1150.83	1151.02	1151.13	1151.23	1151.34	1151.43
US Millarville	7.65	1147.37	1149.06	1149.47	1149.64	1149.79	1149.95	1150.07	1150.19	1150.29	1150.52	1150.73	1150.87	1151.01	1151.12
US Millarville	7.33	1146.24	1148.22	1148.85	1149.00	1149.23	1149.39	1149.49	1149.60	1149.68	1149.84	1149.99	1150.10	1150.21	1150.29
US Millarville	7.02	1145.33	1147.36	1147.78	1148.09	1148.24	1148.36	1148.43	1148.52	1148.60	1148.82	1148.98	1149.09	1149.21	1149.30
US Millarville	6.82	1145.23	1146.66	1147.35	1147.68	1148.00	1148.14	1148.26	1148.35	1148.41	1148.59	1148.73	1148.83	1148.93	1149.01
US Millarville	6.44	1144.15	1145.80	1146.51	1146.95	1147.41	1147.65	1147.65	1147.76	1147.85	1148.05	1148.21	1148.34	1148.42	1148.51
US Millarville	6.14	1143.80	1144.93	1145.66	1146.10	1146.36	1146.66	1146.88	1146.98	1147.04	1147.19	1147.30	1147.35	1147.47	1147.53
US Millarville	5.85	1142.26	1144.27	1144.93	1145.32	1145.68	1145.76	1145.86	1145.99	1146.09	1146.30	1146.51	1146.61	1146.77	1146.87
US Millarville	5.55	1141.98	1143.78	1144.29	1144.58	1144.82	1145.02	1145.16	1145.32	1145.46	1145.72	1146.02	1146.18	1146.41	1146.51
US Millarville	5.25	1141.11	1142.93	1143.61	1144.05	1144.34	1144.59	1144.78	1144.99	1145.15	1145.56	1145.88	1146.04	1146.27	1146.36
US Millarville	4.90	1140.09	1141.85	1142.73	1143.35	1143.94	1144.18	1144.37	1144.60	1144.78	1145.26	1145.62	1145.78	1146.03	1146.11
US Millarville	4.66	1139.31	1141.19	1142.02	1142.52	1142.96	1143.34	1143.57	1143.84	1144.02	1144.50	1144.94	1145.01	1145.13	1145.28
US Millarville	4.33	1138.83	1140.60	1141.18	1141.67	1142.18	1142.60	1142.76	1143.05	1143.16	1143.44	1143.79	1144.37	1144.57	1144.62
US Millarville	4.29	1138.77	1140.35	1141.14	1141.62	1142.05	1142.39	1142.62	1142.88	1142.95	1143.02	1143.22	1143.49	1144.38	1144.46
US Millarville	4.05	1138.37	1140.05	1140.72	1141.20	1141.55	1141.79	1141.99	1142.21	1142.43	1142.85	1143.06	1143.22	1143.42	1143.58
US Millarville	3.93	1138.23	1139.93	1140.45	1140.80	1141.18	1141.49	1141.68	1141.91	1142.06	1142.33	1142.63	1142.84	1143.08	1143.28
US Millarville	3.79	1137.94	1139.83	1140.23	1140.58	1140.93	1141.22	1141.42	1141.65	1141.84	1142.18	1142.51	1142.74	1143.00	1143.20
US Millarville	3.67	1137.94	1139.70	1139.74	1140.04	1140.34	1140.46	1140.53	1140.60	1140.64	1140.97	1141.22	1141.39	1141.60	1141.72
US Millarville	3.47	1137.48	1139.20	1139.37	1139.43	1139.71	1139.92	1140.04	1140.19	1140.31	1140.61	1140.85	1140.99	1141.13	1141.22
US Millarville	3.15	1136.69	1138.24	1138.67	1138.94	1139.27	1139.55	1139.70	1139.89	1140.02	1140.36	1140.64	1140.76	1140.89	1140.97
US Millarville	2.77	1134.83	1136.89	1137.51	1137.99	1138.42	1138.76	1138.94	1139.10	1139.21	1139.54	1139.81	1140.04	1140.29	1140.50
US Millarville	2.56	1134.77	1136.22	1136.91	1137.38	1137.76	1138.07	1138.27	1138.48	1138.65	1139.11	1139.42	1139.64	1139.89	1140.09
US Millarville	2.38	1134.38	1135.84	1136.56	1137.02	1137.34	1137.65	1137.87	1138.11	1138.30	1138.84	1139.13	1139.35	1139.59	1139.79
US Millarville	2.17	1133.95	1135.28	1135.99	1136.48	1137.00	1137.37	1137.62	1137.88	1138.09	1138.65	1138.92	1139.14	1139.37	1139.57
US Millarville	1.98	1133.14	1134.67	1135.46	1135.99	1136.51	1136.94	1137.22	1137.46	1137.69	1138.27	1138.42	1138.56	1138.71	1138.86
US Millarville	1.71	1132.16	1134.16	1134.91	1135.38	1135.84	1136.23	1136.49	1136.50	1136.67	1137.09	1137.44	1137.69	1137.96	1138.17
US Millarville	1.42	1131.79	1133.04	1133.49	1133.83	1134.20	1134.50	1134.69	1134.95	1135.11	1135.49	1135.81	1136.03	1136.26	1136.44
US Millarville	1.22	1130.89	1132.26	1132.81	1133.20	1133.54	1133.80	1133.97	1134.17	1134.31	1134.66	1134.96	1135.16	1135.37	1135.52
US Millarville	1.01	1130.10	1131.57	1132.12	1132.52	1132.79	1133.02	1133.17	1133.35	1133.48	1133.79	1134.05	1134.22	1134.40	1134.54
US Millarville	0.81	1129.45	1130.89	1131.48	1131.86	1132.15	1132.41	1132.58	1132.77	1132.91	1133.20	1133.41	1133.56	1133.72	1133.85
US Millarville	0.63	1128.33	1130.03	1130.60	1131.05	1131.43	1131.74	1131.94	1132.19	1132.37	1132.76	1132.93	1133.09	1133.28	1133.43
US Millarville	0.48	1127.88	1129.08	1129.68	1130.11	1130.50	1130.81	1131.00	1131.23	1131.36	1131.75	1132.09	1132.33	1132.58	1132.77
US Millarville	0.20	1126.88	1128.60	1129.08	1129.43	1129.74	1129.97	1130.11	1130.26	1130.43	1130.65	1130.83	1130.95	1131.07	1131.16

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Threepoint	59.66	1272.02	1274.10	1274.54	1275.03	1275.57	1276.08	1276.43	1276.85	1277.16	1277.95	1278.66	1279.15	1279.68	1280.10
US Threepoint	59.46	1271.27	1272.86	1273.44	1273.90	1274.40	1274.82	1275.10	1275.40	1275.53	1276.01	1276.64	1277.00	1277.43	1277.73
US Threepoint	59.23	1269.57	1271.64	1272.20	1272.57	1272.99	1273.38	1273.64	1274.00	1274.28	1274.92	1275.45	1275.80	1276.18	1276.48
US Threepoint	59.00	1268.94	1270.49	1271.04	1271.58	1272.13	1272.54	1272.82	1272.85	1273.04	1274.05	1274.20	1274.53	1275.11	1275.17
US Threepoint	58.69	1267.60	1268.98	1269.48	1269.78	1270.17	1270.64	1270.94	1271.38	1271.61	1271.76	1272.70	1273.01	1273.37	1273.63
US Threepoint	58.33	1265.73	1266.60	1267.06	1267.40	1267.75	1267.99	1268.06	1268.27	1268.40	1268.72	1269.00	1269.20	1269.41	1269.58
US Threepoint	58.08	1263.56	1264.73	1265.26	1265.78	1266.25	1266.63	1266.84	1266.96	1267.08	1267.41	1267.70	1267.90	1268.13	1268.30
US Threepoint	57.82	1262.40	1263.23	1263.67	1263.97	1264.30	1264.50	1264.55	1264.79	1264.98	1265.34	1266.10	1266.72	1267.41	1267.95
US Threepoint	57.56	1260.45	1261.31	1261.79	1262.17	1262.50	1262.89	1263.27	1263.78	1264.15	1265.13	1266.05	1266.68	1267.39	1267.95
US Threepoint	57.32	1257.53	1259.34	1260.08	1260.45	1261.03	1261.57	1261.96	1262.44	1262.81	1263.67	1264.42	1264.94	1265.52	1265.96
US Threepoint	57.04	1256.23	1257.58	1258.27	1258.98	1259.54	1259.97	1260.25	1260.58	1260.83	1261.66	1262.41	1262.89	1263.41	1263.83
