Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow River, Elbow River and Oldman River Basins
Volume 4 – Flood Mitigation Measures

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1.1 Monitoring, Forecasting and Warning Improvements

1.1.1 Introduction

In terms of damage reduction, the benefits of flood forecasting and warning are well proven. The longer the lead time, the more damage can be reduced by taking proactive measures to remove people and property from the areas at risk, or by implementing temporary emergency measures, to reduce flood damages.

In general, there are two ways of disseminating flood warnings. Direct flood warnings are those which are sent to recipients via SMS text message, email, door to door or telephone warnings. Indirect flood warnings are those sent out via an emergency broadcast system or the media; for example through television, Facebook, Twitter, or on dedicated websites. There are advantages to both systems and some internet sites, such as Facebook, can be extremely effective in contacting individuals quickly via their mobile devices. Facebook and Twitter may be considered both direct and indirect because individuals will receive an alert direct to their device; however, the sender has no control over the message once it has been sent and reliance is on the third party to deliver it, so there is no direct communication line with the recipient.

Given the rapid onset of flooding that occurred in June 2013 in southern Alberta, with little warning, it is recommended that the Government of Alberta (GoA) consider improvements to the flood warning service. The potential benefits would include:

- Improved public awareness and preparedness;
- Improved collaboration between differing government agencies;
- Risk-driven approach to hazard identification, risk analysis and mitigation; and
- Flexible approach to help reduce the consequences of flooding.

A centralized technical approach to flood warning covering the major urban areas of Alberta is required. The proposed development of a flood warning service aligns with the GoA's seven pillars of mitigation. This would build upon the work currently carried out by the Alberta Environment and Sustainable Resource Development (ESRD) River Forecast Centre (RFC) and would provide residential property owners, business owners and first responders with direct flood warnings via text and email for specific river reaches.

Recommendation 4.1: The GoA should seek to improve the flood forecasting and warning system by developing a Provincial Flood Forecasting Shell and introducing an SMS or email warning system for all members of the public who sign up to receive direct flood warnings for a given flood risk area.

1.1.2 Current Initiatives by Alberta Environment and Sustainable Resources Development

There are a number of current projects being carried out by ESRD in relation to improving the flood forecasting and warning capability in the province. These are described below.

1.1.2.1 Performance Measures Development Project

The purpose of this project is to propose potential performance measures for the RFC that can be used to assess ongoing program and model suitability and effectiveness.

1.1.2.2 Assessing Flood Vulnerability Based on Temporal Variability in Rainfall/Runoff Characteristics

The purpose of this project is to understand better the time scale at which flooding events occur for identified areas at risk, for a reasonable spectrum of precipitation events that vary in amount and intensity. This will better equip the RFC to communicate flooding potential and risks to communities.

1.1.2.3 Weather Forecast Review Project

The RFC has the mandate to provide Albertans with information related to current and future river or river ice conditions that enable Albertans to make decisions related to water supply and emergency response planning. Based on the events in southern Alberta in June 2013, it is possible that weather forecast/model variability can impact the forecast precipitation totals and rainfall intensities, which in turn impacts the forecast river flows. Although high and low precipitation scenarios are currently used to estimate potential flows prior to an event, the actual uncertainty surrounding weather models, documented after a meteorological review of all the data, is required to assist in the enhancement of river forecasting processes. The purpose of this project is to develop an understanding of the uncertainties in weather forecasting and propose a method of how the RFC can manage those uncertainties when modeling rainfall scenarios and issuing flood advisories.

1.1.2.4 2013 Southern Alberta Flood – River Forecast Centre Lessons Learned and Partner Engagement

The purpose of this project is to coordinate and document the discussions with various RFC partner groups and clients regarding the 2013 southern Alberta flood. The documentation will provide the GoA with the information surrounding what occurred in each community, how each group responded, and what they have learned. This project will help RFC:

- Determine what information provided by the RFC that the partners/clients consider most useful;
- Understand how the partners/clients use or disseminate the information provided;
- Update key river stages/thresholds or flows;

- Improve communication or services between RFC and its partners/clients; and
- Compile a list of updated client contact information including names, telephone (work, home and cell) numbers (for all clients in Alberta) and use it to update the information currently contained within the RFC Flood Notification Manual.

1.1.3 Improving the Flood Warning Service

The public consultation exercise and literature review has identified that there are a number of community benefits that can be delivered through the implementation of flood warning service improvements. However, at present, a combination of policy and a step change in investment will be required to deliver the multifunctional aspirations of a world class flood warning system in Alberta.

To this end, an inter-agency working group (IAWG) should be established to develop an improved flood forecasting and warning service for Albertans. The suggested partners for the IAWG would include the following:

- Consultants and academic researchers;
- ESRD;
- Environment Canada;
- Natural Sciences and Engineering Research Council of Canada (NSERC);
- Cities and municipal districts (MDs);
- Industry experts and consultants; and
- Non-government organizations (NGOs; Canadian Water Resources Association, Canadian Dam Association, Association of Professional Engineers and Geologists of Alberta.

The role of the IAWG would be to determine the functional requirements of a flood warning service and to make decisions on:

- Governance;
- Decision-support tools;
- Functionality implementation; and
- Policy.

Figure 1.1 provides a suggested outline of topic areas for the IAWG.

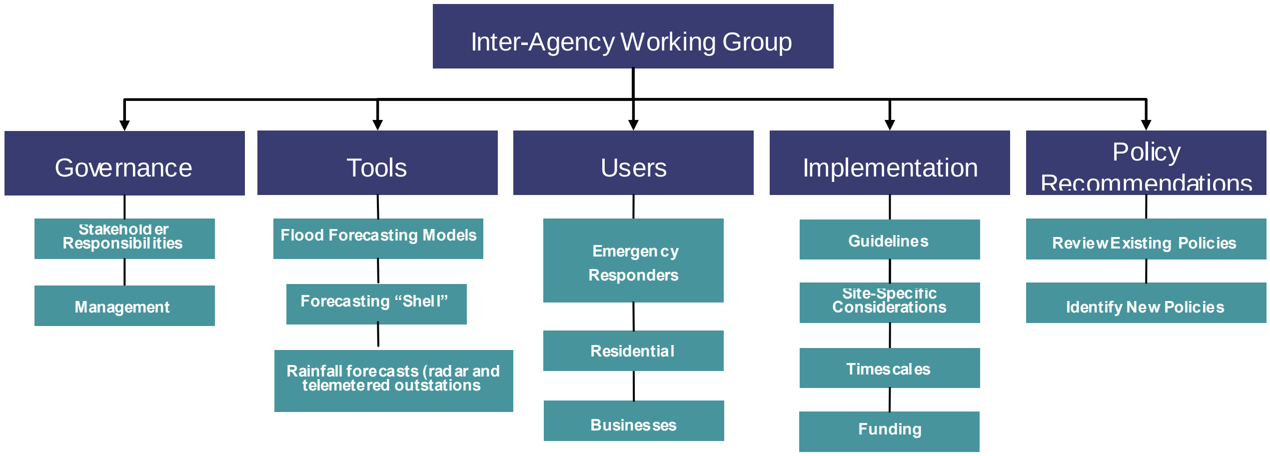


Figure 1.1: Suggested Mandate for the IAWG

Operational forecasting and warning capabilities have been developed in many river basins across the world. The four key elements of the flood forecasting and warning process are summarized by Haggett (1998) and include:

- Detection;
- Forecasting;
- Dissemination; and
- Warning.

1.2 Strategy for Developing an Improved Flood Warning Service for Alberta

Table 1.1 establishes the objectives and strategies to improve the flood warning service in Alberta. The table was developed by a detailed literature review of existing policy and guidance, and interviews with leading practitioners in the United Kingdom and Netherlands.

Table 1.1
Strategies for Developing a Flood Warning System

Objectives	Strategy
Co-ordinated and consistent approach to flood forecasting and flood warning.	Development of new and stronger integrated flood forecasting (monitoring, modelling and integrated forecasting) system, and flood warning tools and identification of lead body.
Reduce the consequences of flooding to people and property through the development and implementation of a comprehensive flood warning system.	Develop a province-wide public information dissemination plan.
Improved partnership working to minimize overlaps.	Development of flood management and incident governance structure will aid inter-agency working.
Link proposed new flood warning service with improvements to emergency planning.	Set out clear policy to link flood warning service with emergency planning.

1.3 Flood Warning System Requirements

There are a wide range of characteristic watercourses in southern Alberta. Some creeks respond very quickly to rainfall with an increase in water level, for example the Elbow River or Pincher Creek. In contrast, the Bow River may take several days for rainfall in the upper basin to generate a noticeable difference in flow levels at the receptor areas; particularly if reservoir managers artificially alter the basin response by operating control structures.

The benefit gained from flood warning is directly proportional to the available lead time (the amount of advance notice that recipients will receive in advance of a flood threshold being crossed). Lead time is generally increased through the use of forecasting models. Forecasts can be probabilistic (i.e., there is a 50% chance that a flood will occur) or deterministic (the forecast level at a given location is explicitly stated). The preference is generally for deterministic forecasts because municipalities and the public generally want to know how bad a flood is going to be; not just to be given a probability that one might occur in the next few hours or days. The reality is that the flood forecaster will generally provide a hybrid of the two and qualify the forecast with a statement such as “there is a 50% chance that the flood threshold of X m will be surpassed in the next few hours at location Y”.

Forecasting models can be simple. A simple system could comprise a trigger based on a rate of rise model and a known water level at a gauging station upstream. Depending on hydrologic inflows between the gauging site and the flood risk area, an accurate forecast can be taken from an upstream station and lead time can be gained simply from the travel time of the flood hydrograph down the river. For example, a telemetered outstation in Bragg Creek can be used to directly forecast flows at Glenmore Reservoir and will provide a lead time in the order of 8 to 12 hours by virtue of the length of time it takes for the water to flow from Bragg Creek to Calgary.

A forecasting model can also be a very complex system using data from radar precipitation forecasts, inputs from antecedent conditions (soil moisture), snow pack data and hydrodynamic routing models with real time updating.

A typical flood forecasting system will strike a balance of forecast accuracy, timeliness and cost. The forecasting and warning system is inherently reliant on the skill, judgement and experience of the staff, and it is therefore vital that the relevant skills are developed and retained within the responsible authority. This is best done at the provincial level.

1.4 Improving Community Resilience Through Dissemination

Many stakeholders including homeowners, business owners, and emergency responders would benefit from longer lead times for flooding events. To this end, a flood warning could be issued via text, email, government website and through the media. An example of flood warning symbols from the United Kingdom is provided on **Figure 1.2**.

(Source: Environment Agency)

Figure 1.2: A Simple Visual Tool for Flood Warning Used in the United Kingdom

It is also sometimes beneficial to extend the visual tool to include an “All Clear” symbol which flood forecasting and warning staff can use to officially inform recipients that the danger is judged to have passed. A flood warning service would provide at-risk communities with a common picture and a more complete understanding of developing flood risk, thereby reducing the consequences of flooding to people and property.

One challenge is that recipients of the flood warnings generally do not understand the difference between a Flood Alert and a Flood Warning or a Severe Flood Warning. To address this challenge, simple statements are provided on the website to explain what each means. Flood Alerts are generally basin-wide non targeted warnings that merely state that a basin or river reach may flood. These types of warnings are publicised only on the internet or media. A Flood Warning is often a targeted (direct) warning and these are sent out via SMS text message or email to individuals and businesses who have signed up to the online distribution list for a given flood risk area. A severe flood warning is also targeted (direct) and means a danger to life or a large number of properties (> 100) are at risk of flooding.

The delivery of an improved flood warning service in Alberta will require a strategic planning approach and will require input from a wide variety of government bodies supported by specialist technical expertise. This is the recommended route that will allow for sufficient input and consultation with affected communities and offers the best route for development and delivery of an improved flood warning service.

It is recognized that a top-down approach is no longer the preferred route for guiding provincial decisions. Some form of driver needs to be embedded in provincial policy to encourage a long-term commitment and investment into a robust flood warning service as part of future flood risk management strategy.

1.4.1 Improving the Resilience of the Telemetry Network

Hydrometric data underpins flood risk management. Without data from rainfall outstations and flow gauges, it is not possible to develop accurate forecasting models or to make improvements to the flood mapping or flood warning system.

During the June 2013 flood event, 15 Water Survey of Canada (WSC) gauges were destroyed or had equipment damage. A number of gauges were also bypassed, which meant that some of the discharge from the basin could not be measured.

The accuracy of flow data from any gauging station is only as good as the rating curve or stage discharge relationship that has been developed for the gauge site. In order to achieve a stable rating, the station must be designed and constructed in a stable cross-section (sometimes a weir) or in a location where the flow will be confined in a channel where the river banks are stable.

There are several benefits to having a robust gauging and telemetry network. First, it is important to capture the peak discharge and receding limb of an event. For flood forecasting, understanding how the stage at a gauging station typically recedes allows the forecaster to issue the “All Clear.” During an event, it allows the forecaster to understand that the peak may have passed at an upstream station so the worst may be over or indeed yet to come.

When a gauge has been destroyed during an event, the loss of the maximum stage data means that future flood frequency analyses become less reliable as estimated data must be used.

Finally, a robust gauging station can be relied on and trusted. So when a critical threshold is reached, or an event is “off the scale” in terms of rate of rise or peak level, the forecaster has confidence that the gauge is indeed correct and that an extreme event is unfolding.

It is recommended that a major investment be made to replace the stations that were destroyed with a more robust arrangement and to research the gauging stations that are critical for flood forecasting and for flood frequency across the province and to undertake improvements to these stations to ensure continuity and integrity of the gauge record.

Recommendation 4.2: It is recommended that a major investment be made to replace the destroyed telemetry outstations and to upgrade those that were damaged or other vulnerable stations to improve the robustness of the forecasting and warning system.

1.5 Flood Management Authority

There can be little argument that the response to the June 2013 flood at a municipal level was exemplary. There are countless anecdotes in the media of the community coming together to offer assistance and to aid in the recovery. The willingness of local people to take the initiative and to rebuild, repair and reconstruct is admirable. It is a desirable characteristic of local populations to act locally to rebuild houses and infrastructure that has been destroyed and to do it as quickly as possible, so life can return to normal.

For flood mitigation; however, a basin-wide, strategic program is recommended. There are a number of advantages to taking the time to strategically plan mitigation projects. These advantages include:

1. A fundamental aspect of undertaking to provide flood at a location is that the defences must not cause an increase in risk elsewhere. Construction of flood defences in one location can vary significantly, increasing the risk of flooding elsewhere. For example, building dykes or diversions that protect one area from flooding may jeopardize the operation or safety of a downstream asset such as a reservoir (dam) or downstream dykes. In reviewing proposals made by others, for example a diversion of Elbow River flood flows into Priddis Creek, AMEC has taken into consideration the effects of the diversion on the downstream riparian communities and assets such as Priddis and Fish Creek Provincial Park. It is recommended that any proposals for flood defences be supported with sufficient engineering evidence that the downstream flood risk to communities or infrastructure will not be increased or that it is done so in a planned and manageable way.

Recommendation 4.3: It is recommended that any proposals for flood defences are supported with sufficient engineering evidence that the downstream flood risk to communities or infrastructure will not be increased or that it is done so in a planned and manageable way.

2. Basin-wide approaches can make more efficient use of resources both in terms of engineering and capital expenditure. Taking a piecemeal approach to providing flood defences means that some defences may become redundant once other measures are in place.