US Threepoint	56.53	1253.98	1255.29	1255.90	1256.17	1256.67	1257.13	1257.45	1257.82	1258.11	1258.85	1259.50	1260.21	1261.04	1261.67
US Threepoint	56.35	1253.02	1254.10	1254.70	1255.36	1256.20	1256.94	1257.42	1258.03	1258.48	1259.68	1260.77	1261.51	1262.32	1262.95
US Threepoint	56.12	1251.50	1252.77	1253.49	1254.00	1254.49	1254.92	1255.29	1255.73	1256.07	1256.94	1257.76	1258.30	1258.89	1259.36
US Threepoint	55.74	1249.61	1250.63	1251.16	1251.61	1252.16	1252.65	1252.99	1253.40	1253.71	1254.49	1255.21	1255.68	1256.22	1256.65
US Threepoint	55.47	1248.06	1249.14	1249.58	1249.93	1250.34	1250.74	1250.95	1251.19	1251.41	1252.11	1252.77	1253.07	1253.37	1253.61
US Threepoint	55.27	1246.63	1248.09	1248.54	1248.92	1249.26	1249.52	1249.77	1250.08	1250.33	1250.98	1251.35	1251.89	1252.26	1252.55
US Threepoint	55.08	1245.66	1246.80	1247.38	1247.90	1248.44	1248.77	1249.01	1249.25	1249.46	1249.82	1250.24	1250.63	1250.82	1251.07
US Threepoint	54.55	1242.53	1243.51	1244.02	1244.37	1244.70	1245.09	1245.36	1245.71	1245.95	1246.71	1247.21	1247.43	1247.94	1248.19
US Threepoint	54.33	1239.90	1241.87	1242.37	1242.82	1243.45	1243.86	1244.17	1244.57	1244.87	1245.63	1246.33	1246.82	1247.35	1247.78
US Threepoint	54.10	1239.41	1240.59	1241.18	1241.57	1241.87	1242.40	1242.68	1243.00	1243.24	1243.82	1244.33	1244.69	1245.07	1245.36
US Threepoint	53.67	1236.66	1237.82	1238.43	1238.88	1239.49	1239.89	1240.14	1240.47	1240.80	1241.15	1241.65	1242.00	1242.36	1242.65
US Threepoint	53.35	1234.36	1235.92	1236.44	1236.85	1237.28	1237.68	1237.97	1238.32	1238.46	1239.48	1239.95	1240.23	1240.56	1240.79
US Threepoint	52.95	1232.82	1233.64	1234.09	1234.48	1234.92	1235.21	1235.39	1235.75	1236.01	1236.37	1236.71	1236.92	1237.14	1237.32
US Threepoint	52.70	1231.34	1232.73	1233.31	1233.71	1234.09	1234.32	1234.54	1234.78	1234.95	1235.37	1235.80	1236.08	1236.37	1236.60
US Threepoint	52.40	1229.51	1230.96	1231.38	1231.82	1232.20	1232.60	1232.70	1232.85	1232.99	1233.33	1233.58	1233.76	1234.00	1234.18
US Threepoint	52.10	1228.08	1229.38	1229.91	1230.28	1230.69	1230.94	1231.26	1231.52	1231.67	1232.00	1232.38	1232.62	1232.71	1232.86
US Threepoint	51.74	1226.19	1227.11	1227.51	1227.90	1228.32	1228.74	1228.92	1229.12	1229.27	1229.68	1230.02	1230.35	1230.87	1231.11
US Threepoint	51.44	1224.39	1225.94	1226.60	1227.07	1227.52	1227.88	1228.12	1228.39	1228.60	1229.14	1229.61	1229.94	1230.30	1230.58
US Threepoint	51.17	1223.15	1224.53	1224.99	1225.37	1225.87	1226.19	1226.41	1226.67	1226.85	1227.27	1227.66	1227.90	1228.17	1228.40

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Threepoint	50.96	1221.78	1223.42	1224.09	1224.38	1224.64	1224.90	1225.10	1225.35	1225.57	1226.05	1226.63	1227.08	1227.60	1228.00
US Threepoint	50.61	1219.23	1220.75	1221.48	1222.01	1222.46	1223.00	1223.37	1223.81	1224.15	1225.14	1225.96	1226.52	1227.13	1227.60
US Threepoint	50.51	1218.53	1220.30	1221.01	1221.56	1222.19	1222.74	1223.12	1223.57	1223.91	1224.79	1225.57	1226.10	1226.69	1227.16
US Threepoint	50.21	1217.65	1218.99	1219.83	1220.53	1221.21	1221.74	1222.09	1222.52	1222.83	1223.63	1224.32	1224.78	1225.29	1225.69
US Threepoint	49.83	1215.71	1217.26	1217.84	1218.18	1218.70	1219.18	1219.49	1219.80	1220.05	1220.67	1221.22	1221.61	1222.02	1222.34
US Threepoint	49.54	1214.09	1215.60	1216.36	1216.91	1217.47	1217.94	1218.26	1218.66	1218.97	1219.78	1220.51	1221.00	1221.56	1221.85
US Threepoint	49.18	1211.47	1213.43	1214.21	1214.82	1215.45	1215.99	1216.39	1216.81	1217.14	1217.98	1218.74	1219.31	1219.95	1220.66
US Threepoint	48.94	1210.53	1212.09	1212.88	1213.49	1214.11	1214.69	1215.09	1215.57	1215.91	1216.56	1217.15	1217.51	1217.77	1218.05
US Threepoint	48.69	1208.88	1210.63	1211.24	1211.76	1212.33	1212.79	1213.07	1213.38	1213.62	1214.41	1214.99	1215.42	1216.00	1216.43
US Threepoint	48.44	1207.09	1208.77	1209.64	1210.28	1210.95	1211.54	1211.94	1212.42	1212.78	1213.70	1214.54	1215.12	1215.77	1216.28
US Threepoint	48.19	1205.74	1208.06	1208.91	1209.55	1210.23	1210.80	1211.19	1211.66	1212.02	1212.94	1213.77	1214.36	1214.98	1215.44
US Threepoint	48.15	1205.93	1207.79	1208.52	1209.06	1209.62	1210.09	1210.39	1210.77	1211.06	1211.75	1212.17	1212.47	1212.96	1213.36
US Threepoint	48.08	1205.62	1207.12	1207.79	1208.28	1208.78	1209.18	1209.44	1209.70	1209.89	1210.36	1210.72	1211.00	1211.34	1211.61
US Threepoint	47.92	1203.76	1205.76	1206.26	1206.74	1207.32	1207.71	1207.98	1208.41	1208.74	1209.51	1210.24	1210.74	1211.30	1211.74
US Threepoint	47.88	1203.23	1205.55	1206.24	1206.74	1207.28	1207.74	1208.06	1208.45	1208.75	1209.49	1210.17	1210.64	1211.17	1211.59
US Threepoint	47.62	1203.81	1204.81	1205.25	1205.64	1205.98	1206.25	1206.42	1206.61	1206.75	1207.28	1207.78	1208.12	1208.50	1208.80
US Threepoint	47.35	1201.82	1202.89	1203.54	1204.13	1204.69	1205.14	1205.45	1205.81	1206.08	1206.78	1207.42	1207.85	1208.30	1208.66
US Threepoint	47.08	1199.95	1201.79	1202.41	1202.81	1203.21	1203.65	1203.90	1204.17	1204.38	1204.89	1205.21	1205.47	1205.83	1206.09
US Threepoint	46.78	1198.84	1200.05	1200.56	1201.05	1201.51	1201.68	1201.86	1202.06	1202.21	1202.59	1203.08	1204.07	1204.27	1204.41
US Threepoint	46.63	1197.65	1199.16	1199.91	1200.38	1200.86	1201.22	1201.45	1201.68	1201.83	1202.28	1203.03	1204.13	1204.36	1204.53
US Threepoint	46.46	1197.09	1198.51	1199.14	1199.43	1199.71	1200.04	1200.30	1200.67	1200.98	1201.71	1202.77	1204.05	1204.28	1204.45
US Threepoint	46.20	1195.55	1196.57	1197.26	1197.85	1198.53	1199.07	1199.47	1199.95	1200.31	1201.32	1202.55	1203.94	1204.16	1204.32
US Threepoint	46.10	1194.45	1196.03	1196.82	1197.44	1198.12	1198.58	1198.96	1199.41	1199.75	1200.61	1202.07	1203.84	1204.05	1204.21
US Threepoint	46.06	1194.37	1195.69	1196.22	1196.59	1197.00	1197.42	1197.73	1198.09	1198.35	1199.01	1199.82	1200.24	1200.69	1201.01
US Threepoint	46.01	1194.33	1195.43	1195.97	1196.40	1196.89	1197.33	1197.62	1197.96	1198.23	1198.92	1199.52	1199.96	1200.45	1200.76
US Threepoint	45.97	1193.87	1195.17	1195.58	1195.87	1196.17	1196.46	1196.71	1197.00	1197.21	1197.77	1198.28	1198.64	1199.00	1199.47
US Threepoint	45.94	1193.51	1194.79	1195.20	1195.53	1195.98	1196.29	1196.50	1196.74	1196.91	1197.36	1197.73	1197.98	1198.34	1198.58
US Threepoint	45.88	1193.08	1194.25	1194.86	1195.34	1195.88	1196.22	1196.44	1196.70	1196.90	1197.41	1197.84	1198.14	1198.65	1198.96
US Threepoint	45.73	1191.92	1193.38	1193.93	1194.52	1195.04	1195.34	1195.56	1195.83	1196.04	1196.58	1196.90	1197.15	1197.41	1197.61
US Threepoint	45.53	1191.40	1192.50	1193.17	1193.76	1194.26	1194.64	1194.92	1195.27	1195.53	1196.24	1196.52	1196.81	1197.14	1197.39
US Threepoint	45.29	1190.01	1191.81	1192.49	1192.98	1193.49	1193.56	1193.71	1193.85	1193.97	1194.22	1194.78	1195.04	1195.28	1195.49
US Threepoint	45.05	1189.23	1190.42	1190.88	1191.22	1191.61	1192.28	1192.44	1192.61	1192.71	1192.93	1193.08	1193.23	1193.40	1193.54
US Threepoint	44.78	1187.21	1188.48	1189.12	1189.64	1190.22	1190.68	1190.96	1191.32	1191.47	1191.70	1191.90	1192.06	1192.28	1192.42
US Threepoint	44.41	1184.74	1186.67	1187.34	1187.87	1188.42	1188.82	1189.06	1189.32	1189.52	1190.05	1190.53	1190.87	1191.06	1191.31
US Threepoint	44.13	1184.28	1185.64	1186.25	1186.73	1187.26	1187.71	1187.97	1188.23	1188.45	1189.01	1189.56	1189.84	1190.30	1190.62
US Threepoint	44.00	1183.31	1184.68	1185.14	1185.53	1185.92	1186.33	1186.69	1187.05	1187.25	1187.71	1188.05	1188.43	1188.72	1188.92

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Threepoint	43.91	1182.47	1184.04	1184.54	1184.92	1185.31	1185.66	1185.88	1186.14	1186.40	1186.73	1187.05	1187.33	1187.60	1188.02
US Threepoint	43.47	1180.57	1181.72	1182.13	1182.3	1182.59	1182.85	1183.01	1183.21	1183.36	1183.72	1184.05	1184.27	1184.51	1184.66
US Threepoint	43.28	1179.42	1180.76	1180.95	1181.12	1181.4	1181.57	1181.7	1181.84	1181.94	1182.16	1182.35	1182.47	1182.6	1182.75
US Threepoint	43.04	1178.15	1179.08	1179.49	1179.74	1179.89	1180.07	1180.17	1180.28	1180.35	1180.57	1180.77	1180.9	1181.04	1181.15
US Threepoint	42.82	1175.80	1177.17	1177.58	1177.79	1178.13	1178.26	1178.38	1178.48	1178.56	1178.74	1178.88	1178.98	1179.09	1179.17
US Threepoint	42.62	1174.68	1175.68	1176.1	1176.29	1176.78	1177.15	1177.37	1177.61	1177.78	1178.16	1178.48	1178.69	1178.92	1179.09
US Threepoint	42.45	1173.23	1174.44	1174.96	1175.42	1175.97	1176.36	1176.78	1177.08	1177.26	1177.7	1178.04	1178.26	1178.5	1178.69
US Threepoint	42.29	1172.09	1173.55	1174.29	1174.9	1175.6	1176.07	1176.53	1176.8	1176.96	1177.32	1177.6	1177.79	1177.98	1178.13
US Threepoint	42.24	1171.12	1173.34	1174.01	1174.57	1175.36	1175.72	1176.3	1176.56	1176.72	1177.17	1177.43	1177.61	1177.78	1177.91
US Threepoint	42.21	1171.16	1172.87	1173.21	1173.69	1174.16	1174.59	1174.86	1175.66	1175.85	1176.36	1176.64	1176.83	1176.96	1177.07
US Threepoint	42.12	1170.64	1172.28	1172.77	1173.21	1173.65	1174.02	1174.26	1174.54	1174.73	1175.19	1175.52	1175.72	1175.90	1176.02
US Threepoint	41.94	1170.11	1171.33	1171.92	1172.37	1172.77	1173.11	1173.35	1173.63	1173.86	1174.02	1174.62	1174.74	1174.94	1175.15
US Threepoint	41.80	1169.79	1170.79	1171.33	1171.76	1172.26	1172.63	1172.89	1173.20	1173.43	1174.05	1174.65	1174.68	1174.90	1175.06
US Threepoint	41.63	1168.99	1169.91	1170.34	1170.62	1170.81	1171.11	1171.32	1171.57	1171.77	1172.26	1172.70	1173.58	1173.82	1173.98
US Threepoint	41.36	1166.79	1167.94	1168.52	1168.89	1169.16	1169.30	1169.44	1169.55	1169.67	1169.92	1170.10	1170.22	1170.36	1170.47
US Threepoint	41.13	1165.31	1166.51	1167.17	1167.72	1167.82	1168.09	1168.17	1168.33	1168.39	1168.59	1168.80	1168.94	1169.08	1169.18
US Threepoint	40.81	1162.66	1163.77	1164.29	1164.74	1165.10	1165.27	1165.58	1165.82	1165.99	1166.34	1166.63	1166.82	1167.11	1167.29
US Threepoint	40.51	1160.71	1162.33	1162.88	1163.23	1163.62	1163.96	1164.16	1164.21	1164.30	1164.61	1164.89	1165.07	1165.15	1165.30
US Threepoint	40.23	1159.26	1160.44	1160.89	1161.13	1161.39	1161.63	1161.79	1162.24	1162.39	1162.65	1162.84	1162.97	1163.22	1163.32
US Threepoint	39.85	1157.02	1158.40	1158.72	1159.02	1159.32	1159.50	1159.62	1159.76	1159.87	1160.14	1160.33	1160.47	1160.62	1160.73
US Threepoint	39.50	1155.15	1156.17	1156.49	1156.58	1156.68	1156.80	1156.88	1156.97	1157.03	1157.20	1157.35	1157.45	1157.57	1157.64
US Threepoint	39.23	1152.76	1154.19	1154.58	1154.76	1154.93	1155.09	1155.18	1155.31	1155.39	1155.58	1155.77	1155.89	1156.03	1156.13
US Threepoint	39.12	1152.08	1153.91	1153.91	1154.15	1154.38	1154.53	1154.63	1154.76	1154.84	1155.06	1155.26	1155.40	1155.55	1155.67
US Threepoint	38.84	1149.74	1151.47	1152.17	1152.41	1152.63	1152.84	1152.96	1153.10	1153.20	1153.46	1153.70	1153.86	1154.03	1154.16
US Threepoint	38.65	1149.49	1150.57	1151.04	1151.46	1151.78	1151.96	1152.11	1152.27	1152.38	1152.63	1152.84	1152.99	1153.15	1153.28
US Threepoint	38.35	1147.39	1149.22	1149.86	1150.14	1150.49	1150.62	1150.74	1150.89	1151.00	1151.26	1151.51	1151.65	1151.82	1151.95
US Threepoint	38.17	1147.09	1148.52	1148.83	1149.13	1149.26	1149.47	1149.58	1149.70	1149.79	1149.99	1150.17	1150.28	1150.39	1150.47
US Threepoint	37.99	1145.72	1147.62	1147.94	1147.95	1148.18	1148.20	1148.24	1148.30	1148.35	1148.48	1148.60	1148.68	1148.79	1148.87
US Threepoint	37.74	1144.10	1145.34	1145.91	1146.38	1146.47	1146.66	1146.79	1146.92	1147.02	1147.26	1147.48	1147.64	1147.81	1147.94
US Threepoint	37.58	1143.55	1144.96	1145.60	1145.89	1146.08	1146.23	1146.32	1146.43	1146.51	1146.73	1146.94	1147.10	1147.27	1147.41
US Threepoint	37.40	1142.68	1144.12	1144.74	1145.30	1145.59	1145.79	1145.92	1145.97	1146.01	1146.08	1146.11	1146.11	1146.23	1146.32
US Threepoint	37.25	1141.57	1142.60	1142.85	1142.95	1143.30	1143.47	1143.58	1143.69	1143.76	1143.94	1144.10	1144.23	1144.36	1144.37
US Threepoint	36.93	1139.51	1141.10	1141.35	1141.65	1141.66	1141.81	1141.90	1141.97	1142.03	1142.15	1142.29	1142.38	1142.53	1143.01