It is understandable that communities want to be proactive and take action to protect themselves against future flood events. The best means to do this is through a central coordinating authority which is granted the legal, moral and authoritative duty to ensure that the citizens of Alberta are protected from floods in an efficient and sustainable way. Other jurisdictions undertake flood risk management in a very coordinated fashion, such as England where approximately 5.2 million (or 1 in 6) properties are at risk of flooding (Environment

Agency, 2009) from fluvial flooding, surface water, coastal flooding or groundwater. In 2010, the *Flood and Water Management Act* was enacted in England which placed specific responsibilities on local authorities (municipalities) and the Environment Agency. Local authorities became responsible for:

- Investigating significant flood incidents as deemed appropriate and, where possible, recommending potential solutions;
- Issuing consent to carry out works in an ordinary watercourse (e.g, small creek);
- Enforcing action to rectify unlawful and potentially damaging work to a watercourse;
- Offering advice on property level protection to residents; and
- Being the approval body for local drainage schemes for housing developments.

The Environment Agency became the sole responsible authority for:

- The prevention, mitigation and remediation of flood damage for main rivers, coastal areas and reservoirs; and
- The provision of flood maps, flood warnings and flood alerts.

In discharging their responsibilities, both under English and European law, the Environment Agency has undertaken Catchment Flood Management Plans for the whole of England and Wales to plan and coordinate flood risk mitigation activities and to determine in advance the areas that will be retreated from in the face of increasing flood risk (for example along the coastline). It is recommended that Alberta undertake Basin Flood Management Plans as part of the long-term flood management strategy, and that these plans are executed under a single responsible authority. Current studies being undertaken by consultants for the Athabasca, Red Deer, Highwood, Sheep, Elbow, Bow and Oldman river basins could form the foundation for these plans.

Recommendation 4.4: It is recommended that the Government of Alberta fund the development of Basin Flood Management Plans for each of the major basins in the province and that these plans are developed and executed by a single responsible authority.

Taking a basin wide approach and having a single authority responsible for executing plans can avoid duplication of effort. In the post-2013 flood recovery effort, there has been considerable duplication of effort amongst consultants. Though this may have been unavoidable given the sense of urgency and the level of perceived flood risk, the public does not benefit dramatically from multiple entities looking into mitigation measures for the same basin at the same time.

1.6 Flood Mapping Updates

During the course of this study, flood studies undertaken as part of the Flood Damage Reduction Program have been used to aid in emergency response planning the mitigation design. Many of these studies were undertaken in the 1980s and some are now out of date.

For example, as a consequence of development in the Town of Cochrane, the flood study is known to be somewhat obsolete in the area around the confluence of Jumpingpound Creek (**Section 2.6.4**).

There has been considerable improvement in the availability of high quality topographic data on a basin scale since the 1980s. The use of light detection and ranging (LiDAR) to undertake flood mapping is now standard and the accuracy to which floodplain extents can be delineated has improved considerably as a result.

It is recommended that current flood mapping for the province be reviewed and that all flood studies undertaken without benefit of LiDAR or other high quality Digital Terrain Model (DTM), or those where there has been considerable development, be revisited to ensure accuracy.

Recommendation 4.5: It is recommended that current flood mapping for the province is reviewed and that all flood studies undertaken without benefit of LiDAR or other high quality DTM, or those where has been considerable development, be revisited to ensure accuracy.

2.0 BOW RIVER BASIN MITIGATION MEASURES

2.1 Bow River Basin Description

The Bow River Sub-basin is part of the South Saskatchewan River Basin (SSRB), which is one of seven major basins within the province of Alberta. The drainage area of the Bow River basin is approximately 25,300 km^2 to the confluence with the Oldman River. It originates in the eastern slopes of the Rocky Mountains, flows through Banff National Park and continues eastward through the foothills and prairie regions. The Bow River is approximately 618 km long and drops approximately 1,250 m over that distance. **Figure 2.1** illustrates the Bow River basin. It contributes nearly 43% of the 9.5 million dam^3 (1 dam^3 = 1,000 m^3) average annual flow of the SSRB.

Discharge in the Bow River is dependent on snowmelt from the Rocky Mountains. Snowmelt from progressively higher elevations provides significant flows during the late spring and early summer seasons, generally peaking in June. Flows decline significantly during the late summer, fall, and winter, with melt water from the glaciers providing much of the water during the late summer and fall. Flow during the winter is mainly from groundwater discharge into the river and the release of water from TAC reservoirs for electricity generation.

The Bow River basin is home to 22 urban municipalities, including the City of Calgary, 12 rural or regional municipalities and 3 First Nations, making it the most populous river basin in Alberta (BRBC, 2010).

The flow in the Bow River at Calgary is influenced primarily by TransAlta Corporation (TAC) hydropower operations and the City of Calgary's Bearspaw municipal water supply intake.

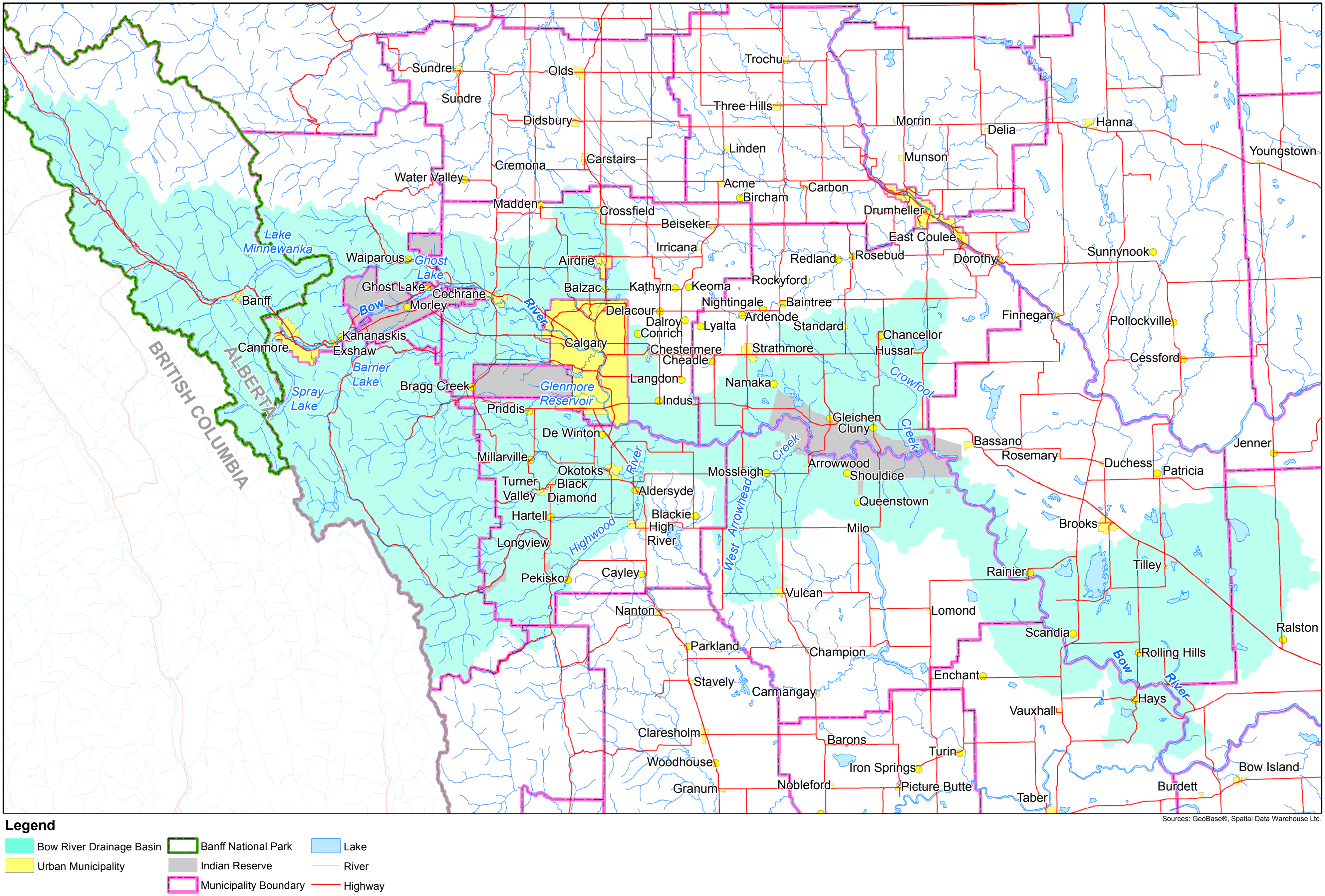
Mean annual naturalized flow of the Bow River at Calgary from 1972 to 2001 was 2.8 million dam^3, and the mean recorded flow was about 2.7 million dam^3, a difference of only 3.0%. This indicates that very little water is permanently removed from the river in this reach.

Downstream of Calgary the river is more heavily utilized, mainly by diversions to the Western Irrigation District (WID), Bow River Irrigation District and Eastern Irrigation District (EID). These three districts have a total irrigated area, in 2006, of almost 250,000 ha, plus other irrigation and water supply commitments on the Bow River as well as the Elbow and Highwood river tributaries.

Water storage within the basin includes large man-made and natural waterbodies such as Upper and Lower Kananaskis lakes, Spray Lake, Lake Minnewanka, Hector Lake, Bow Lake, Lake Louise, Moraine Lake and others.

In 1911, Calgary Power constructed the first of 11 hydroelectric stations on the Bow. Since that time, hydropower has been the main influence on the storage and release of water in the river and its tributaries.

The total storage capacity of existing TAC reservoirs is about 704,000 dam^3. Most of the water is released for hydropower during the winter months, when demand for power is the greatest. This has increased minimum flows in the Bow River beyond the natural flows.



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PDF: Fig2.1 Bow Basin 14-05-22	
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Bow River Basin

Figure 2.1

2.2 Water Management Issues

Water supplies are limited in this sub-basin, and may be a constraint to economic growth as water demand continues to increase. Droughts are not uncommon in this region, and climate change may bring more intense and longer lasting droughts in the future.

2.2.1 Water Supply and Demand

The SSRB Water Management Plan was proclaimed in 2007 in response to concerns that limits for water allocations had been reached or exceeded in the Bow, Oldman, and South Saskatchewan river sub-basins. As a result, applications for new water allocations are no longer accepted in these river basins. However, demand for water will continue to grow in the Bow River Sub-basin in response to increased population and economic growth.

Existing water users must learn to live within their current allocations, and new water users are required to obtain water from existing users through the water market established under the 1999 *Water Act*. This has particularly impacted towns and municipalities in the Calgary region where population and development pressures are rapidly exceeding existing water license allocations. Finding new sources of water is proving to be challenging as existing water license holders recognize the value of water and want to retain surplus water to meet their own future needs.

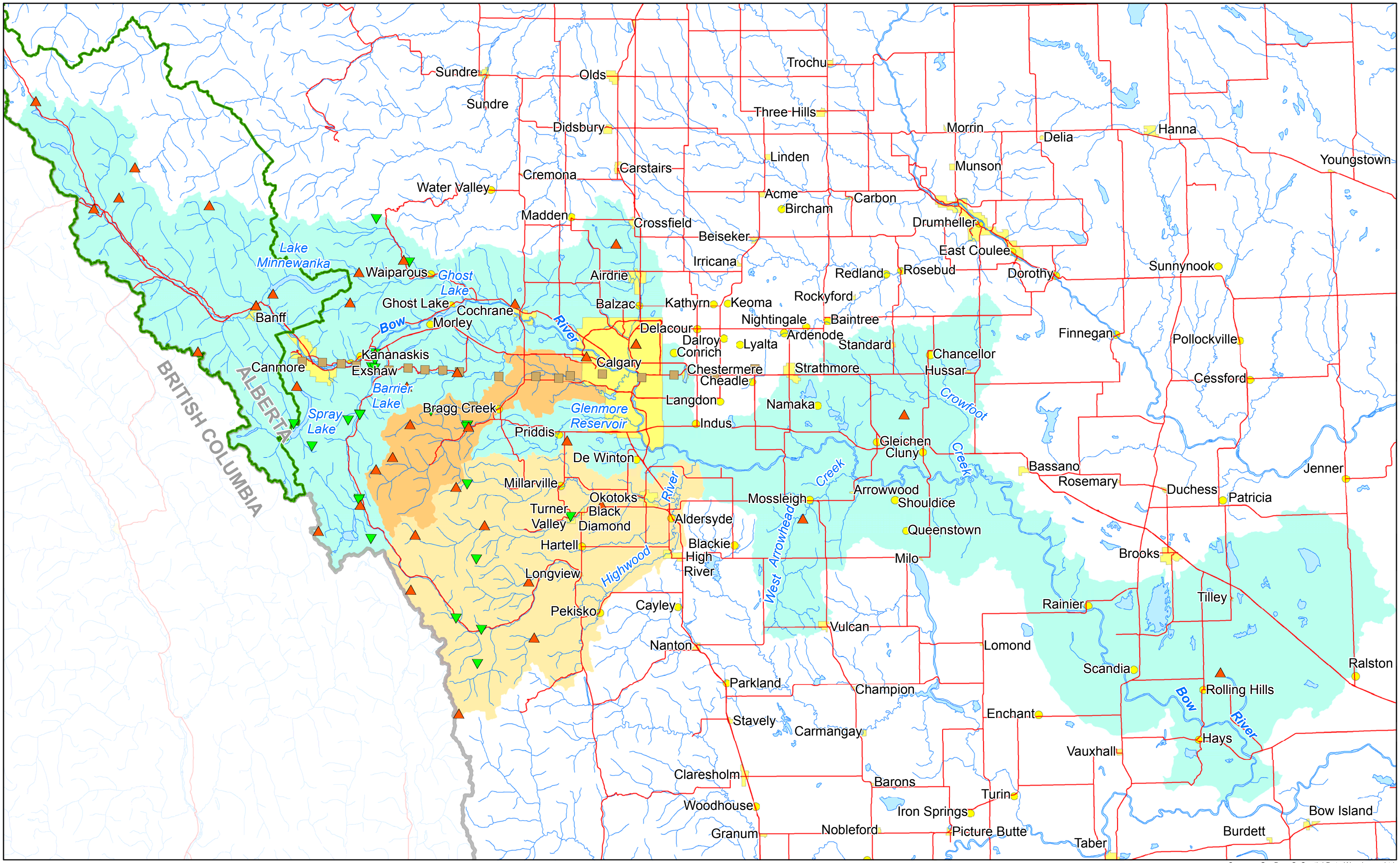
The Bow River is dependent on spring snowmelt for much of its water supply, with up to 80% of its supply coming during late spring and early summer. As a result, flow in the river can be quite low during the late summer and fall months.

The three irrigation districts that rely on water from the Bow River during the summer months may see water shortages during dry years because of a lack of on-stream storage reservoir capacity. The TAC reservoirs, which store water during the summer months and release it during winter to meet peak electricity demands, are not generally used to supplement summer flows. The WID and EID are particularly vulnerable because of a lack of off-stream storage capacity.

2.3 Data Collection and Review

2.3.1 Meteorological Data

As the primary flood producing mechanism for the Bow River is rainfall in the Rocky Mountains and Foothills on a mature snow pack, the key climate stations are situated in the upper portion of the basin. **Figure 2.2** shows the upper Bow River basin and the meteorological stations that are used for flood forecasting purposes by ESRD.