US Threepoint	36.64	1138.80	1140.01	1140.00	1140.24	1140.42	1140.55	1140.66	1140.75	1140.80	1140.90	1140.99	1141.05	1141.13	1141.19
US Threepoint	36.53	1138.34	1139.22	1139.47	1139.59	1139.84	1139.99	1140.14	1140.22	1140.27	1140.38	1140.47	1140.55	1140.62	1140.70
US Threepoint	36.31	1136.56	1137.71	1138.02	1138.22	1138.40	1138.51	1138.57	1138.63	1138.66	1138.74	1138.81	1138.87	1138.93	1138.98

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
US Threepoint	35.91	1133.84	1135.46	1135.61	1135.93	1136.16	1136.26	1136.31	1136.38	1136.41	1136.49	1136.60	1136.68	1136.72	1136.75
US Threepoint	35.61	1132.24	1133.48	1133.79	1133.81	1133.91	1134.00	1134.06	1134.07	1134.14	1134.23	1134.23	1134.24	1134.36	1134.46
US Threepoint	35.37	1131.46	1132.34	1132.59	1132.84	1133.07	1133.20	1133.30	1133.38	1133.45	1133.58	1133.69	1133.78	1133.88	1133.96
US Threepoint	35.27	1130.87	1132.26	1132.43	1132.59	1132.77	1132.84	1132.92	1133.00	1133.06	1133.18	1133.28	1133.35	1133.44	1133.51
US Threepoint	35.02	1129.22	1130.07	1130.46	1130.71	1130.92	1131.10	1131.16	1131.22	1131.24	1131.33	1131.42	1131.48	1131.56	1131.63
US Threepoint	34.89	1128.98	1129.80	1129.80	1129.95	1130.22	1130.45	1130.54	1130.64	1130.76	1130.90	1131.02	1131.12	1131.22	1131.31
DS Threepoint	34.28	1126.03	1127.85	1128.19	1128.48	1128.75	1128.93	1129.03	1129.14	1129.22	1129.41	1129.57	1129.68	1129.80	1129.89
DS Threepoint	34.12	1125.01	1127.23	1127.87	1127.93	1128.24	1128.45	1128.55	1128.66	1128.74	1128.92	1129.06	1129.16	1129.26	1129.34
DS Threepoint	33.83	1124.45	1126.20	1126.26	1126.91	1127.19	1127.34	1127.43	1127.53	1127.60	1127.77	1127.94	1128.07	1128.21	1128.33
DS Threepoint	33.62	1124.00	1125.25	1125.72	1126.06	1126.39	1126.59	1126.71	1126.84	1126.93	1127.17	1127.38	1127.53	1127.70	1127.83
DS Threepoint	33.44	1122.42	1124.53	1125.29	1125.47	1125.86	1126.13	1126.27	1126.42	1126.53	1126.80	1127.03	1127.19	1127.37	1127.52
DS Threepoint	33.23	1122.14	1123.77	1124.41	1124.83	1125.28	1125.56	1125.71	1125.86	1125.96	1126.22	1126.45	1126.61	1126.80	1126.95
DS Threepoint	33.04	1121.41	1123.17	1123.65	1124.02	1124.39	1124.67	1124.84	1125.02	1125.15	1125.48	1125.76	1125.97	1126.20	1126.38
DS Threepoint	32.89	1120.48	1122.59	1123.13	1123.46	1123.80	1124.06	1124.23	1124.41	1124.53	1124.85	1125.09	1125.25	1125.41	1125.53
DS 128 Street	32.68	1119.92	1121.88	1122.72	1122.99	1123.36	1123.60	1123.76	1123.92	1124.02	1124.30	1124.52	1124.67	1124.82	1124.94
DS 128 Street	32.51	1119.08	1121.20	1122.08	1122.51	1122.97	1123.23	1123.42	1123.56	1123.65	1123.90	1124.09	1124.23	1124.37	1124.48
DS 128 Street	32.32	1118.41	1120.47	1121.27	1121.63	1122.05	1122.42	1122.57	1122.73	1122.83	1123.10	1123.32	1123.46	1123.59	1123.69
DS 128 Street	32.00	1117.55	1119.58	1120.28	1120.73	1120.96	1121.19	1121.36	1121.48	1121.58	1121.81	1122.00	1122.13	1122.24	1122.33
DS 128 Street	31.63	1115.99	1118.35	1118.83	1119.13	1119.46	1119.70	1119.83	1119.94	1120.00	1120.17	1120.31	1120.40	1120.50	1120.57
DS 128 Street	31.27	1115.19	1117.39	1117.63	1117.90	1118.01	1118.22	1118.30	1118.42	1118.50	1118.67	1118.80	1118.91	1119.00	1119.07
DS 128 Street	30.87	1114.01	1115.91	1116.18	1116.30	1116.58	1116.71	1116.81	1116.89	1116.93	1117.08	1117.22	1117.34	1117.42	1117.49
DS 128 Street	30.44	1112.43	1113.92	1114.32	1114.52	1114.57	1114.70	1114.77	1114.87	1114.96	1115.14	1115.27	1115.35	1115.44	1115.51
DS 128 Street	30.09	1110.34	1112.29	1112.85	1113.21	1113.34	1113.57	1113.71	1113.77	1113.79	1113.98	1114.13	1114.24	1114.35	1114.44
DS 128 Street	29.73	1109.08	1110.58	1111.05	1111.33	1111.65	1111.80	1111.89	1112.14	1112.35	1112.52	1112.65	1112.73	1112.81	1112.86
DS 128 Street	29.46	1107.80	1109.20	1109.43	1109.57	1109.63	1109.74	1109.83	1109.91	1109.98	1110.14	1110.28	1110.36	1110.45	1110.51
DS 128 Street	29.12	1105.65	1107.21	1107.63	1107.91	1108.15	1108.26	1108.34	1108.44	1108.51	1108.67	1108.78	1108.87	1108.96	1109.03
DS 128 Street	28.89	1104.27	1106.27	1106.63	1106.94	1107.16	1107.38	1107.47	1107.53	1107.58	1107.72	1107.87	1107.94	1108.01	1108.07
DS 128 Street	28.66	1103.25	1104.91	1105.45	1105.66	1105.89	1105.95	1106.04	1106.19	1106.27	1106.43	1106.53	1106.63	1106.72	1106.80
DS 128 Street	28.38	1102.37	1103.91	1104.16	1104.54	1104.74	1104.88	1104.98	1105.11	1105.19	1105.42	1105.62	1105.68	1105.79	1105.86
DS 128 Street	28.02	1099.38	1102.36	1102.83	1102.92	1103.10	1103.15	1103.25	1103.33	1103.39	1103.53	1103.66	1103.73	1103.79	1103.84
DS 128 Street	27.79	1099.01	1101.11	1101.11	1101.36	1101.44	1101.54	1101.64	1101.75	1101.83	1102.03	1102.20	1102.31	1102.43	1102.52
DS 128 Street	27.53	1097.72	1099.12	1099.84	1100.44	1100.67	1101.01	1101.16	1101.28	1101.37	1101.59	1101.77	1101.90	1102.02	1102.11
DS 128 Street	27.25	1094.84	1097.47	1098.50	1099.12	1099.49	1099.63	1100.36	1100.46	1100.54	1100.71	1100.85	1100.94	1101.02	1101.09
DS 128 Street	26.88	1094.03	1096.36	1097.37	1097.95	1098.36	1098.54	1098.68	1098.76	1098.87	1099.13	1099.34	1099.49	1099.63	1099.76
DS 128 Street	26.47	1093.01	1094.87	1095.59	1095.82	1096.10	1096.47	1096.60	1096.73	1096.80	1096.98	1097.12	1097.21	1097.29	1097.34
DS 128 Street	26.24	1091.71	1094.07	1094.41	1094.78	1095.03	1095.20	1095.31	1095.43	1095.52	1095.72	1095.88	1095.99	1096.10	1096.19

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
DS 128 Street	25.82	1090.61	1092.68	1093.17	1093.29	1093.55	1093.66	1093.76	1093.87	1093.94	1094.12	1094.27	1094.39	1094.50	1094.59
DS 128 Street	25.50	1088.13	1090.82	1091.59	1092.01	1092.19	1092.41	1092.54	1092.68	1092.78	1093.03	1093.24	1093.33	1093.44	1093.53
DS 128 Street	25.21	1087.57	1089.69	1090.12	1090.37	1090.89	1091.07	1091.34	1091.44	1091.51	1091.69	1091.82	1091.98	1092.10	1092.17
DS 128 Street	24.99	1086.24	1088.92	1089.41	1089.65	1089.84	1089.98	1090.07	1090.17	1090.24	1090.36	1090.52	1090.62	1090.73	1090.81
DS 128 Street	24.78	1085.32	1088.51	1088.53	1088.65	1088.82	1088.97	1089.07	1089.19	1089.27	1089.48	1089.65	1089.77	1089.88	1089.97
DS 128 Street	24.54	1085.20	1087.45	1087.74	1088.04	1088.31	1088.44	1088.55	1088.67	1088.75	1088.95	1089.12	1089.24	1089.35	1089.43
DS 128 Street	24.40	1084.68	1086.89	1087.56	1087.91	1088.18	1088.31	1088.41	1088.51	1088.60	1088.78	1088.94	1089.05	1089.15	1089.23
DS 128 Street	24.12	1083.50	1085.45	1086.04	1086.69	1087.24	1087.57	1087.65	1087.74	1087.78	1087.93	1088.03	1088.09	1088.17	1088.25
DS 128 Street	23.85	1082.67	1084.65	1085.45	1085.59	1085.82	1086.00	1086.14	1086.33	1086.46	1086.67	1086.87	1086.97	1087.10	1087.19
DS 128 Street	23.58	1080.78	1083.43	1084.05	1084.42	1084.82	1085.00	1085.16	1085.33	1085.46	1085.75	1085.95	1086.15	1086.25	1086.38
DS 128 Street	23.27	1080.11	1081.82	1082.57	1082.98	1083.27	1083.54	1083.70	1083.87	1084.00	1084.32	1084.59	1084.78	1084.96	1085.10
DS 128 Street	22.98	1078.69	1080.87	1081.60	1082.04	1082.40	1082.55	1082.71	1082.88	1083.00	1083.31	1083.57	1083.75	1083.89	1084.01
DS 128 Street	22.77	1078.06	1080.25	1080.87	1081.27	1081.56	1081.70	1081.84	1082.00	1082.12	1082.42	1082.66	1082.84	1083.01	1083.16
DS 128 Street	22.46	1076.93	1079.11	1079.61	1080.03	1080.38	1080.61	1080.78	1080.97	1081.09	1081.42	1081.69	1081.87	1082.06	1082.21
DS 128 Street	22.17	1075.89	1078.05	1078.69	1079.06	1079.22	1079.51	1079.70	1079.83	1079.96	1080.30	1080.56	1080.75	1080.94	1081.10
DS 128 Street	21.85	1074.81	1076.12	1076.78	1077.10	1077.59	1077.80	1077.93	1078.24	1078.36	1078.67	1079.02	1079.26	1079.50	1079.70
DS 128 Street	21.80	1072.52	1075.15	1076.05	1076.62	1077.26	1077.69	1077.97	1078.26	1078.35	1078.59	1078.88	1079.08	1079.31	1079.48
DS 128 Street	21.49	1071.75	1073.75	1074.74	1075.39	1075.92	1076.34	1076.62	1076.91	1077.14	1077.72	1078.17	1078.44	1078.71	1078.94
DS 128 Street	21.06	1070.39	1072.68	1073.58	1074.12	1074.50	1074.76	1074.91	1075.08	1075.19	1075.36	1075.55	1075.79	1076.02	1076.20
DS 128 Street	20.81	1070.05	1072.10	1072.87	1072.96	1073.34	1073.57	1073.72	1073.85	1073.96	1074.24	1074.44	1074.57	1074.72	1074.82
DS 128 Street	20.69	1069.83	1071.77	1072.25	1072.63	1072.66	1072.83	1072.93	1073.01	1073.08	1073.22	1073.35	1073.44	1073.55	1073.64
DS 128 Street	20.41	1069.40	1070.79	1071.24	1071.32	1071.54	1071.70	1071.81	1071.93	1072.01	1072.26	1072.47	1072.63	1072.80	1072.93
DS 128 Street	20.09	1067.02	1069.45	1070.01	1070.24	1070.43	1070.65	1070.81	1070.98	1071.10	1071.44	1071.73	1071.93	1072.13	1072.29
DS 128 Street	19.71	1064.98	1067.12	1068.18	1068.77	1069.20	1069.49	1069.67	1069.85	1069.98	1070.30	1070.57	1070.75	1070.92	1071.06
DS 128 Street	19.29	1063.47	1066.08	1067.06	1067.51	1067.87	1068.12	1068.28	1068.46	1068.59	1068.90	1069.15	1069.32	1069.49	1069.63
DS 128 Street	18.99	1062.68	1065.35	1066.32	1066.81	1067.15	1067.34	1067.52	1067.57	1067.62	1067.88	1068.10	1068.25	1068.40	1068.51
DS 128 Street	18.69	1061.97	1063.66	1064.12	1064.61	1064.92	1065.13	1065.23	1065.49	1065.66	1065.91	1066.07	1066.17	1066.28	1066.36
DS 128 Street	18.34	1060.09	1062.51	1063.05	1063.19	1063.43	1063.63	1063.77	1063.77	1063.87	1064.08	1064.28	1064.40	1064.53	1064.62
DS 128 Street	18.21	1059.43	1061.90	1062.39	1062.60	1062.85	1063.03	1063.15	1063.43	1063.55	1063.65	1063.78	1063.91	1064.04	1064.14
DS 128 Street	18.15	1059.20	1061.76	1062.18	1062.41	1062.63	1062.80	1062.91	1063.04	1063.14	1063.53	1063.65	1063.77	1063.90	1064.00
DS 128 Street	18.07	1058.49	1061.20	1061.66	1061.97	1062.17	1062.35	1062.49	1062.66	1062.77	1063.10	1063.41	1063.53	1063.64	1063.74
DS 128 Street	18.01	1058.19	1060.89	1061.33	1061.63	1061.92	1062.13	1062.28	1062.46	1062.59	1062.93	1063.14	1063.23	1063.33	1063.42
DS 128 Street	17.65	1056.47	1059.35	1059.58	1060.02	1060.30	1060.59	1060.75	1060.90	1061.01	1061.25	1061.56	1061.78	1061.98	1062.14
DS 128 Street	17.45	1056.42	1058.55	1059.32	1059.93	1060.20	1060.48	1060.66	1060.84	1060.97	1061.29	1061.55	1061.74	1061.91	1062.06
DS 128 Street	17.22	1054.82	1057.46	1058.05	1058.47	1059.34	1059.57	1059.77	1059.93	1060.03	1060.29	1060.49	1060.63	1060.76	1060.86
DS 128 Street	17.04	1055.24	1056.91	1057.62	1057.93	1058.19	1058.37	1058.49	1058.63	1058.73	1059.00	1059.23	1059.40	1059.56	1059.73

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
DS 128 Street	16.77	1053.81	1055.81	1056.66	1056.88	1057.19	1057.43	1057.59	1057.77	1057.90	1058.22	1058.51	1058.72	1058.92	1059.15
DS 128 Street	16.45	1052.57	1054.45	1055.28	1055.96	1056.46	1056.92	1057.07	1057.26	1057.39	1057.68	1057.99	1058.23	1058.42	1058.72
DS 128 Street	16.22	1051.81	1053.55	1054.33	1054.84	1055.24	1055.37	1055.85	1056.28	1056.40	1057.04	1057.46	1057.76	1057.96	1058.37
DS 128 Street	16.07	1051.12	1053.05	1053.74	1054.24	1054.72	1055.30	1055.68	1055.98	1056.30	1057.08	1057.47	1057.76	1057.95	1058.35
DS 128 Street	15.95	1050.80	1052.62	1053.38	1053.98	1054.43	1054.82	1055.11	1055.88	1056.22	1057.03	1057.42	1057.71	1057.89	1058.30
DS 128 Street	15.91	1051.09	1052.49	1053.29	1053.91	1054.34	1054.72	1054.99	1055.39	1055.90	1056.89	1057.29	1057.59	1057.77	1058.20
DS 128 Street	15.88	1050.91	1052.31	1053.14	1053.79	1054.17	1054.51	1054.80	1055.17	1055.52	1056.56	1056.93	1057.24	1057.36	1057.81
DS 128 Street	15.86	1050.68	1052.23	1053.06	1053.67	1053.94	1054.07	1054.21	1054.35	1054.44	1054.74	1055.42	1055.89	1056.26	1056.44
DS 128 Street	15.73	1050.03	1051.65	1052.28	1052.70	1053.33	1053.66	1053.81	1053.98	1054.09	1054.37	1054.61	1054.76	1054.89	1055.06
DS 128 Street	15.56	1049.37	1051.27	1051.79	1052.14	1052.49	1052.75	1052.93	1053.15	1053.30	1053.69	1053.92	1054.10	1054.29	1054.45
DS 128 Street	15.40	1049.23	1050.74	1051.53	1051.83	1052.17	1052.42	1052.60	1052.83	1052.94	1053.27	1053.34	1053.53	1053.70	1053.82
DS 128 Street	15.36	1048.39	1050.65	1051.32	1051.67	1051.99	1052.22	1052.41	1052.68	1052.81	1053.20	1053.25	1053.45	1053.64	1053.79