Legend

- Bow River Drainage Basin
- Elbow River Drainage Basin
- Highwood River Drainage Basin
- Urban Municipality
- Banff National Park
- Lake
- River
- Highway
- Meteorological Station (ESRD)
- Meteorological Station (Alberta Forest Service)
- U of C, Foothills Climate Array

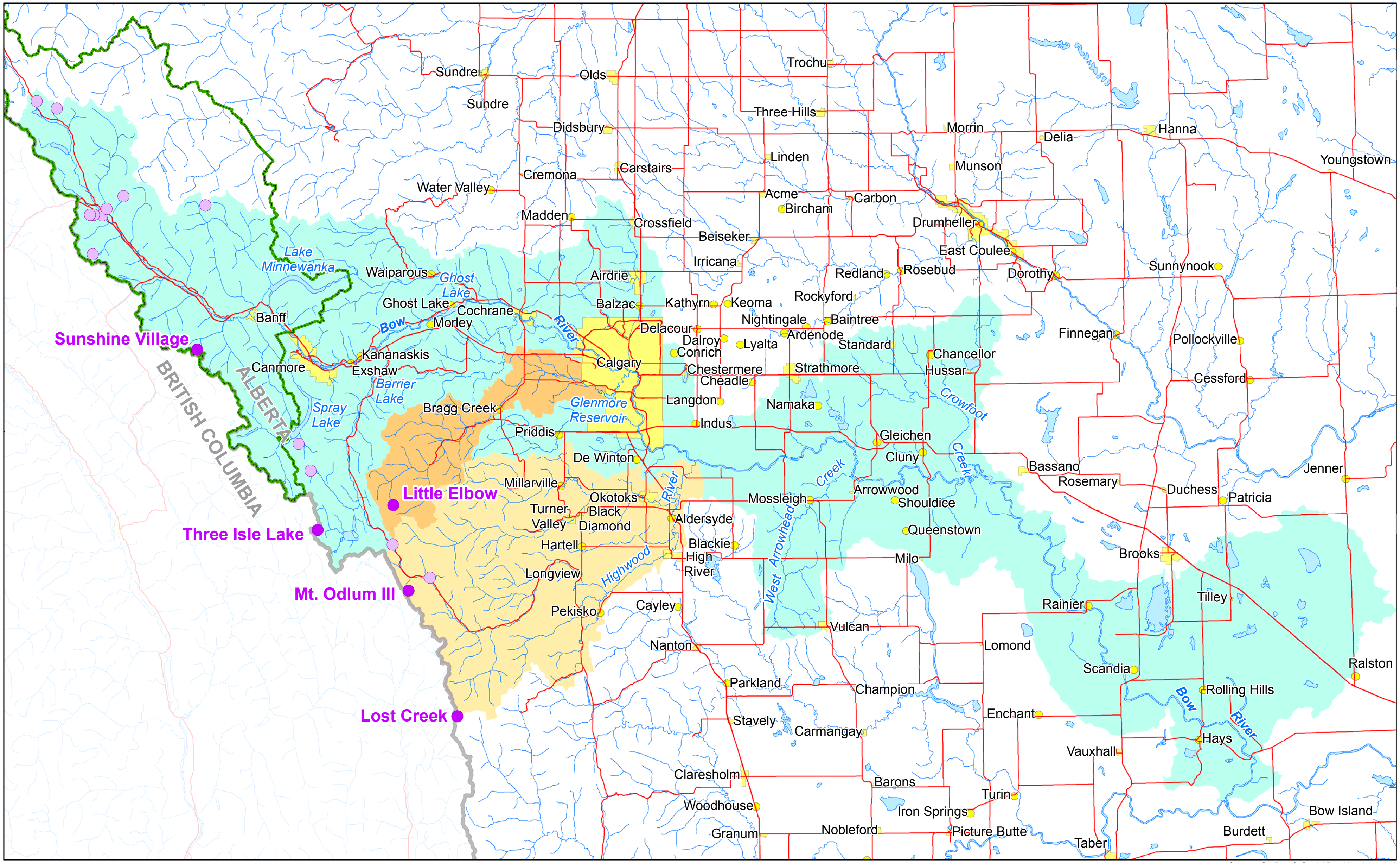
amec	PDF: Fig2.2 Bow Basin Met Stns 14-05-22	**Southern Alberta Flood Recovery Task Force** Flood Mitigation Study	Meteorological Stations in the Bow River Basin
	DATE: May 2014 / PROJECT: CW2174	10 0 10 20 Kilometres 1:1,500,000 N	**Figure 2.2**
	PROJECTION/DATUM: 10TM/NAD83 / ANALYST: TR		

Also shown on **Figure 2.2** are rainfall monitoring stations operated by the University of Calgary. Originally part of a much larger monitoring network called the Foothills Climate Array (FCA), the remaining rainfall gauges extend in an approximate west to east alignment from the Rocky Mountains, across the Foothills and onto the prairies east of Calgary.

Figure 2.3 illustrates the snow survey stations in the Bow River Basin, which include snow pillow sites and snow courses.

2.3.2 Hydrometric Data

The locations of streamflow monitoring stations currently in operation are illustrated in **Figure 2.4**. Key long-term stations are located on the Bow River at Banff, near Cochrane, at Calgary, near Carseland, at Bassano, and near the mouth. Gauges also exist on major tributaries including the Spray River, Kananaskis River, Ghost River, Waiparous Creek, Jumpingpound Creek, Nose Creek, Fish Creek, and the Highwood River.



Legend

- Bow River Drainage Basin
- Elbow River Drainage Basin
- Highwood River Drainage Basin
- Urban Municipality
- Banff National Park
- Lake
- River
- Highway
- Snow Pillow
- Snow Course

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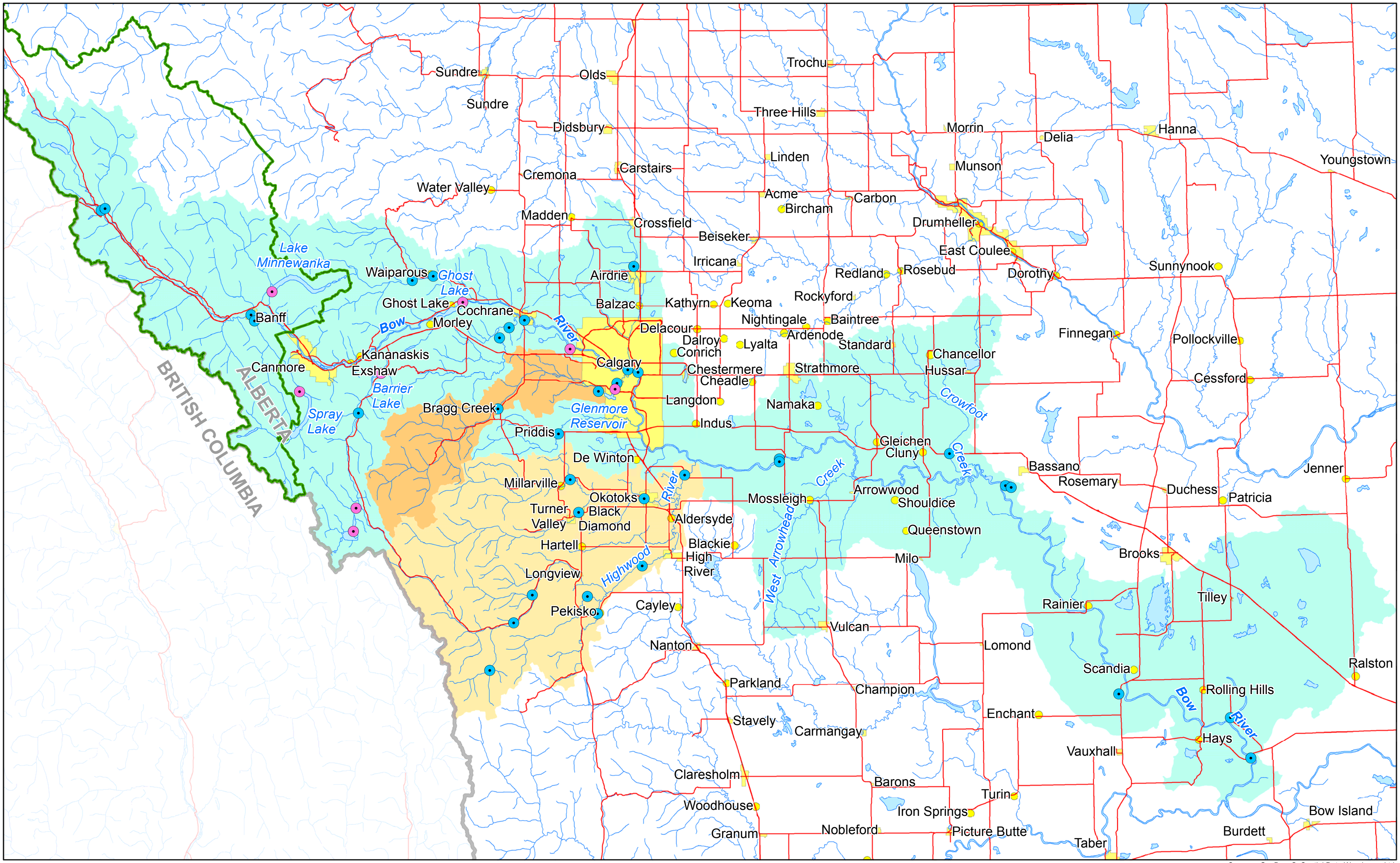
Snow Survey Stations in the Bow River Basin

Figure 2.3



Legend

- Bow River Drainage Basin
- Elbow River Drainage Basin
- Highwood River Drainage Basin
- Urban Municipality
- Banff National Park
- Lake
- River
- Highway

Hydrometric Station

- Discharge
- Water Level

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PDF: Fig2.4 Bow Basin Hydrom Stns 14-05-22	
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Hydrometric Stations in the Bow River Basin

Figure 2.4

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At least nine hydrometric stations were damaged or destroyed during the 2013 flood. Stations that did not operate throughout the 2013 flood included, but might not be limited to the following:

- Kananaskis River below Barrier Dam (WSC station 05BF025 operated by TAC) - Communication was and is still lost, but the data logger and sensor inside the shack operated throughout the flood. Data has been retrieved and flows have been calculated using an extension to the stage discharge curve.
- Bow River near Seebe (WSC station 05BE004 operated by TAC) - Communication and power to shack was lost. Data logger and sensor inside the shack operated throughout the flood. Gauge continued to operate on a backup power source without telemetry until approximately 26 January 2014 when the stilling well froze. TAC has not computed the 2013 flow data for this site yet but will start soon.
- Ghost Tailrace (WSC Station 05BE999 operated by TAC) - Operated throughout the flood. Water level and flow did exceed the existing rating curve but TAC extended the curve. TAC has sent the preliminary computed flow data to WSC for analysis and comparison to their downstream sites. TAC awaiting comments back from WSC.
- Bow River below Bearspaw Dam (WSC station 05BH008 operated by TAC) - Different than the other sites as this station operated using an orifice line and pressure system rather than a direct link to the river. The orifice line was dislodged prior to the peak flow so TAC does not have a good record of the water levels at the peak. TAC has been using calculated spill numbers to piece together flows for the period of the flood. TAC has also sent this information to WSC and is waiting for some information back from them before TAC submits the final data. Even though the orifice line managed to re-anchor itself, TAC believes they will be forced to use spill numbers at this site because the channel changed so dramatically at the gauge that the curve is no longer valid.
- Waiparous Creek near the Mouth – WSC station 05BG006 destroyed.
- Jumpingpound Creek near Cox Hill – WSC station 05BH013 destroyed.
- Ghost River above Waiparous Creek - WSC station 05BG010 destroyed); data up to loss is questionable due to rating curve issues.
- Bow River at Carseland (WSC station 05BM002)
- Jumpingpound Creek at Township Road 252 (WSC station 05BH015)

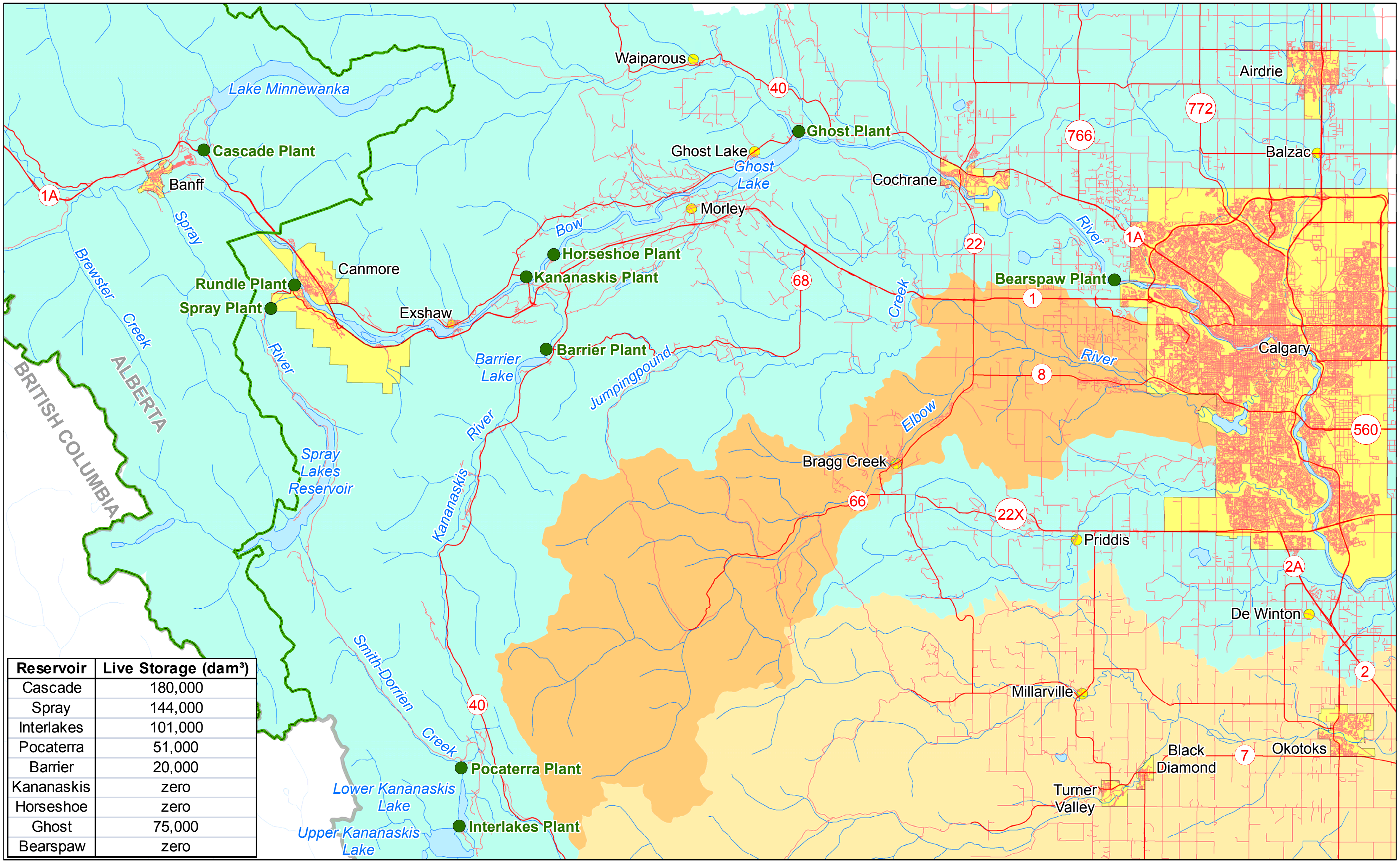
2.4 Bow River Basin Hydrology

Flows in the Bow River basin are defined by the source mechanisms, and the modifications to the natural flow regime between the source areas and the mouth. Streamflow is generated from glacier melt, snowmelt and rainfall runoff. Average annual runoff for the Bow River at Banff is 558 mm. This decreases to 362 mm at Calgary, and to 113 mm at the mouth, as the basin extends into areas of lesser precipitation that produce lesser rates of runoff.

Flows within the river system are modified by diversions, withdrawals and reservoir storage. The following is a description of some of the important flow regulation structures within the Bow

River basin. Other flow regulation structures may exist, however, their importance in the context of flooding within the Bow River basin is believed to be minor.

In the upper part of the basin flows are regulated by hydroelectric dams and related facitlities owned and operated by TAC. **Figure 2.5**, provided by TAC, indicates the key facilities in their power generation system upstream of Calgary. Insofar as flood mitigation is concerned, flood peak attenuation is available from the 95 200 dam^3 of live storage available at the Ghost Dam. Other live storage, such as that potentially available at Interlakes Plant (between Upper and Lower Kananaskis Lakes) might attenuate the peak outflow from only a very small drainage area, with little benefit in reducing the peak discharge in the Bow River approaching Cochrane and Calgary.



Reservoir	Live Storage (dam³)
Cascade	180,000
Spray	144,000
Interlakes	101,000
Pocaterra	51,000
Barrier	20,000
Kananaskis	zero
Horseshoe	zero
Ghost	75,000
Bearspaw	zero

Legend

- Bow River Drainage Basin
- Elbow River Drainage Basin
- Highwood River Drainage Basin
- Urban Municipality
- Banff National Park
- Lake
- River
- Highway
- Road
- Hydroelectric Plant

amec

PDF: Fig2.5 TransAlta Plant Sites 14-05-22

DATE: May 2014

PROJECT: CW2174

PROJECTION/DATUM: 10TM/NAD83

ANALYST: NH

Southern Alberta Flood Recovery Task Force

Flood Mitigation Study

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TransAlta Corporation Hydroelectric Plants

Figure 2.5

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The major TAC structures became operational in the early 1940s. Thus, they had no effect in reducing the peak flows during the 1932 flood, although the Ghost Dam is known to have been under construction at the time.

Other major flow regulation structures within the Bow River basin include:

- Water withdrawal from the Bow River at Bearspaw Dam for City of Calgary water supply;
- Water withdrawal for WID, Bow River Irrigation District and EID;
- Waste-water return flows from City of Calgary; and
- Other industrial water withdrawals.

2.4.1 Historical Flooding

Flood hazard maps are provided in the report **Appendix A**.

2.4.1.1 Bow River

There are records of flood discharges in the Bow River basin extending back over 100 years. **Figure 2.6** illustrates the historical record of flood peak discharges recorded on the Bow River at Banff and on the Bow River at Calgary. Historical floods are known to have occurred on the Bow River in 1879, 1897, and 1902, prior to the start of the systematic period of record. The estimated discharges at Calgary for those historical events are 2,270, 2,270, and 1,560 m^3/s, respectively; though these estimates should be used with extreme caution since the methods used to estimate the flow, and the observed stages, are not available for review. The flood of 2013 was a major flood within the period of record at these locations.

Figure 2.6 also indicates the dates that dams were built for hydropower production.

Figure 2.7 illustrates historical floods recorded for the Bow River downstream of Calgary (and below the confluence with the Highwood River). The timing of major flood peaks evident in **Figure 2.7** are consistent with that depicted in **Figure 2.6** for the Bow River at Calgary, with the following exceptions.

Cochrane, located on the Bow River upstream of Calgary, has an open-water flood record that is generally consistent with that for the Bow River at Calgary. The noticeable exception is that at Cochrane, the variable releases from the TAC Ghost Dam can result in ice build-up and ice jams along the river during the winter. Alberta Environment (AENV now ESRD; 1990) indicate that ice jam flood levels can exceed open water flood levels. Indeed, ice jam levels govern along the Bow River and within the downstream reaches of Jumpingpound Creek and Bigknife Creek within Cochrane.

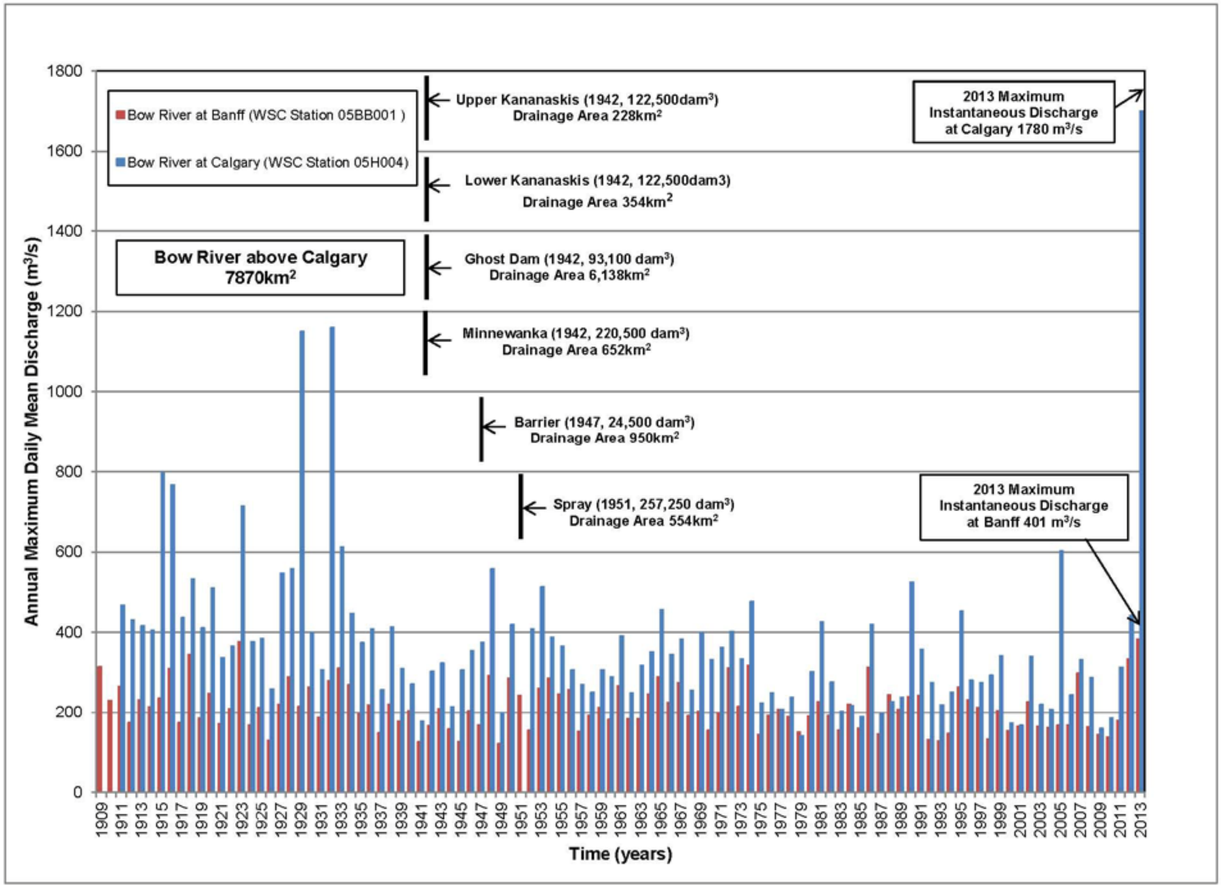


Figure 2.6: Historical Floods on the Bow River at Banff and at Calgary

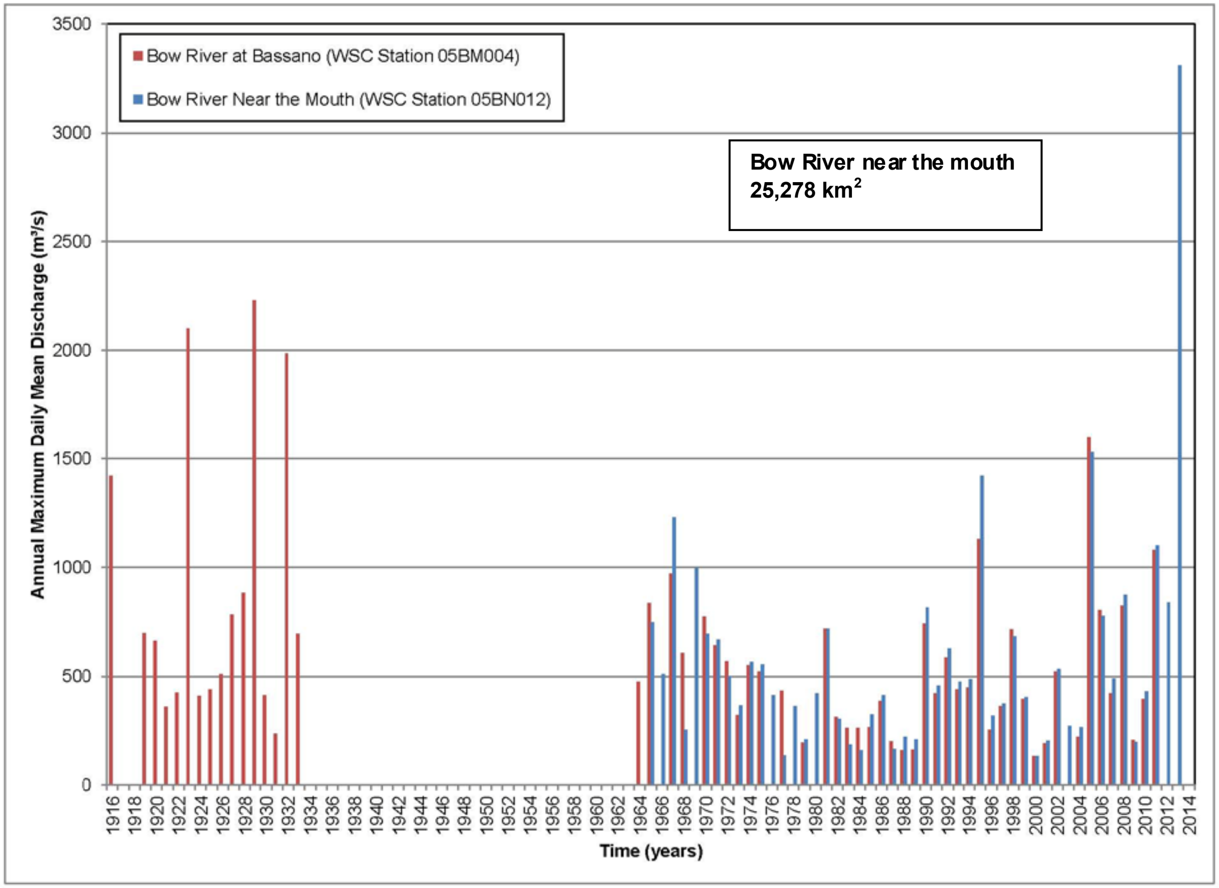


Figure 2.7: Historical Floods on the Bow River at Bassano and Near the Mouth

2.4.1.2 Nose Creek (Airdrie)

The Nose Creek drainage basin ustream of its confluence with the Bow River is 989 km^2 in gross area. The main stem of the creek is oriented approximately north to south, with West Nose Creek entering the lower reach and draining an area to the northwest. The Nose Creek drainage basin is relatively flat (110 m drop over 75 km length) with mostly grassland (pasture) or agricultural crop-land having little tree cover (Golder, 2006). Urban areas have developed in Airdrie to the north and within the City of Calgary to the south.

In 1983, AEVN presented a comprehensive investigation of the history of flooding along Nose Creek and West Nose Creek within the City of Calgary, including anecdotal and photographic information of flooding that occurred mainly in the 1920s, 30s, and 40s, prior to the concentrated urban development that now exists within the basin. As flooding along Nose Creek and West Nose Creek was usually associated with local events caused by heavy rainstorms and/or ice jams (AENV, 1983), the conclusions regarding the severity and frequency of flood for the downstream reach in Calgary can be extended upstream to the City of Airdrie.

On Nose Creek, major flooding occurred in 1902, 1906, 1915, 1923, 1941 and 1948 (AENV, 1983). Most of these flood events were caused by heavy rainstorms and/or ice jams (Hydrocon, 1980). It should be noted that the WSC hydrometric station on Nose Creek at Calgary (05BH003) has flood data available for only 25 years, 1911 to 1919 and 1973 to 1986. In 2005, when flooding was experienced on many streams in southern Alberta, there is no known record of flood damages occurring along Nose Creek in Airdrie.

2.4.1.3 Fish Creek (Priddis)

The Fish Creek Basin is oriented approximately west to east, with flow generated in the Foothills to the west flowing east through the City of Calgary to the Bow River in Fish Creek Provincial Park. Urban stormwater flows enter the creek in its lower reach. Flood discharges commonly result from moist air moving upslope from the prairies to the foothills generating high precipitation values. Precipitation on top of melting snow in the foothills and mountains can result in very severe flooding.

The WSC hydrometric station, Fish Creek near Priddis (05BK001), has data from 1911 to 1916, and 1956 to present. Flood discharges commonly occur in June, but some have occurred as late as August. The flood of record, 482 m^3/s, occurred on 18 June 2005, and the second highest flood of 200 m^3/s occurred on 26 June 1915. Data regarding the flood of June 2013 are not currently available for Fish Creek.

2.4.2 Flood of 2013

The flood of 2013 resulted from extreme high rainfall over the upper Bow River basin during a period when snowmelt was still ongoing. **Figure 8.1, Figure 8.2** and **Figure 8.3** in **Volume 2** illustrate the rainfall isohyets, which indicates areas of high precipitation near the Spray River valley south of Banff. A more significant zone of high rainfall is evident a short distance to the southeast in the headwaters of the Elbow River and Sheep River. The rainfall depths decrease sharply to the northwest into the upper Bow River Basin. Overall, the Bow River basin upstream of Calgary (excluding the Elbow River Basin) received an average of 138 mm of rainfall.

Comparing the isohyets for 2013 (**Figure 8.1, Volume 2**) to those for the events in 2005 (**Figure 8.2, Volume 2**) and 1995 (**Figure 8.3, Volume 2**), it is evident that rainfall depths were much lower for 2005 and lower yet for 1995 within the Bow River Basin. This conclusion is corroborated by computed average rainfall depths of 65 mm for 2005 (approximately half of that for 2013) and 44 mm for 1995 (one-third of that for 2013).

2.4.2.1 Bow River at Banff

The flow at Banff reached a record high peak discharge of 401 m^3/s at 17:00 on 21 June 2013, based on preliminary data received from WSC. The previous historical high discharge was 399 m^3/s on 14 June 1923. **Figure 2.8** illustrates the 1923 and 2013 flood hydrographs.

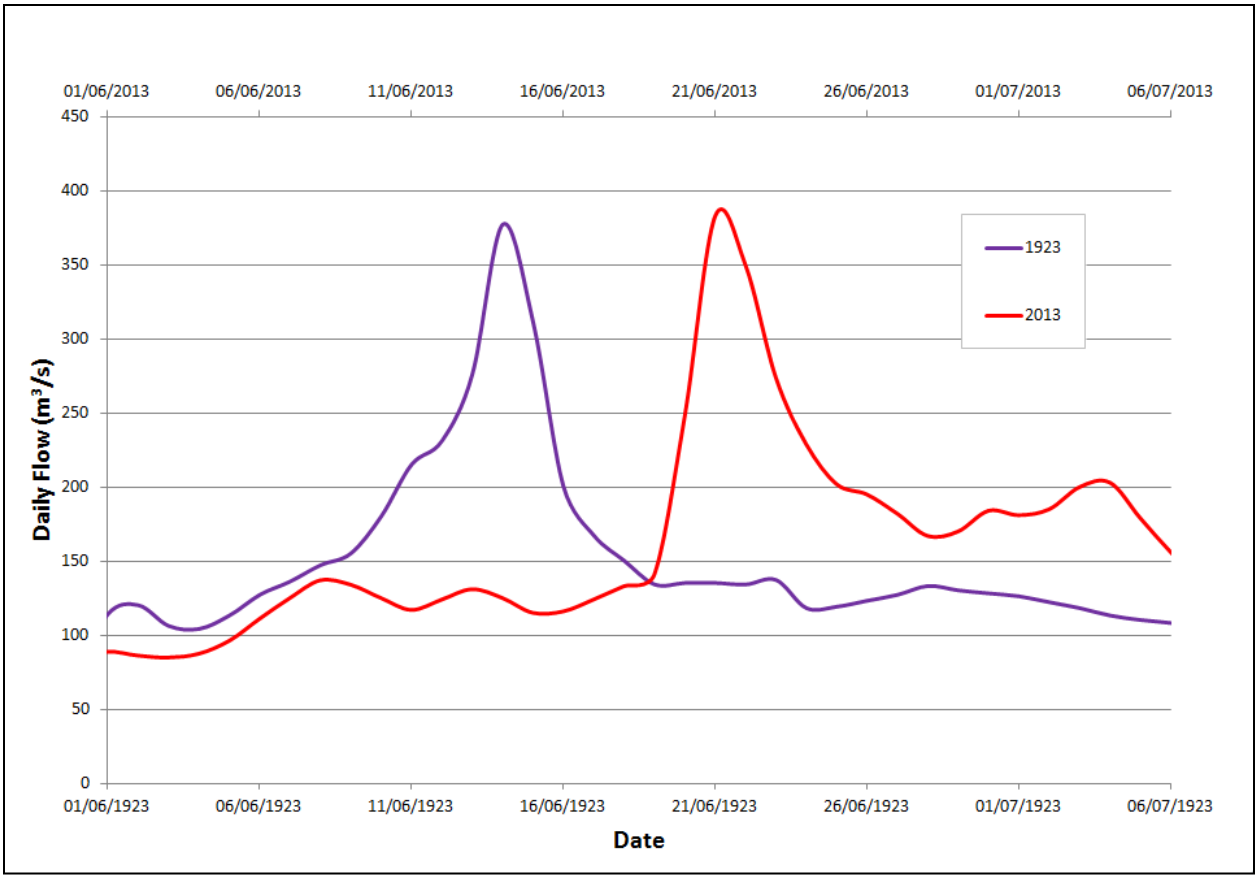


Figure 2.8: Comparative Flood Discharge Hydrographs for 1923 and 2013, Bow River at Banff

The 2013 peak discharge at Banff is estimated to have an annual exceedence probability of less than 0.5%, based on a frequency analysis provided by Northwest Hydraulic Consultants (2013).