DS 128 Street	15.35	1048.29	1050.65	1051.32	1051.68	1051.96	1052.22	1052.40	1052.59	1052.71	1053.03	1053.29	1053.46	1053.63	1053.77
DS 128 Street	15.24	1047.97	1050.46	1050.85	1051.18	1051.51	1051.74	1051.89	1052.05	1052.18	1052.50	1052.73	1052.89	1053.05	1053.17
DS 128 Street	15.17	1047.58	1049.80	1050.60	1050.98	1051.11	1051.30	1051.42	1051.56	1051.66	1051.91	1052.16	1052.29	1052.43	1052.54
DS 128 Street	15.06	1048.02	1049.52	1050.05	1050.36	1050.65	1050.89	1051.05	1051.24	1051.37	1051.63	1051.80	1051.94	1052.04	1052.12
DS 128 Street	14.92	1046.92	1049.08	1049.48	1049.79	1049.93	1050.10	1050.21	1050.29	1050.37	1050.66	1050.89	1051.01	1051.18	1051.32
DS 128 Street	14.78	1046.43	1047.81	1048.53	1049.07	1049.47	1049.78	1049.91	1050.10	1050.21	1050.52	1050.77	1050.95	1051.11	1051.25
DS 128 Street	14.62	1044.77	1047.18	1048.04	1048.60	1049.02	1049.36	1049.53	1049.73	1049.83	1050.12	1050.36	1050.52	1050.68	1050.81
DS 128 Street	14.45	1045.00	1046.51	1047.34	1047.88	1048.36	1048.54	1048.70	1048.83	1049.00	1049.26	1049.45	1049.58	1049.71	1049.80
DS 128 Street	14.25	1043.50	1045.78	1046.59	1046.97	1047.34	1047.72	1047.86	1048.00	1048.09	1048.31	1048.48	1048.73	1049.26	1049.44
DS 128 Street	14.04	1042.91	1045.13	1045.84	1046.21	1046.60	1046.85	1047.17	1047.30	1047.44	1047.88	1048.18	1048.51	1049.14	1049.33
DS 128 Street	13.82	1042.17	1044.11	1044.90	1045.35	1045.66	1045.94	1046.11	1046.33	1046.45	1046.74	1047.36	1048.12	1048.93	1049.12
DS 128 Street	13.65	1041.71	1043.66	1044.45	1044.90	1045.25	1045.41	1045.49	1045.56	1045.76	1046.55	1047.33	1048.09	1048.90	1049.08
DS 128 Street	13.48	1041.02	1042.53	1043.33	1043.78	1044.23	1044.57	1044.94	1045.37	1045.67	1046.48	1047.27	1048.04	1048.86	1049.04
DS 128 Street	13.25	1040.03	1042.05	1042.75	1043.28	1043.86	1044.34	1044.71	1045.13	1045.43	1046.26	1047.08	1047.87	1048.71	1048.88
DS 128 Street	13.13	1038.93	1041.62	1042.32	1042.81	1043.32	1043.73	1044.06	1044.46	1044.75	1045.53	1046.35	1047.73	1048.64	1048.81
DS 128 Street	13.12	1039.27	1041.45	1041.95	1042.34	1042.74	1043.16	1043.79	1044.21	1044.52	1045.33	1046.02	1046.51	1048.16	1048.44
DS 128 Street	13.01	1039.34	1040.68	1041.48	1042.12	1042.61	1043.11	1043.81	1044.27	1044.59	1045.45	1046.17	1046.68	1048.14	1048.42
DS 128 Street	12.85	1038.42	1040.32	1041.20	1041.92	1042.42	1042.97	1043.74	1044.22	1044.58	1045.48	1046.22	1046.73	1048.14	1048.42
DS 128 Street	12.75	1037.61	1040.10	1040.94	1041.65	1042.05	1042.57	1043.46	1043.92	1044.26	1045.26	1046.08	1046.63	1048.09	1048.38
DS 128 Street	12.73	1037.28	1039.85	1040.51	1041.14	1041.54	1041.75	1041.95	1042.22	1042.44	1042.93	1042.94	1043.05	1043.13	1043.22
DS 128 Street	12.64	1037.53	1039.73	1040.35	1040.92	1041.33	1041.37	1041.45	1041.53	1041.56	1041.92	1042.78	1042.97	1043.13	1043.25
DS 128 Street	12.55	1037.50	1039.51	1039.78	1039.99	1040.37	1040.99	1041.13	1041.26	1041.35	1041.57	1041.75	1041.86	1041.97	1042.10
DS 128 Street	12.47	1037.30	1039.14	1039.35	1039.63	1039.92	1040.16	1040.32	1040.50	1040.62	1040.81	1041.03	1041.17	1041.31	1041.42
DS 128 Street	12.34	1036.69	1038.50	1038.98	1039.31	1039.61	1039.83	1039.98	1040.14	1040.25	1040.57	1040.79	1040.94	1041.08	1041.19

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
DS 128 Street	12.25	1035.85	1038.01	1038.66	1039.00	1039.26	1039.44	1039.55	1039.69	1039.82	1040.10	1040.30	1040.40	1040.49	1040.58
DS Okotoks	12.02	1033.51	1035.97	1036.59	1036.96	1037.32	1037.58	1037.76	1037.95	1038.05	1038.36	1038.62	1038.82	1039.00	1039.14
DS Okotoks	11.90	1033.66	1035.61	1036.31	1036.66	1036.96	1037.25	1037.44	1037.64	1037.72	1038.00	1038.24	1038.40	1038.57	1038.70
DS Okotoks	11.75	1032.12	1034.60	1035.49	1035.72	1036.02	1036.15	1036.29	1036.45	1036.74	1037.01	1037.27	1037.44	1037.56	1037.70
DS Okotoks	11.54	1031.95	1034.09	1034.71	1035.16	1035.47	1035.87	1036.11	1036.40	1036.63	1036.77	1036.98	1037.12	1037.25	1037.35
DS Okotoks	11.47	1031.81	1033.74	1034.40	1034.83	1034.86	1035.08	1035.21	1035.33	1035.41	1036.15	1036.33	1036.48	1036.59	1036.67
DS Okotoks	11.25	1030.10	1032.70	1033.10	1033.32	1033.60	1033.74	1033.85	1033.98	1034.07	1034.28	1034.46	1034.58	1034.69	1034.78
DS Okotoks	10.93	1029.44	1031.65	1032.24	1032.63	1032.71	1032.88	1032.98	1033.08	1033.16	1033.35	1033.51	1033.63	1033.75	1033.86
DS Okotoks	10.63	1027.53	1030.31	1030.87	1031.30	1031.82	1031.95	1032.05	1032.19	1032.31	1032.57	1032.81	1032.96	1033.11	1033.24
DS Okotoks	10.45	1027.98	1029.34	1030.09	1030.63	1031.18	1031.63	1031.69	1031.81	1031.83	1032.27	1032.53	1032.69	1032.84	1032.97
DS Okotoks	10.15	1026.10	1027.92	1028.60	1029.06	1029.50	1029.93	1030.47	1030.82	1031.09	1031.10	1031.30	1031.48	1031.72	1031.90
DS Okotoks	9.87	1024.20	1026.64	1027.22	1027.68	1028.18	1028.39	1028.54	1028.70	1028.92	1029.56	1029.91	1030.09	1030.28	1030.42
DS Okotoks	9.58	1023.59	1025.72	1026.52	1027.11	1027.72	1027.83	1028.04	1028.34	1028.59	1028.82	1029.16	1029.37	1029.58	1029.75
DS Okotoks	9.31	1022.73	1024.69	1025.32	1025.75	1026.19	1026.49	1026.69	1026.80	1026.81	1027.46	1027.72	1028.00	1028.16	1028.29
DS Okotoks	9.09	1021.23	1023.77	1024.18	1024.44	1024.67	1025.11	1025.34	1025.63	1025.74	1026.12	1026.41	1026.59	1026.78	1026.92
DS Okotoks	8.79	1018.83	1022.39	1023.41	1023.80	1024.29	1024.72	1025.00	1025.33	1025.41	1025.78	1026.05	1026.21	1026.38	1026.51
DS Okotoks	8.44	1017.78	1020.75	1021.57	1022.07	1022.55	1022.89	1023.11	1023.38	1024.01	1024.40	1024.82	1025.00	1025.12	1025.23
DS Okotoks	8.2	1017.84	1019.83	1020.48	1020.86	1021.23	1021.63	1021.94	1022.29	1022.40	1023.21	1023.45	1023.82	1024.06	1024.32
DS Okotoks	7.94	1016.12	1018.19	1018.70	1019.17	1019.82	1020.32	1020.69	1021.18	1021.39	1021.91	1022.31	1022.57	1022.89	1023.19
DS Okotoks	7.71	1014.85	1016.89	1017.86	1018.66	1019.47	1020.08	1020.51	1021.06	1021.27	1021.80	1022.21	1022.48	1022.80	1023.12
DS Okotoks	7.52	1013.47	1016.23	1017.20	1017.83	1018.39	1018.62	1018.75	1018.88	1019.99	1020.57	1021.09	1021.34	1021.94	1022.39