TAC (2013) provided the preliminary information presented in **Table 2.1** for flow releases from their upstream facilities up to end of day on 21 June 2013.

Table 2.1
Flow Releases from TransAlta Upstream Facilities

Facility	Maximum Inflow (m^3/s)	Maximum Release (m^3/s)
Lake Minnewanka	314	27
Spray Lake	255	18
Upper Kananaskis Lake[1]	99	0
Lower Kananaskis Lake[1]	117	0
Barrier Lake[2]	360	

Notes:
1. AMEC understands that maximum releases occurred following 21 June 2013.
2. At Barrier Dam, the spillway operation passed the inflow.

Hydrometric information is not readily available for many of the tributary streams entering the Bow River because many stream gauging stations were not operable at the time of peak flow. However, an indirect assessment of the peak discharge reached along the Ghost River was provided by TAC (Golder, 2013a and 2013b). The estimated peak discharge for the Ghost River at Benchlands (downstream of the mouth of Waiparous Creek and upstream of the discontinued WSC gauge 05BG001) was 670 m^3/s. The estimated exceedence frequency of this June 2013 peak discharge is 0.56% to 0.67%.

TAC indicates that the spill from Barrier Dam on the Kananaskis River could have reached 360 m^3/s and that the peak flow in Jumpingpound Creek likely exceeded 130 m^3/s (the gauge was out of service prior to the peak).

The flow in the Bow River at Calgary (upstream of the Elbow River confluence) reached a record high peak discharge of 1,780 m^3/s at 02:45 on 21 June 2013, based on preliminary data received from WSC. The previous historical maximum recorded discharge was 1,520 m^3/s on 3 June 1932. **Figure 2.9** illustrates the 1932 and 2013 flood hydrographs.

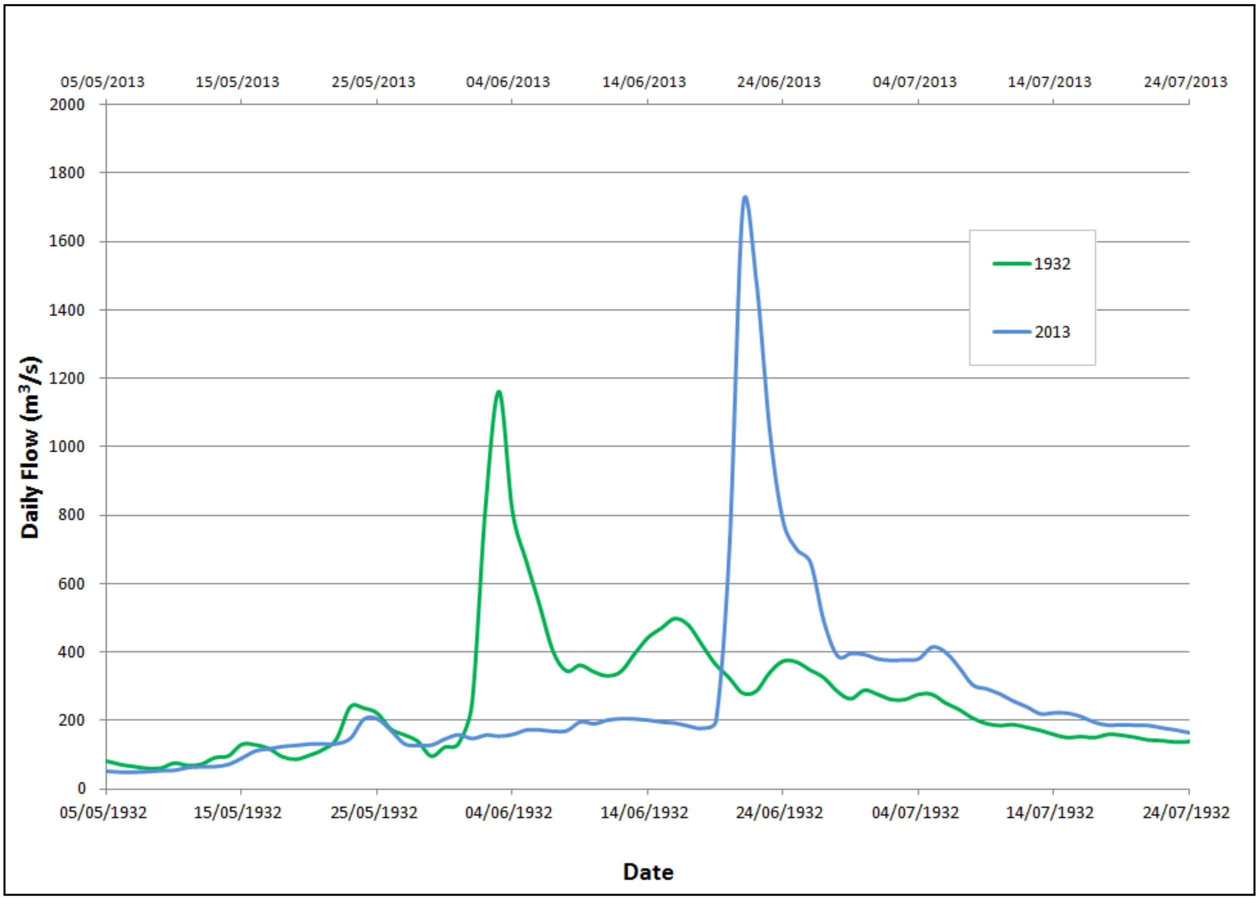


Figure 2.9: Comparative Flood Discharge Hydrographs for 1932 and 2013, Bow River at Calgary

The 2013 peak discharge for the Bow River at Calgary is estimated to have an annual exceedence probability of less than 1%, based on a frequency analysis provided in Golder Associates (Golder) 2010.

June 2013 rainfall within the Nose Creek basin appears to be in the range of 50 to 70 mm. There has been no indication that flooding was a problem along Nose Creek. Based on an interview with the Town of Airdrie, there was no flooding along Nose Creek during the 2013 storm.

The Elbow River enters the Bow River downstream of the WSC station 05BH004. Flooding occurred along the Elbow River, which is discussed more fully in **Section 3.0** in this volume.

As Fish Creek has its headwaters in the foothills southwest of Calgary, high rainfalls resulted in high streamflows in Fish Creek. No estimate of discharges for the Fish Creek at Priddis WSC hydrometric station is currently available. AMEC understands that there was erosion damage and overbank flooding at and around Priddis. Further downstream, several pedestrian bridges were washed out in Fish Creek Provincial Park.

The Highwood River enters the Bow River downstream of Calgary. The characteristics of the Highwood River flood hydrology and damages are addressed by AECOM under a separate contract.

Downstream of the mouth of the Highwood River, very high discharges and water levels were experienced during the 2013 flood. At Carseland Weir, where the discharge likely exceeded 3,540 m^3/s (WSC gauge 05BM002 was not operable), a fuse plug in the diversion embankment washed out.

Further downstream at the Bassano Dam, the peak discharge is estimated to have reached between 3,900 and 4,200 m^3/s based information provided by the EID. ESRD commented that when the discharges are high, the river tends to flood the river valley and the station rating curve indicates an unrealistic low discharge value (approximately 3,340 m^3/s) for the measured 2013 peak water level compared to the EID spillway discharge estimates.

Near the mouth, WSC has estimated the peak discharge to have been 3,490 m^3/s on 23 June 2013 at station 05BN012.

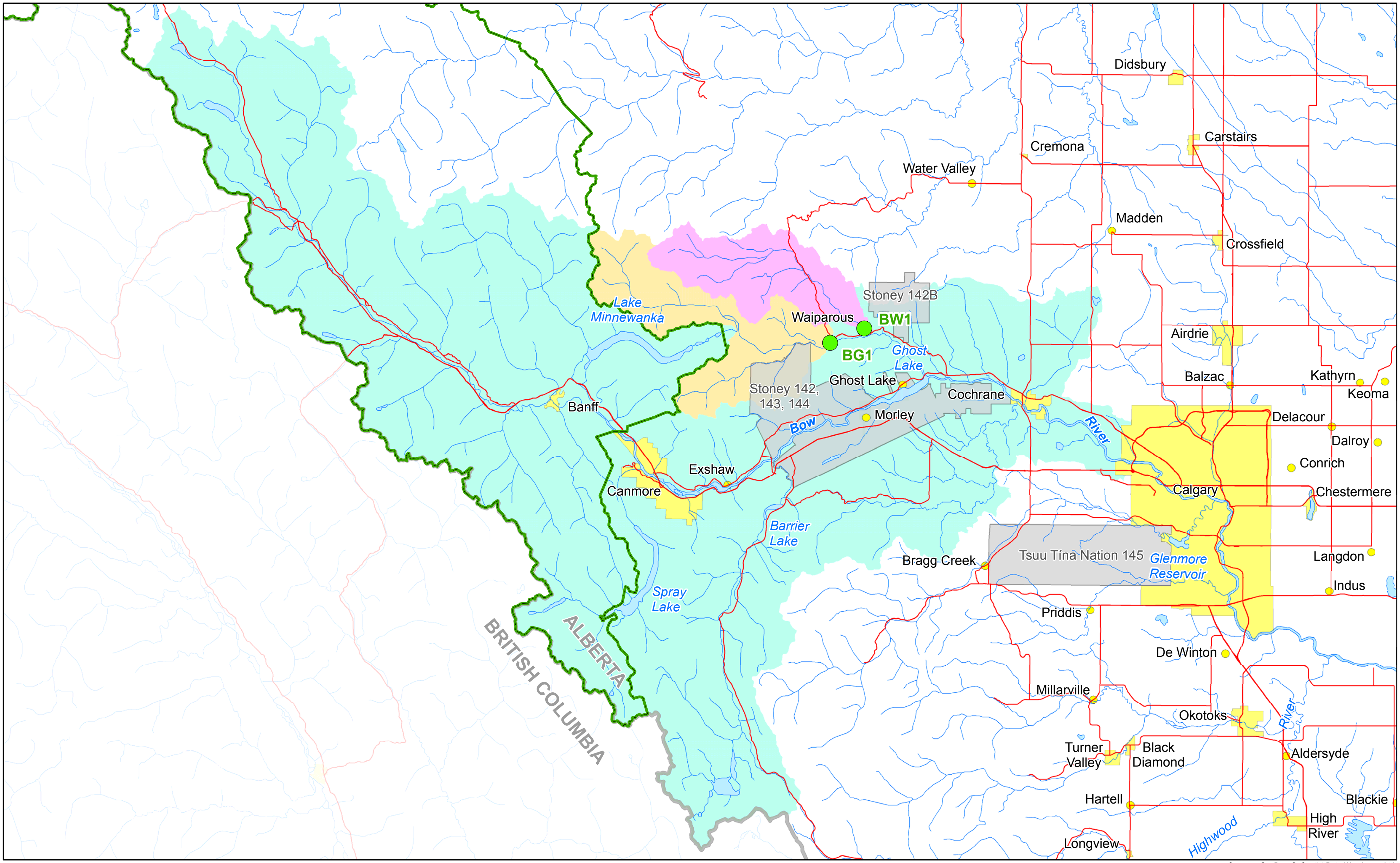
2.5 Major Infrastructure Projects

The multi-criteria decision making (MCDM) assessment process (**Appendix B**) concluded that a new dam on the Bow River system for flood control was one of the least preferred solutions. However, given that such proposals were made by the Flood Advisory Panel (FAP), the Southern Alberta Flood Recovery Task Force (SAFRTF) requested that AMEC undertake a high level review of the locations identified. A summary of the findings is provided below.

2.5.1 Summary Review of Stantec Proposals at BG1 (Ghost River Dam)

A hydrological assessment of the BG1 dam proposed by the FAP was undertaken to determine likely reductions in water levels along the Bow River in Calgary.

The drainage area of the Ghost River upstream of the proposed BG1 dam is approximately 485 km^2 or approximately 4.2% of the drainage area of the Bow River upstream of the Elbow River confluence. **Figure 2.10** illustrates the drainage basin upstream of the proposed BG1 Dam in relation to the catchment of the Bow River basin upstream of Calgary; it also shows the location of BW1, which is another site proposed by the FAP.



Legend

- Bow River Basin Upstream of Calgary
- Ghost River Basin Upstream of BG1
- Waiparous Creek Basin Upstream of BW1
- Urban Municipality
- Banff National Park
- Indian Reserve
- Lake
- River
- Highway
- Proposed Flood Advisory Panel Dam Site

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DATE: May 2014	PROJECT: CW2174
PROJECTION/DATUM: 10TM/NAD83	ANALYST: TR

Southern Alberta Flood Recovery Task Force

Flood Mitigation Study

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Location of BG1 and BW1 Detention Dams

Figure 2.10

The assessment was based on a routing model, which determined:

- The outflows from Ghost Dam based on inflows from the Bow River near Seebe, the Ghost River above Waiparous Creek and from Waiparous Creek near the mouth; and
- Characteristics of Ghost Dam and Ghost Lake upstream of the dam.

Flows from Jumpingpound Creek were added to the Ghost Dam outflows to provide a representation of the flows in the Bow River at Calgary. To evaluate the effects of the proposed BG1 Dam on the Ghost River, two scenarios were modeled:

1. No outflow from the Ghost River above Waiparous Creek – representative of a dam retaining 100% of the Ghost River flow, which would result in a maximum effect that is likely not attainable; and
2. A 60% reduction in the flows in the Ghost River above Waiparous Creek – representative of a detention dam as proposed by the Flood Advisory Panel at Quirk Creek on the Elbow River.

The key findings from the evaluation were:

- Peak discharges would be reduced by a maximum of 10% (129 m^3/s) with no outflow from BG1, and by 6% (77 m^3/s) for the detention dam scenario (60% outflow).
- Water levels along the Bow River in Calgary would potentially be reduced by a maximum of 0.18 to 0.27 m if 100% of the Ghost River flow is retained. Water level reductions for a detention dam at the BG1 site would more likely be less, in the range of 0.1 to 0.16 m.

A similar assessment has not been undertaken for the proposed dam site on Waiparous Creek upstream of Benchlands. The reason for this omission is that the basin area of Waiparous Creek is less than that of the Ghost River (upstream of Waiparous Creek) and; therefore, a logical conclusion can be drawn that the benefit of a dam on this creek is even less.

A copy of the full review memo is included as **Appendix C** to this report.

2.6 Options by Flood Risk Area

2.6.1 Canmore

2.6.1.1 Stakeholder Engagement Response

The stakeholder questionnaire was completed by the Flood Coordinator from the Town of Canmore and returned by email. The town suffered minor flood damage in 2005 and major damage in 2013. The primary problem in June 2013 was sediment and debris flow in nine mountain creeks. The most significant damage was along Cougar Creek where bank armouring was overwhelmed, resulting in significant erosion and widening of the watercourse.

The Town of Canmore is currently undertaking detailed hazard and risk assessments for the major mountain creeks in Canmore. The measures for flood mitigation in the area suggested by the Town are:

- To work with mountain communities to develop detailed hazard and risk assessments. Once complete, develop and implement active and passive mitigation measures appropriate for the hazards and risks determined.
- Specifically related to the Bow River valley (Lake Louise, Banff, Canmore, Exshaw, Lac Des Arcs) ensure that a comprehensive study is conducted to determine if the current infrastructure (dykes, banks, etc.) should be enhanced to provide protection beyond a 1 in 100-year return period event. Develop policies that pertain to water management in power producing dams as it relates to flood mitigation.
- Enhance the current weather monitoring/river forecasting centers. Implement mountain creek weather monitoring and forecasting systems. This won't reduce or prevent flooding in the future but will serve to help protect people, property and infrastructure.

2.6.1.2 Known Flood Pathways

A flood risk mapping study was undertaken for the Bow River and Policeman's Creek Canmore by W-E-R Agra Ltd in March 1993. The study was primarily a hydraulic modelling and mapping exercise. In relation to ice related floods, there is only reference to an historical event in 1936 or 1937, which was water and ice. Theories regarding the absence of ice related flooding are presented in the flood study. These are not restated here; suffice to say that ice has not historically been a significant risk.

There is a lengthy history of fluvial flooding in Canmore with events occurring fairly often in the late 1800s and early 1900s (AGRA, 1993). Flood control dykes were constructed by ESRD in 1977 in response to the 1974 flood. A number of erosion control measures were also implemented along the Bow River including bank armouring and riprap spurs.

As mentioned above, the Town of Canmore stated that the main problem in June 2013 was related to debris flow, sediment and severe erosion along mountain creeks. Flood risk mapping for Cougar Creek had been prepared by CH2M Hill Engineering Ltd. in 1994. The conveyance capacity of Cougar Creek was demonstrated in that study to have been adequate to pass the 1% AEP flood. However, during the June 2013 flood, the creek banks suffered severe erosion.

2.6.1.3 Recommendations

Though some conveyance improvements along the Bow River upstream of Bridge Road might help reduce flood levels through the town centre, it is known that previous efforts to dredge the river and to reduce the deposition of sediment at this location have not been successful in the long term.

No specific recommendations are made in this study for improvements to the flood mitigation infrastructure in the Town of Canmore. It is understood that the town has undertaken "forensic" studies for all nine mountain creeks in Canmore and detailed hazard and risk assessments for the major mountain creeks in Canmore are currently being prepared.

Given the broader scale of this study, the local studies being undertaken for the town should provide the necessary recommendations for flood mitigation in Canmore.

2.6.2 Exshaw

2.6.2.1 Stakeholder Engagement Response

The stakeholder engagement response was by email from MD of Bighorn. There were recent flooding problems in 2005 and 2013, but no knowledge of any problems prior to 2005.

Regarding past experience of flooding, the MD stated that there were "too many to provide here." In 2013, several creeks (including Pigeon, Heart, Grotto, Exshaw, Jura, Livingstone and one unnamed creek) overflowed or otherwise created flood problems, while the Bow River caused erosion problems at the Hamlet of Lac Des Arcs. In 2005, one creek (Jura) and one river (Ghost) created substantial flooding concerns. Jura did overflow, while the Ghost came close to overwhelming the protective berm.

In response to the June 2013 event, the MD is purchasing properties in both Exshaw (along Exshaw Creek) and Lac Des Arcs (along the Bow River bank) to provide remedial/protective measures for the respective communities.

2.6.2.2 Known Flood Pathways

Both Jura Creek and Exshaw Creek are known to have capacity issues at Highway 1A and the Canadian Pacific Railway (CPR) crossings.

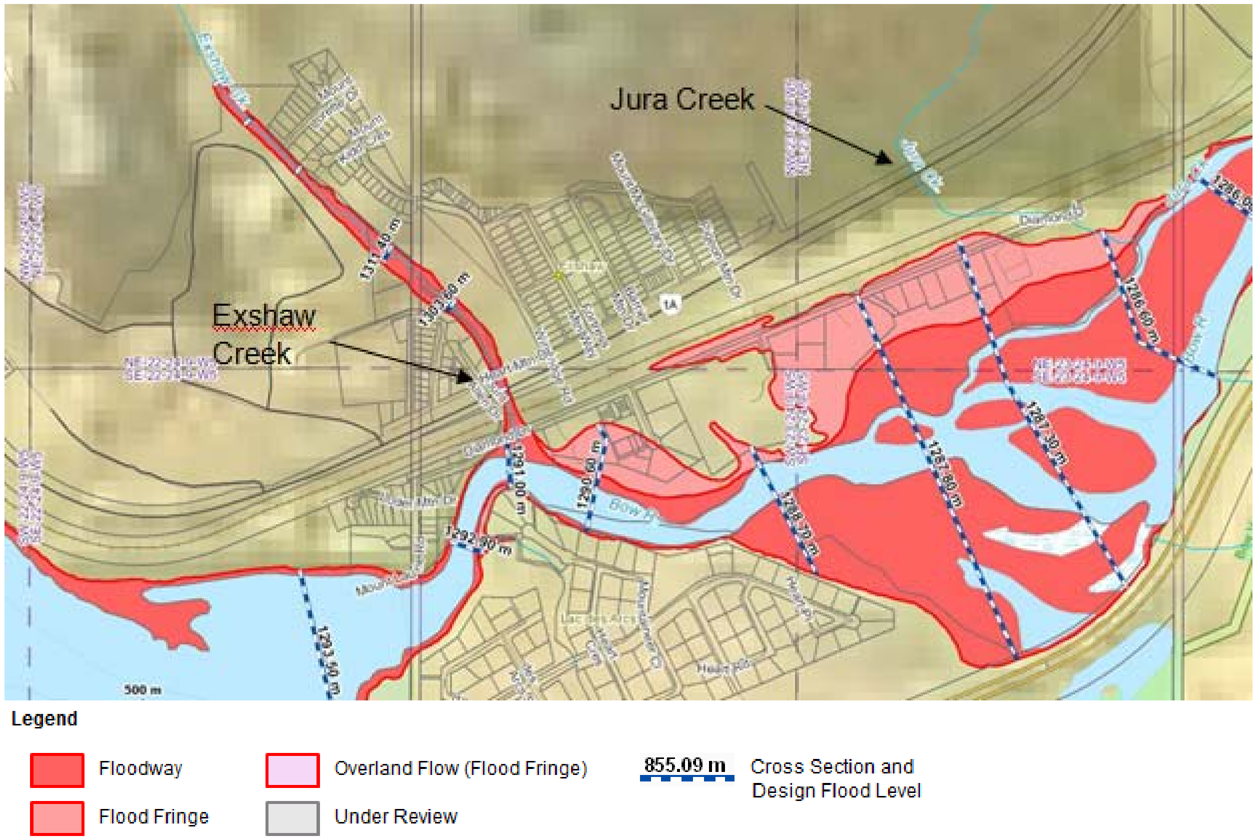
The 1996 flood study undertaken by Acres International Limited stated:

"The calculated water levels on Exshaw Creek for the 100 year return period flood were all within banks. However, this steep stream is subject to erosion and sediment deposition during floods. Also, debris could quite easily block the rather small bridge openings on Exshaw Creek. Either of these possibilities could cause flood waters to overtop the banks."

The flood study report also states the bridge crossings of Exshaw Creek are problematic:

"These bridge crossings are not very high above the creek bed. The creek carries a large amount of bed load gravels during high flows which tend to deposit in the area of the three lower bridges. Regular removal of bed material is required to maintain a clear channel under the bridges."

Figure 2.11 shows the location of known mountain creek channel conveyance problems at Exshaw.



(Source: ESRD, 2014)

Figure 2.11: Location of Channel Conveyance Problems at Exshaw

At Jura Creek, Alberta Transportation (AT) is replacing the corrugated steel pipe (CSP) culvert with a twin box concrete culvert which can carry more flow and be cleaned out more easily. AT does not currently have plans to replace the structure at Exshaw Creek. Replacing this culvert would have little effect on reducing floods because of the CPR constriction immediately downstream. AT has undertaken damage repairs to this structure.

2.6.2.3 Recommendations

No additional structural improvements are likely at Exshaw. The nature of the landscape and the basins on Exshaw and Jura creeks means that debris will be an emergency response perpetual problem. It may be possible to install a debris fence across Exshaw Creek upstream of the community to help limit debris blockage of the bridges; however, annual maintenance would still be required. The benefits of installing such a debris screen would depend on a location with suitable topography being located within the debris transport reach.

It has not been possible within the context of this study to approach CPR regarding replacement of the rail bridge over Exshaw Creek. The replacement of the rail bridge would be a costly long-term solution and it is likely that the benefit in reduced maintenance would likely not be justifiable in economic terms.

2.6.3 Stoney Nakoda First Nation

The Stoney Nakoda Nation (SNN) covers land outside of AMEC's study area. This section focuses primarily on the community of, and general area around, Morley.

2.6.3.1 Stakeholder Engagement Response

The SNN was engaged at a meeting on 14 February 2014. The meeting was attended by four nation representatives. The consultation response was very informative and a very good description of the nature and effect of the event was provided.

Similar to other communities in the area, damage and disruption was primarily caused by runoff and debris from small mountain creeks. Roads were impacted by heavy rain and spring runoff exceeding banks of creeks on reserve lands. The SNN people traditionally build their houses close to sources of water. The impact of overland flow from mountain creeks is significant. In the 2005 flood, the flood water rose more gradually and they were able to be better prepared. The nature of rainfall and runoff from the mountain streams in June 2013 meant that less than 24 hours notice was available and as such, there was less time to react and prepare for the event.

Approximately 400 homes were affected in the Morley area with significant numbers experiencing contamination of their water wells by overland water from heavy rain and creeks overflowing banks. Sections of on-reserve roads were under water resulting in some homes/residents being isolated for days and unable to access potable water. Access to the water treatment plant was also cut off for a few days due to flooding of access roads.

2.6.3.2 Known Flood Pathways

The flooding that occurred in June 2013 was caused primarily from runoff from mountain creeks. A large number of houses have basements and a considerable number of these were affected. Another major problem was contamination of wells from overland flow from the mountain creeks. Damage is certainly possible from both the Bow River and countless small mountain creeks which line the valley.

2.6.3.3 Multi-Criteria Decision Making and Detailed Reviews

At the time of the MCDM workshops, the SNN engagement meeting had not been held and insufficient information was available to AMEC regarding the nature of the damages and the flooding hotspots to enable a MCDM approach to be taken. The recommendations set out below are therefore based on the engagement response from SNN.

2.6.3.4 Recommendations

In the draft engagement response the SNN stated that they would benefit from an emergency response plan for all emergencies, not just for flooding. The emergency response plan would need to be supported by a flood warning system to enable the responders to act on the plan. The SNN did not have much warning about flooding from the mountain streams.

Based on the history of flooding at Morley, the elders expected significant flooding about once every 60 years. Since there had been events in 1995 and 2005, the people did not expect another significant event so soon.[1]

In reality, it would be difficult to provide reliable flood warnings with sufficient lead time to take action to reduce the impact of flooding from mountain streams as the basin response is too fast. However, some basic information provided in an emergency response plan would help first responders act in a planned way and would also help with the post event recovery.
The emergency response plan should include:

- Implementation “triggers” or a list of possible scenarios that would lead to the enactment of certain parts of the emergency response plan.
- Maps showing the places where roads may be impassable – this can be based on elders experience and known flooded locations from June 2013.
- A confidential list of addresses where particularly vulnerable people may reside to aid evacuation.
- Maps showing which water supply wells might be affected.
- Identify a building that has safe (from flooding) access and egress routes that can be used as a reception centre during an emergency. The school was used during June 2013; however, the emergency response plan should confirm that this is the best location for the emergency reception centre.

Often, after the flood has subsided and the media attention diminishes, the victims of flooding can feel a sense of abandonment. It is understood that the SNN community thrives on sharing and helping each other[2]. Some of the difficulties encountered during the 2013 flood were related to communication and members of the community accessing those in need.

A recovery plan should therefore be developed to enable swift assessment of priorities and to identify sources of funding or relief that can be drawn upon in the immediate aftermath of a flood event. In assessing the need for disaster relief, the recovery strategy should explicitly set out the process for relief and specifically should set reasonable limits on the number of inspections required to assess damage. It is understood that some houses were inspected six times.
No more than two inspections should be necessary - one by a disaster relief program assessor and one by an insurance adjuster, where applicable.

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[1] Information from consultation response.
[2] Engagement response

The development of the emergency response plan will require significant engagement with the SNN and will take time to develop effectively. It is not possible to undertake this work within the timeframe of this study. However, funding should be allocated to the SNN to hire consultants with specialist flooding and emergency response experience to undertake the work on their behalf.

Recommendation 4.6: It is recommended that an emergency response plan be developed for Stoney Nakoda First Nation and for it to include a plan for recovery.

2.6.4 Cochrane

2.6.4.1 Stakeholder Engagement Response

The Town of Cochrane responded to the stakeholder engagement questionnaire over the telephone. Regarding the 2013 flood event, the following description of damage was offered:

- The flood affected mostly park areas, some bridges, and the intake of water treatment plant. There were no effects on houses, building infrastructure, or roads; just pathways.
- The flood was fluvial. It rained, the river came up and washed out pathways, resulted in some erosion, gravel deposits and some damage to the bridges from the high water.
- The bridge across the Jumpingpound Creek was affected, the channel changed significantly and lots of debris was left, but no residential flooding.
- The intake on the water treatment plant was affected.
- There was no damage along the Bow River other than pathways, parks and bank undercutting.
- Some pathways were washed out in Big Hill with minor impacts on houses.

2.6.4.2 Known Flood Pathways

The Cochrane Flood Plain Study (undertaken by AENV in 1990) and historical evidence demonstrates that the channel capacity of the Bow River at Cochrane is unlikely to cause flooding on a frequent basis. The 1% annual exceedance probability (AEP) flood extent is less than that shown on the current ESRD mapping.