DS Okotoks	7.3	1013.29	1015.39	1016.17	1016.74	1017.32	1018.05	1018.52	1019.05	1019.45	1020.33	1021.32	1021.57	1022.09	1022.54
DS Okotoks	7.13	1013.06	1014.82	1015.88	1016.62	1017.33	1017.98	1018.42	1018.93	1019.31	1020.24	1021.24	1021.47	1021.99	1022.43
DS Okotoks	7.02	1011.83	1014.69	1015.80	1016.54	1017.25	1017.98	1018.45	1018.97	1019.39	1020.31	1021.31	1021.55	1022.06	1022.50
DS Okotoks	6.9789	1011.58	1014.48	1015.50	1016.17	1016.76	1017.25	1017.59	1017.97	1018.25	1018.61	1019.70	1020.14	1020.58	1020.96
DS Okotoks	6.94	1012.22	1014.28	1015.24	1015.86	1016.34	1016.69	1016.96	1017.21	1017.37	1017.77	1018.09	1018.30	1018.51	1018.75
DS Okotoks	6.85	1011.82	1014.04	1015.05	1015.66	1016.06	1016.31	1016.45	1016.65	1016.79	1017.22	1017.48	1017.64	1017.77	1017.85
DS Okotoks	6.6	1010.33	1012.59	1013.42	1013.84	1014.66	1014.99	1015.15	1015.41	1015.54	1015.77	1016.24	1016.51	1016.69	1016.82
DS Okotoks	6.32	1009.22	1011.73	1012.44	1012.89	1013.29	1013.57	1013.74	1013.95	1014.07	1014.44	1014.70	1014.86	1015.02	1015.16
DS Okotoks	6.01	1008.85	1010.59	1011.68	1012.08	1012.56	1012.88	1013.09	1013.36	1013.58	1013.97	1014.28	1014.45	1014.62	1014.75
DS Okotoks	5.77	1007.23	1009.59	1010.38	1011.15	1011.80	1012.40	1012.60	1012.84	1012.98	1013.49	1013.88	1014.03	1014.18	1014.30
DS Okotoks	5.59	1006.32	1008.74	1009.42	1009.94	1010.64	1011.03	1011.70	1011.95	1012.15	1012.60	1013.20	1013.34	1013.47	1013.56
DS Okotoks	5.29	1006.27	1007.77	1008.37	1008.77	1009.18	1009.48	1009.66	1009.88	1010.04	1010.44	1010.78	1011.02	1011.24	1011.43
DS Okotoks	5.16	1005.09	1007.11	1007.89	1008.40	1008.88	1009.21	1009.45	1009.70	1009.87	1010.31	1010.67	1010.92	1011.16	1011.36
DS Okotoks	5	1003.74	1006.52	1007.25	1007.77	1008.27	1008.52	1008.72	1008.95	1009.12	1009.52	1009.88	1010.13	1010.33	1010.52
DS Okotoks	4.83	1003.61	1005.92	1006.42	1006.78	1006.96	1007.40	1007.58	1007.78	1007.92	1008.29	1008.58	1008.74	1009.04	1009.27

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
DS Okotoks	4.64	1002.87	1005.00	1005.54	1005.90	1006.34	1006.67	1006.92	1007.18	1007.38	1007.84	1008.23	1008.55	1008.82	1009.03
DS Okotoks	4.4	1001.59	1004.01	1004.90	1005.38	1005.90	1006.22	1006.43	1006.67	1006.85	1007.20	1007.50	1007.84	1008.05	1008.20
DS Okotoks	4	1000.54	1002.01	1002.64	1003.26	1003.86	1004.56	1004.89	1005.16	1005.32	1005.98	1006.64	1007.22	1007.39	1007.48
DS Okotoks	3.64	998.64	1000.68	1001.54	1002.08	1002.60	1003.11	1003.44	1003.63	1003.69	1004.04	1004.46	1004.50	1005.26	1005.72
DS Okotoks	3.25	996.67	999.23	1000.13	1000.73	1001.36	1001.60	1001.76	1002.13	1002.48	1003.00	1003.31	1003.43	1003.81	1004.01
DS Okotoks	2.98	995.93	998.29	998.94	999.33	999.69	1000.38	1000.68	1000.98	1001.12	1001.85	1002.22	1002.45	1002.57	1002.65
DS Okotoks	2.74	995.19	997.02	997.49	997.89	998.31	998.70	998.94	999.26	999.51	1000.31	1000.97	1001.41	1001.84	1002.19
DS Okotoks	2.55	994.30	996.04	996.90	997.43	998.04	998.58	998.95	999.38	999.67	1000.39	1001.00	1001.42	1001.83	1002.17
DS Okotoks	2.37	993.17	995.01	995.55	996.02	996.50	996.91	997.17	997.53	997.83	998.47	998.98	999.32	999.65	999.88
DS Okotoks	1.99	991.28	993.71	994.60	995.26	995.89	996.41	996.75	997.15	997.45	998.20	998.88	999.40	999.84	1000.19
DS Okotoks	1.7	990.74	992.47	993.06	993.68	994.33	994.79	995.06	995.37	995.60	996.16	996.62	996.79	997.52	997.81
DS Okotoks	1.4	988.88	990.98	991.95	992.69	993.34	993.74	993.99	994.15	994.32	994.73	995.04	995.31	995.77	996.00
DS Okotoks	1.12	986.96	989.94	990.68	991.10	991.78	992.74	992.94	993.28	993.45	993.94	994.30	994.44	995.01	995.43
DS Okotoks	0.87	986.95	988.58	989.36	990.24	991.10	991.76	992.18	992.65	992.99	993.82	994.48	994.94	995.38	995.75
DS Okotoks	0.65	985.71	988.36	989.55	990.48	991.27	991.87	992.25	992.70	993.03	993.85	994.51	994.96	995.41	995.77
DS Okotoks	0.53	985.52	987.54	988.39	989.06	990.00	990.48	990.79	991.11	991.31	992.05	992.55	992.90	993.25	993.53
DS Okotoks	0.24	984.57	986.47	987.30	987.85	988.37	988.82	989.10	989.43	989.67	990.26	990.76	991.04	991.35	991.56
DS Okotoks	0	982.85	984.70	985.52	986.20	986.80	987.23	987.52	987.84	988.07	988.63	989.15	989.54	989.87	990.18
128 St Overflow	2.778	1140.31	1140.42	1140.85	1141.12	1141.46	1141.91	1142.22	1142.68	1142.86	1143.34	1143.68	1143.88	1144.09	1144.24
128 St Overflow	2.72	1139.73	1140.14	1140.71	1140.97	1141.28	1141.64	1141.87	1142.2	1142.45	1142.76	1143.03	1143.19	1143.34	1143.44
128 St Overflow	2.666	1139.63	1139.94	1140.37	1140.55	1140.78	1141.12	1141.31	1141.53	1141.77	1142.3	1142.51	1142.69	1142.87	1143.02
128 St Overflow	2.568	1139.27	1139.51	1139.92	1140.21	1140.44	1140.73	1140.94	1141.26	1141.5	1142.11	1142.16	1142.33	1142.5	1142.65
128 St Overflow	2.531	1138.82	1139.15	1139.67	1139.95	1140.2	1140.54	1140.79	1141.13	1141.39	1142.07	1142.09	1142.26	1142.43	1142.58
128 St Overflow	2.463	1138.51	1138.81	1139.22	1139.44	1139.68	1139.95	1140.13	1140.35	1140.52	1141.03	1141.68	1141.99	1142.17	1142.36
128 St Overflow	2.389	1138.12	1138.28	1138.49	1138.61	1138.79	1139.05	1139.23	1139.48	1139.65	1140.14	1140.56	1140.93	1141.22	1141.39
128 St Overflow	2.33	1137.61	1137.9	1138.2	1138.36	1138.59	1138.91	1139.12	1139.42	1139.63	1140.16	1140.55	1140.79	1141.03	1141.2
128 St Overflow	2.233	1136.98	1137.12	1137.36	1137.49	1137.66	1137.91	1138.08	1138.31	1138.48	1138.91	1139.26	1139.48	1139.69	1139.83
128 St Overflow	2.155	1135.43	1135.94	1136.31	1136.51	1136.77	1137.06	1137.24	1137.49	1137.68	1138.15	1138.47	1138.67	1138.87	1139.01
128 St Overflow	2.05	1135.19	1135.37	1135.68	1135.85	1136.09	1136.37	1136.47	1136.54	1136.59	1136.7	1136.9	1137.01	1137.14	1137.24
128 St Overflow	1.71	1132.24	1132.56	1132.91	1132.98	1133.08	1133.18	1133.33	1133.56	1133.72	1134.1	1134.39	1134.51	1134.7	1134.81
128 St Overflow	1.558	1131.56	1131.85	1132.59	1132.72	1132.84	1133.05	1133.19	1133.38	1133.52	1133.91	1134.21	1134.3	1134.49	1134.6