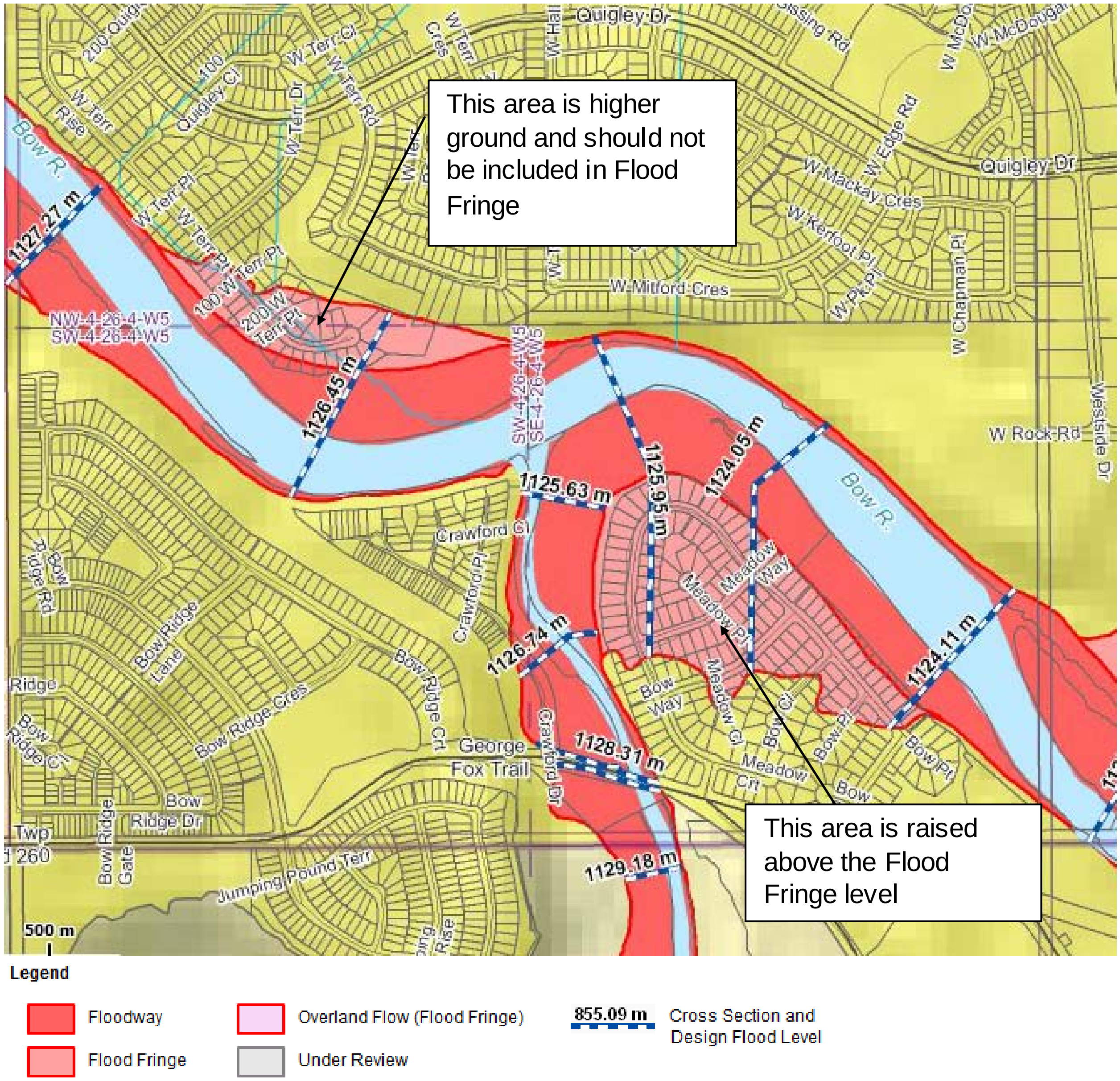
The most likely cause of flooding at Cochrane is related to ice in the Bow River. The flood study reports that the winter ice regime of the Bow River has been greatly influenced by the development of hydro-electric power dams. Winter releases from the Ghost Reservoir (to generate electricity at peak times) result in the production of large quantities of frazil ice[3]. The warmer water stored in the Ghost Reservoir assures that the river reach immediately downstream of the dam remains open throughout the winter producing large quantities of frazil ice which can cause jams further downstream at Bearspaw. These jams can then reach back to Cochrane increasing the flood risk.

[3] Frazil ice is the slush like ice crystals seen in supercooled flowing turbulent water.

2.6.4.3 Multi-Criteria Decision Making and Detailed Reviews

Initially the MCDM analysis for Cochrane identified that the preferred solution at Cochrane was to construct flood dykes along the areas at risk. After obtaining LiDAR data to undertake the conceptual design of the dykes, it was confirmed that the flood mapping at Cochrane is out of date. Analysis of the flood extent using GIS techniques has confirmed the statement from the Town of Cochrane that the flood mapping needs to be redone to reflect the current topography. The areas shown in **Figure 2.12** near the confluence of Jumpingpound Creek appear to be incorrectly mapped.

The MCDM also highlighted the need for improved erosion protection. The town has also acknowledged in the engagement response that several pathways and riverbank areas had experienced erosion during the June 2013 flood. The identification and solution to these problems are most effectively dealt with by the town and no further examination is given to them in this report.



(Source: ESRD, 2014)

Figure 2.12: Flood Mapping Improvements Required

2.6.4.4 Conceptual Design

A substantial review of the Bow River hydrology has been undertaken as part of this study; and LiDAR data has also been obtained. The flood mapping update should revisit the hydraulic modelling using current flood frequency estimates. The update of flood mapping will aid in emergency response planning and the economic appraisal for future improvements. With modern LiDAR topographic data, the extent of flood risk at Cochrane can more accurately be determined. The 1990 study also recognised the limitations of the HEC-2 software package in determining the effects of ice blockages in the river. The updated flood study should also reassess the likelihood and consequences of ice blockages along the Bow River; particularly in relation to the propensity of the river to produce frazil ice downstream of the Ghost Reservoir.

2.6.4.5 Recommendations

It is recommended that the 1990 flood study be updated with current modelling and mapping techniques. Though a 1-D modelling approach will be adequate, there should be some accounting for the likelihood of ice dams occurring downstream of Cochrane and the associated backwater affects.

Recommendation 4.7: It is recommended that an update of the 1990 flood study for Cochrane be undertaken to reflect new development and land raising. This assessment should include a reassessment of the risk of ice dams or blockages.

2.6.5 Calgary

2.6.5.1 Scope of Study for Calgary

Although the City of Calgary (the City) is by far the largest municipality with the most properties at risk of flooding in the Bow River basin, the scope of work agreed at the onset of this study did not include specific local level flood mitigation schemes. The City has both the resources and technical expertise to deliver mitigation measures on behalf of the residents and businesses. However, given the scale of flooding experienced in June 2013, and the major infrastructure proposed by the FAP, AMEC were asked to include a review of proposals for dams in the upper Bow River basin.

Meetings were held with staff from the City and it is understood that the City is evaluating the following solutions to alleviate known flooding hazards identified during the 2013 flood and previous events. These are:

- Selected permanent dykes;
- Selected temporary (demountable) flood protection barriers;
- Amendments to existing storm water outfalls to ensure protection from high river levels and ensure adequate stormwater control during periods of high river levels;
- Relocating vulnerable electrical trunk and feeder services;
- Erosion protection measures for pathways and related facilities along river banks;
- Replacement of pedestrian bridges;
- Engineering evaluation of ice-induced flooding mechanism and forecasting opportunities;
- Engineering feasibility assessment for a tunnel from Glenmore Reservoir to the Bow River; and
- Engineering design of restoration measures for the Harvie Passage facility on the Bow River.

2.6.5.2 Known Flood Pathways

There are two predominant flood-producing mechanisms or pathways along the Bow River within Calgary. The worst flooding is caused by high stream discharges resulting from rain-on-snow runoff from the Rocky Mountains and foothills portions of the upper Bow River basin. Lesser flooding can result from high water levels caused by ice jam blockage predominantly during freeze-up. Both of these mechanisms can result in overland flooding as well as elevated groundwater levels that can lead to basement flooding.

2.6.5.3 Multi-criteria Decision Making Assessment

Due, in part, to the large number of existing reservoirs along the Bow River mainstem and tributaries upstream of Calgary, it is extremely difficult to identify any likely sites for flood storage that would be large enough to accommodate flood events such as the ones experienced in 2005 and 2013. Due to the commercial and water resources purposes of the existing sites, altering the operational procedures comes at a risk of loss of revenue for TAC or a depletion of the City's water supply. Neither are desirable consequences.

The MCDM process identified that the City would benefit from the construction of dykes at strategic locations along the Bow River. It is understood that the City is undertaking feasibility studies in this regard. Another obvious measure highlighted in the MCDM process was the implementation of erosion protection measures along the river banks.

2.6.5.4 Recommendations

Although it is acknowledged that a dam on either the Ghost River or Waiparous Creek at the locations shown would provide some limited reduction to the risk of flooding in Calgary, the relatively small benefit needs to be balanced against the cost of construction. The only means to prove the economic viability of such schemes would be to undertake a detailed cost benefit appraisal to determine if the damage avoided by constructing a dam at either, or both, locations would be warranted.

Until the economic case for construction is proven, a dam at either site should not be considered. In order to undertake the cost benefit appraisal, the feasibility of the sites proposed by the FAP from environmental, social, geotechnical and geologic hazard points of view should be assessed.

No specific recommendations are made in this report for further flood mitigation on the Bow River for the benefit of Calgary since the City is undertaking its own review and development program.

2.6.6 Kananaskis Country (Bow River and Elbow River)

Flood damage was experienced in Kananaskis Country in both the Bow River basin and the Elbow River basin. In relation to damaged infrastructure, the majority of damage in the Kananaskis was to transportation and recreation facilities. AT undertook emergency work to reopen roads that were closed due to erosion and debris flows. Several major structures and numerous culverts on creeks along Highway 40 and Highway 66 were affected.

2.6.6.1 Recommendations

Specific recommendations are limited for Kananaskis Country because several studies and programs are currently underway to rebuild damaged assets. The highest profile work is being done by Alberta Tourism Parks and Recreation to restore the Kananaskis Golf Course and in the order of $25M has been allocated to this repair.

Although it is possible to place a financial value on the indirect damages that occur when a recreation facility is lost, on the scale of Kananaskis Country, the economic basis for flood mitigation will be difficult to quantify. The area is a world class tourist attraction and is visited by millions of visitors each year for recreation purposes. It is a key resource that benefits the health and wellbeing of Albertans; however, some infrastructure should not be repaired. For example, paths and infrastructure at Allen Bill Pond along Highway 66 were destroyed; having been reconstructed following the 2005 flood event. In **Section 3.4.1** of this report considers the construction of a dam at McLean Creek downstream of Allen Bill Pond; the pond would be within the impoundment area of this dam. The conceptual dam design includes a permanent pond and this could be an effective replacement for the lost recreation at Allen Bill Pond.

Recommendation 4.8: It is recommended that the Allen Bill Pond area be returned to nature.

Work will continue by AT to replace or repair infrastructure. One structure that requires a significant investment is at Hood Creek on Highway 40. Although the conveyance capacity of the culvert at Hood Creek is sufficient to pass water flows generated from the upstream basin, the major problem at this location is debris. The watercourse immediately upstream of the highway flows through a deep canyon and enormous volumes of tree and rock debris are carried down from the upper basin to the highway which acts effectively as a dam. In June 2013, the highway was completely blocked by a debris flow approximately 8 m deep. The crossing is at the apex of an alluvial fan and as such, the natural state would be for these debris torrents to be deposited further downstream on the fan. AMEC undertook a separate study for AT and recommended the replacement of this culvert with a single span bridge or concrete box culvert (3.0 m span by 2.4 m rise) at a cost of $2.9M or $2.1M, respectively. AMEC recommended that a bridge would require less maintenance and would provide a larger opening to allow debris flows from the Hood Creek basin to pass beneath the highway.

Recommendation 4.9: The corrugated steel pipe culvert at Hood Creek on Highway 40 is prone to blockages and it is recommended that this culvert be replaced with a new bridge at a capital cost of approximately $2.9M.

2.6.7 Siksika First Nation

2.6.7.1 Stakeholder Engagement Response

Siksika Nation was engaged on 14 February 2014 via email response. The respondents identified a recent flood history mostly related to surface water flooding in 1998, 2005, 2007, 2011 and 2013; although there was no information of specific damages that occurred during those years. In 2013, the Siksika provided the following information:

- They were *"not sure if obstacles or constrictions caused the river to overflow its banks."*
- Flooding affected them *"From west end border completely all the way to east end border of Siksika Nation lands and everywhere in-between. There was no flooding downstream of the Bassano Dam, but the water backed-up and flooded Siksika."*

One solution offered by Siksika was to remove houses from the flood plain.

2.6.7.2 Known Flood Pathways

The flood pathway for this area is primarily out of bank, fluvial flooding from the Bow River. The Siksika noted discharges downstream at Bassano Dam have an effect on their Reserve and that any flood mitigation measures upstream need to be assessed for impact on the Reserve land.

2.6.7.3 Multi-criteria Decision Making and Option Assessment

The MCDM analysis recommended that the best structural measure to protect properties on the Siksika Reserve were flood dykes and the best non-structural measures are buyouts to remove people and properties from the floodway.

2.6.7.4 Conceptual Design

A conceptual design of flood defences was proposed for protection of private properties located within the flood fringe of the Bow River within the Siksika Nation's reserve land. Floodway and flood fringe zones were delineated based on conceptual HEC-RAS modeling of the Bow River for the 1% AEP flood. Relocation of lower density housing or properties within the flood fringe was proposed as a result of a possible low cost-benefit ratio. Flood defences are proposed for high density housing. The flood defence schemes include two flood dykes along the west and east sides of Highway 842 along the Bow River. The subsequent paragraphs provide the details of flood defence structures.

Two earth embankment dykes proposed for the protection of the houses and properties within the floodplain. The dykes are designed to have a minimum 1.0 m freeboard over the high water level of the 1% AEP flood. The dykes have a top width of 3 m and side slopes of 3H:1V as per standard design requirements provided in the guideline *Design and Construction of Levees* (US Army Corps of Engineers, 2000).

Conceptual design sketches in **Appendix D** illustrate the profile and typical cross-sections through the dykes. There is some environmental impact since the footprint of the dyke and construction requires some removal of trees. Typical cross-sections were proposed for the dyke construction based on the location of the dyke in relation to the river bank. The dyke includes a low permeability core with a cover of topsoil and seed. A 300 mm thick Class 1M riprap (D_{50}= 175mm) with a 3 m apron is proposed for protection of the dyke against river erosion.

2.6.7.5 Recommendations

The stakeholder engagement response identified that there were plans to move certain residences and infrastructure from the flood area. There is no detailed flood hazard mapping available for the Siksika reserve and; therefore, it is recommended that a mapping study be undertaken prior to the relocation of this infrastructure to ensure it is moved sufficiently away from floodway and flood fringe where possible.