128 St Overflow	1.42	1130.99	1131.2	1132.59	1132.72	1132.83	1133.03	1133.17	1133.35	1133.49	1133.87	1134.17	1134.25	1134.45	1134.55
128 St Overflow	1.323	1129.42	1130.06	1132.59	1132.71	1132.83	1133.03	1133.15	1133.33	1133.47	1133.85	1134.15	1134.22	1134.41	1134.51
128 St Overflow	1.24	1128.58	1130.06	1132.59	1132.71	1132.83	1133.02	1133.15	1133.32	1133.45	1133.8	1134.09	1134.14	1134.32	1134.4
128 St Overflow	1.21	1128.74	1128.98	1129.4	1129.65	1129.92	1130.25	1130.54	1130.97	1131.26	1131.87	1132.24	1132.41	1132.63	1132.85
128 St Overflow	0.94	1126.34	1127.18	1128.06	1128.53	1129	1129.31	1129.57	1129.9	1130.13	1130.55	1130.84	1131.03	1131.25	1131.36

Reach			W.S. Elevation (m)												
Sheep River	River Station (km)	Min Channel El. (m)	2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
128 St Overflow	0.7	1126.84	1127.02	1127.51	1127.81	1128.09	1128.32	1128.45	1128.62	1128.72	1129.05	1129.3	1129.43	1129.53	1129.66
128 St Overflow	0.53	1124.76	1126.18	1126.43	1126.51	1126.64	1126.81	1126.8	1126.9	1126.92	1126.99	1127.12	1127.27	1127.47	1127.59
128 St Overflow	0.43	1122.15	1126.18	1126.43	1126.51	1126.65	1126.83	1126.84	1126.97	1127.03	1127.24	1127.42	1127.53	1127.65	1127.74
128 St Overflow	0.31	1126	1126.17	1126.4	1126.41	1126.54	1126.67	1126.73	1126.82	1126.89	1127.05	1127.2	1127.3	1127.4	1127.48
128 St Overflow	0.28	1125.71	1125.95	1126.17	1126.3	1126.3	1126.41	1126.48	1126.58	1126.65	1126.85	1127.01	1127.12	1127.24	1127.32
128 St Overflow	0.23	1125.38	1125.62	1125.82	1125.92	1126.01	1126.15	1126.23	1126.35	1126.42	1126.64	1126.82	1126.93	1127.05	1127.14
128 St Overflow	0.12	1124.47	1124.94	1125.23	1125.35	1125.49	1125.6	1125.72	1125.85	1125.94	1126.18	1126.36	1126.46	1126.59	1126.68
128 St Overflow	0	1123.41	1123.62	1124.15	1124.37	1124.51	1124.69	1124.77	1124.9	1124.98	1125.18	1125.39	1125.57	1125.74	1125.87
NorthStream (Okotoks)	5.1129	1056.64	1056.76	1056.76	1056.76	1056.76	1056.76	1056.76	1057.48	1057.8	1057.93	1058.71	1059.07	1059.32	1059.51
NorthStream (Okotoks)	4.9352	1055.45	1055.88	1055.88	1055.88	1055.88	1055.88	1055.88	1056.56	1056.8	1056.9	1057.39	1057.69	1057.88	1058.04
NorthStream (Okotoks)	4.7216	1055.78	1055.87	1055.87	1055.87	1055.87	1055.87	1055.87	1056.13	1056.26	1056.34	1056.6	1056.76	1056.87	1056.96
NorthStream (Okotoks)	4.5382	1054.93	1055.05	1055.05	1055.05	1055.05	1055.05	1055.05	1055.36	1055.44	1055.46	1055.68	1055.84	1055.95	1056.06
NorthStream (Okotoks)	4.4728	1054.53	1054.6	1054.6	1054.6	1054.6	1054.6	1054.6	1054.89	1055.02	1055.09	1055.35	1055.57	1055.71	1055.84
NorthStream (Okotoks)	4.4418	1054.18	1054.54	1054.54	1054.54	1054.54	1054.54	1054.54	1054.87	1055	1055.07	1055.29	1055.5	1055.65	1055.78
NorthStream (Okotoks)	4.4188	1054.47	1054.53	1054.53	1054.53	1054.53	1054.53	1054.53	1054.74	1054.84	1054.88	1055.21	1055.43	1055.57	1055.7
NorthStream (Okotoks)	4.3977	1054.07	1054.23	1054.23	1054.23	1054.23	1054.23	1054.23	1054.66	1054.77	1054.84	1055.2	1055.42	1055.55	1055.68
NorthStream (Okotoks)	4.2637	1054	1054.12	1054.12	1054.12	1054.12	1054.12	1054.12	1054.58	1054.62	1054.66	1054.93	1055.1	1055.22	1055.33
NorthStream (Okotoks)	4.1149	1053.55	1053.68	1053.68	1053.68	1053.68	1053.68	1053.68	1053.9	1054.09	1054.14	1054.43	1054.62	1054.76	1054.88
NorthStream (Okotoks)	3.9458	1052.81	1052.93	1052.93	1052.93	1052.93	1052.93	1052.93	1053.29	1053.41	1053.45	1053.7	1053.85	1053.96	1054.06
NorthStream (Okotoks)	3.7955	1052.2	1052.28	1052.28	1052.28	1052.28	1052.28	1052.28	1052.34	1052.44	1052.49	1052.7	1052.87	1052.99	1053.11
NorthStream (Okotoks)	3.6899	1051.43	1051.53	1051.53	1051.53	1051.53	1051.53	1051.53	1051.87	1051.98	1052.02	1052.25	1052.44	1052.57	1052.7
NorthStream (Okotoks)	3.5414	1050.68	1050.81	1050.81	1050.81	1050.81	1050.81	1050.81	1051.09	1051.18	1051.23	1051.46	1051.62	1051.74	1051.83
NorthStream (Okotoks)	3.3441	1049.61	1049.75	1049.75	1049.75	1049.75	1049.75	1049.75	1050.06	1050.17	1050.26	1050.48	1050.62	1050.73	1050.82
NorthStream (Okotoks)	3.1927	1048.83	1048.96	1048.96	1048.96	1048.96	1048.96	1048.96	1049.17	1049.22	1049.24	1049.44	1049.63	1049.75	1049.86
NorthStream (Okotoks)	3.0522	1047.82	1047.88	1047.88	1047.88	1047.88	1047.88	1047.88	1048.31	1048.47	1048.54	1048.88	1049.06	1049.17	1049.28
NorthStream (Okotoks)	2.9117	1047.38	1047.53	1047.53	1047.53	1047.53	1047.53	1047.53	1048.12	1048.28	1048.35	1048.68	1048.75	1048.89	1049
NorthStream (Okotoks)	2.6961	1046.9	1046.98	1046.98	1046.98	1046.98	1046.98	1046.98	1047.47	1047.59	1047.62	1047.78	1047.89	1047.89	1047.89
NorthStream (Okotoks)	2.5536	1045.39	1045.46	1045.46	1045.46	1045.46	1045.46	1045.46	1045.71	1045.83	1045.88	1046.22	1046.33	1046.4	1046.47
NorthStream (Okotoks)	2.3586	1044.74	1044.81	1044.81	1044.81	1044.81	1044.81	1044.81	1045.03	1045.11	1045.14	1045.28	1045.41	1045.52	1045.61
NorthStream (Okotoks)	2.0580	1042.84	1042.97	1042.97	1042.97	1042.97	1042.97	1042.97	1043.15	1043.24	1043.29	1043.63	1043.77	1043.82	1043.88
NorthStream (Okotoks)	1.8469	1039.8	1039.89	1039.89	1039.89	1039.89	1039.89	1039.89	1040.55	1040.86	1041	1041.77	1042.6	1042.81	1043
NorthStream (Okotoks)	1.7424	1038.76	1039.06	1039.07	1039.07	1039.07	1039.07	1039.06	1040.06	1040.32	1040.44	1040.95	1041.14	1041.32	1041.6
NorthStream (Okotoks)	1.5470	1038.86	1039	1039.01	1039.01	1039.01	1039.01	1038.99	1039.75	1039.87	1039.91	1040.24	1040.52	1040.76	1040.91
NorthStream (Okotoks)	1.3360	1038.02	1038.12	1038.11	1038.11	1038.11	1038.11	1038.15	1038.56	1038.87	1039.09	1039.7	1040.03	1040.26	1040.43
NorthStream (Okotoks)	1.0722	1036.65	1036.83	1037.04	1037.39	1037.7	1037.97	1038.16	1038.38	1038.55	1038.91	1039.27	1039.52	1039.74	1039.92
NorthStream (Okotoks)	0.8836	1036.25	1036.4	1037.04	1037.39	1037.7	1037.97	1038.16	1038.37	1038.51	1038.88	1039.12	1039.24	1039.34	1039.39

Appendix C
Inundation Map Library

(See Separate Map Booklet)