Conceptual design drawings for flood dykes at strategic locations are provided in **Appendix D.**

Recommendation 4.10: It is recommended that flood hazard mapping is undertaken and stakeholder engagement is held with the Siksika Nation to determine which properties are candidates for removal from the floodway. Flood defences should also be constructed at locations identified in **Appendix D** of **Volume 4**

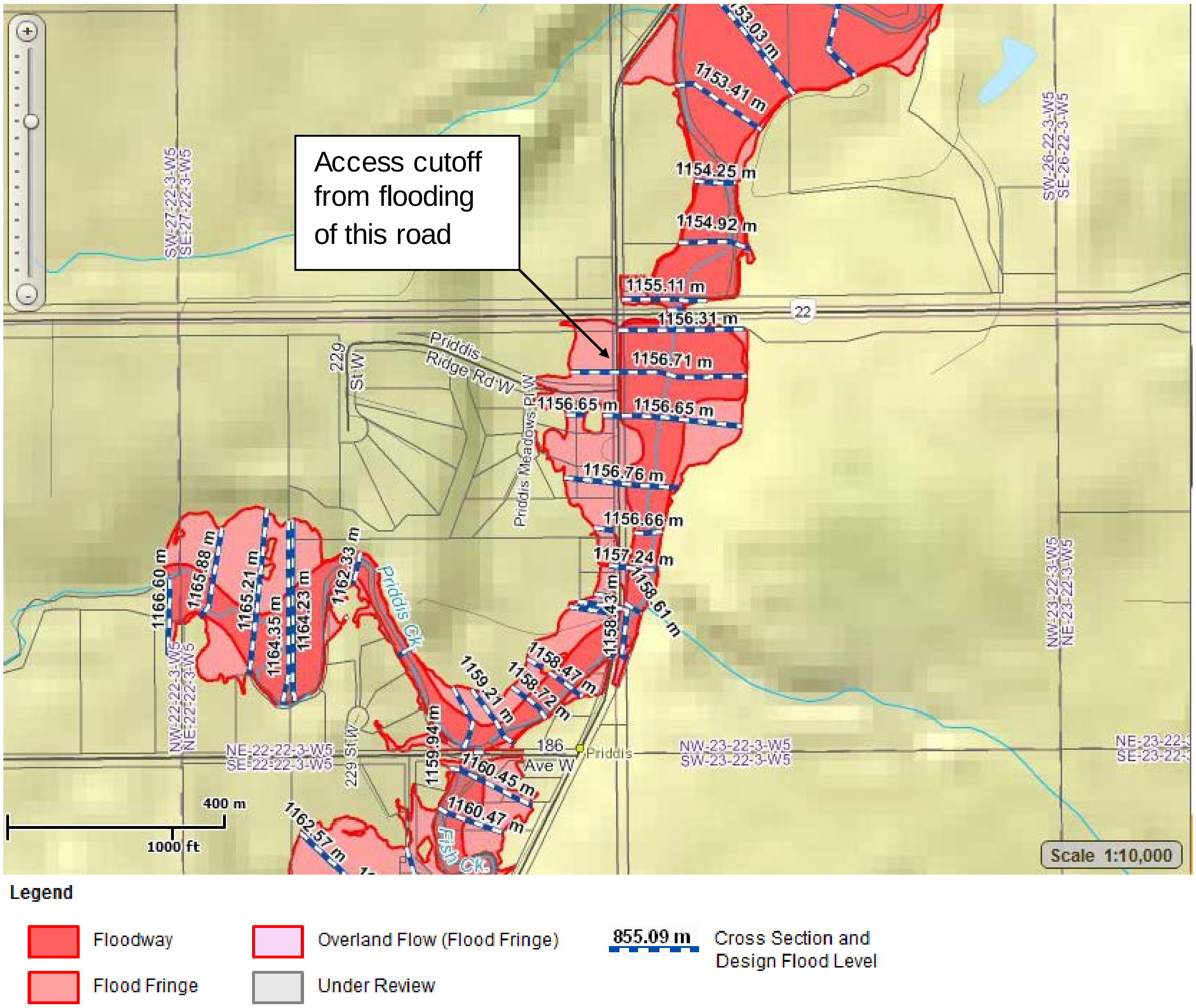
2.6.8 Priddis

2.6.8.1 Stakeholder Engagement Response

Priddis lies within the MD of Foothills and, as such, the engagement response came from the MD. Understandably, the MD was primarily focussed on the damage that occurred in the Highwood and Sheep river basins and; therefore, there was no specific information provided about Priddis. The MD did state that they felt they had done everything they could in the extreme 2013 event and that the GoA had been very helpful. They also noted that a better flood warning system “could certainly help.”

2.6.8.2 Known Flood Pathways

There is currently very little development within the floodway at Priddis. There are several properties at risk in the flood fringe and there is also a number of properties on Priddis Meadows Place and Priddis Ridge Road that are at risk of being cutoff if the road, which effectively defines the floodway boundary, is flooded or washed out. A map showing the overall ESRD flood mapping is provided in **Appendix A**. **Figure 2.13** shows the area where access will be compromised in a large flood.



(Source: ESRD, 2014)

Figure 2.13: ESRD Flood Mapping for Priddis

2.6.8.3 Multi-Criteria Decision Making and Option Assessment

The MCDM analysis revealed that the best structural method for protecting Priddis from floods was to raise the level of Range Road 32 (the access road into Priddis). The best non-structural measure is to limit future development in the floodway. Development in the flood fringe should take into consideration the flood risk and only certain types of flood resilient design should be permitted.

During the assessment, it was also determined that the bridge at Highway 22 may be causing some backwater effect through Priddis and replacement or widening of the bridge openings should be considered.

2.6.8.4 Conceptual Design

A conceptual design of flood defences was proposed for the protection of residential homes and properties located within flood fringe area defined in ESRD flood risk mapping. The flood defence scheme includes flood dykes, raising a section of Range Road 32 and bridge replacement for the Highway 22 crossing of Fish Creek. Four discrete flood risk areas (Zones A, B, C and D) were identified. Flood dykes were proposed for Zones A, C and D. The replacement of the Highway 22 Fish Creek and the raising of Range Road 32 were proposed for Zone B as illustrated in conceptual sketches for flood defences on **Figure E1** in **Appendix E**.

The flood dykes are designed to have minimum 1.0 m freeboard over high water level of the 1% AEP flood. Other aspects of the design are similar to those proposed at Bragg Creek.

A three span bridge was constructed on Highway 22 at Fish Creek in 1966. The bridge was widened in 1973. Based on ESRD's modeling the water level upstream and downstream of bridge for the 1% AEP event has a difference of 1.1 m. The bridge appears to be a hydraulic control on Fish Creek and replacement of the bridge would reduce flood levels within the backwater area affected by the constriction. It was confirmed by AT that the bridge replacement is planned based on the life span of the bridge. Further hydrotechnical assessment is required for confirmation of possible hydraulic constraint of this bridge. Replacement of this bridge would also require some localized dyking of property immediately downstream since more water could pass through the structure.

Range Road 32 forms an informal flood defence however it does not protect properties in the flood fringe or access to several houses. It is proposed that Range Road 32 be raised to a minimum of 1 m above the 1% AEP flood level (subject to feasibility of the connection at Highway 22) to protect access and properties located west of this road.

A conceptual design profile and sections for raising the road are provided in **Appendix E**.

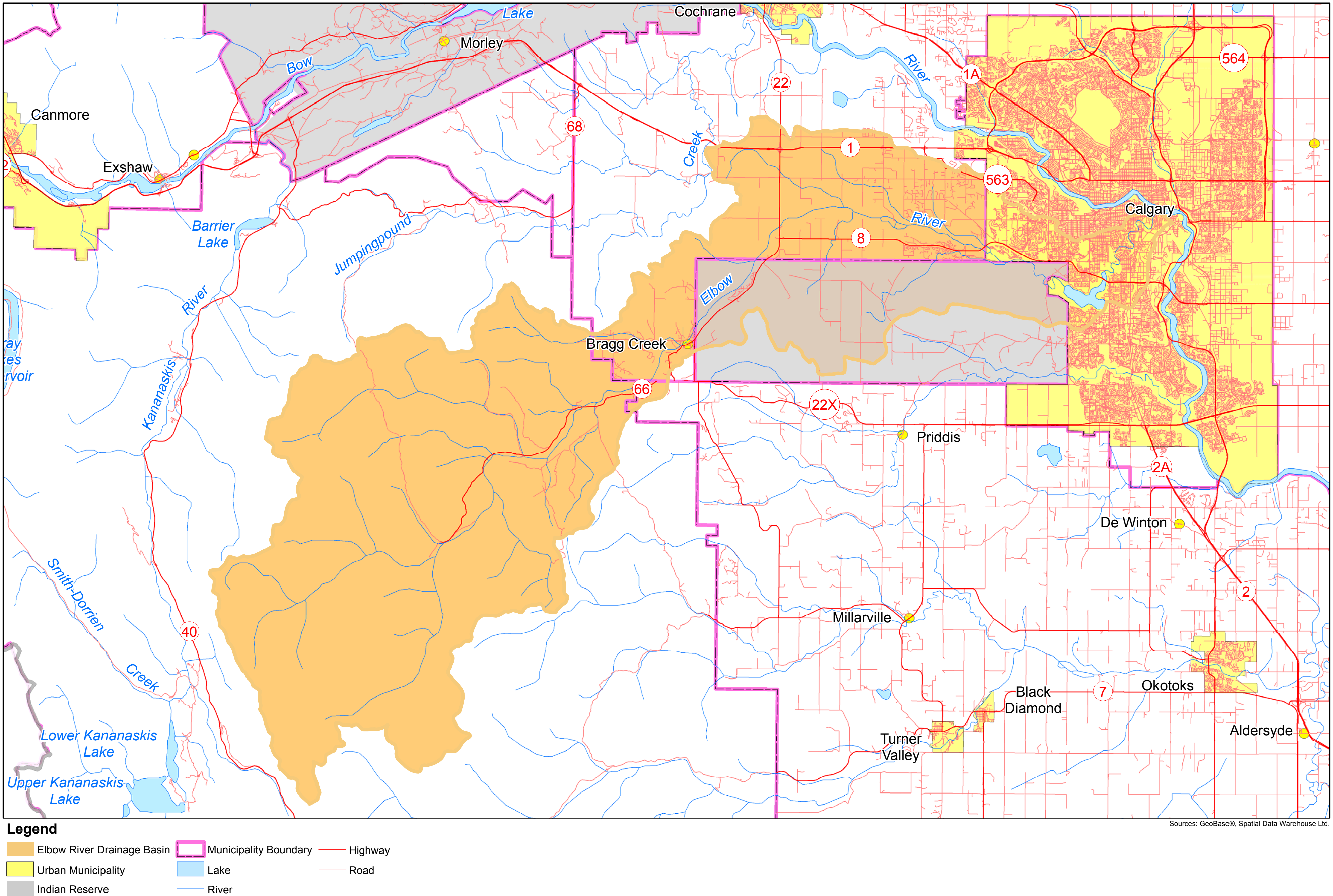
2.6.8.5 Recommendations

There is a risk to access and egress during a flood event at Priddis if Range Road 32 becomes impassable. Several properties will be cut off in this case. A simple means of protecting the integrity of this access is to raise the road and to armour the riverside of the road embankment to ensure that the road does not get eroded. A specific recommendation is not made for this improvement at this time since the benefit cost ratio of the project should be proven in advance.

3.0 ELBOW RIVER BASIN MITIGATION MEASURES

3.1 Basin Description

The hydrology of the Elbow River basin is defined by its catchment. **Figure 3.1** illustrates the Elbow River basin. The basin extends from Elbow Lake in the Rocky Mountains to the Prairies, where the Elbow River meets the Bow River in downtown Calgary.



S:\Gis\Projects\CW2174_Flood_Mitigation\ArcGIS\Report March 2014\Fig3.1 Elbow Basin.mxd

amec

PDF: Fig3.1 Elbow Basin 14-05-22

DATE: May 2014

PROJECT: CW2174

PROJECTION/DATUM: 10TM/NAD83

ANALYST: NH

Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

5 0 5 10 Kilometres
1:400,000
N

Elbow River Basin

Figure 3.1

The Elbow River above its confluence with the Bow River encompasses three physioclimatic zones. Moving from the headwaters to the mouth (i.e., generally from southwest to northeast), the basin extends from the Rocky Mountains to the foothills and finally to the Prairies. There is an elevation drop of approximately 1,000 m over the 127 km length from source near Elbow Lake to mouth.

3.1.1 Water Management Issues

The Elbow River Basin Watershed Management Plan identified both water quantity and quality as issues in the watershed. The Elbow River watershed continues to see increasing levels of development in both rural and urban areas. Demand includes industry, agriculture, aquaculture, golf courses, oil and gas, timber harvesting, recreation, and residential and commercial development.

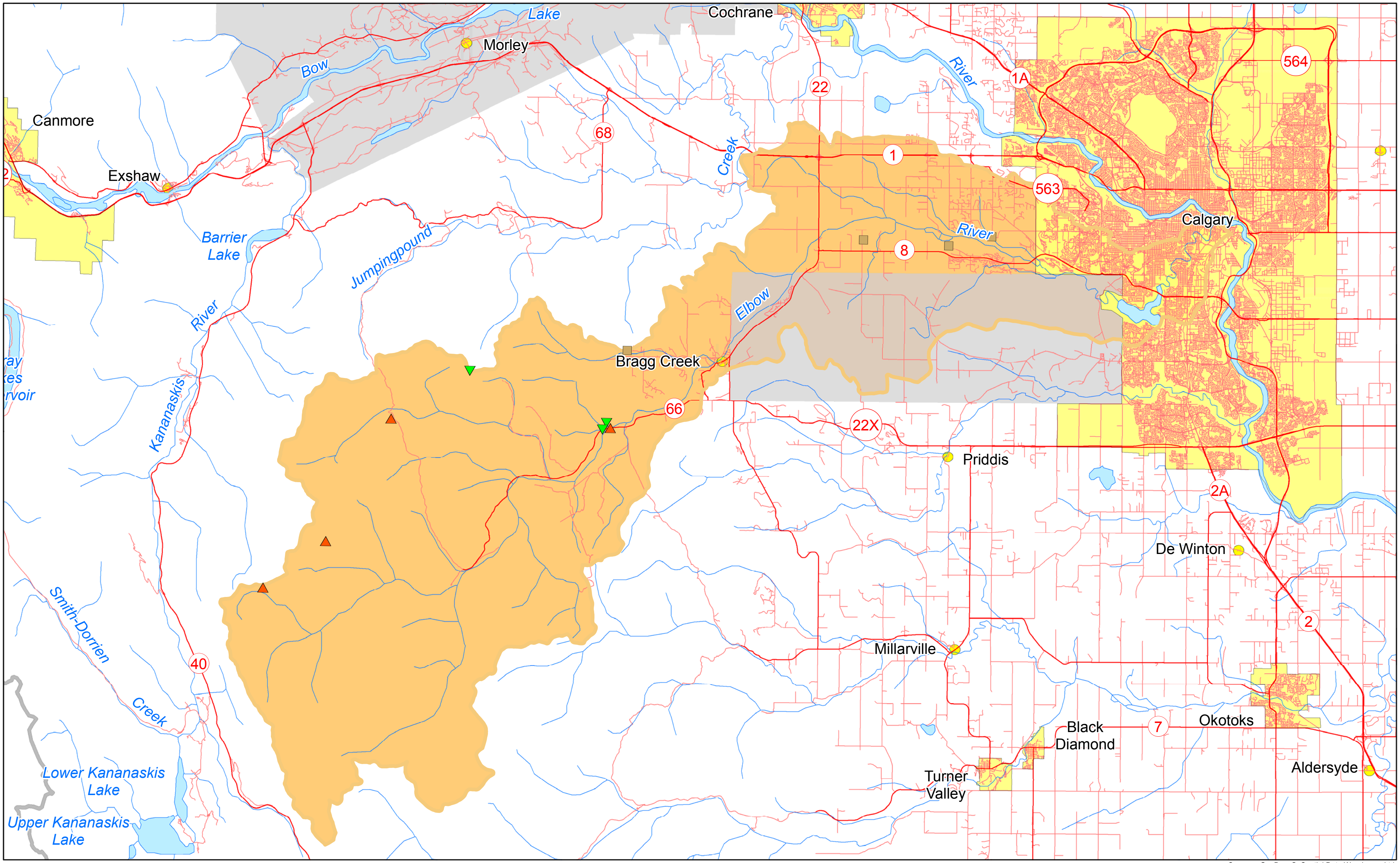
Water quality is excellent in the upper reaches of the watershed, but deteriorates in the more downstream reaches. Phosphorus, nitrogen, and coliform bacteria are the main contaminants.

3.1.2 Areas at Risk

Areas at risk of inundation and erosion from flooding exist along the entire length of the river. The major receptors (people and infrastructure) are at Bragg Creek, Redwood Meadows (Tsuu T'ina Nation), and the City of Calgary, with the majority of properties and assets at risk downstream of Glenmore Dam.

3.1.3 Meteorological Data

Meteorological stations in the Elbow River basin that are used for flood forecasting purposes are illustrated on **Figure 3.2**.



Sources: GeoBase®, Spatial Data Warehouse Ltd.

Legend

- Elbow River Drainage Basin
- Urban Municipality
- Indian Reserve
- Lake
- River
- Highway
- Road
- Meteorological Station (ESRD)
- Meteorological Station (AFS)
- U of C, Foothills Climate Array

amec

PDF: Fig3.2 Elbow Basin Met Stns 14-05-22

DATE: May 2014

PROJECT: CW2174

PROJECTION/DATUM: 10TM/NAD83

ANALYST: NH

Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

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Meteorological Stations in the Elbow River Basin

Figure 3.2

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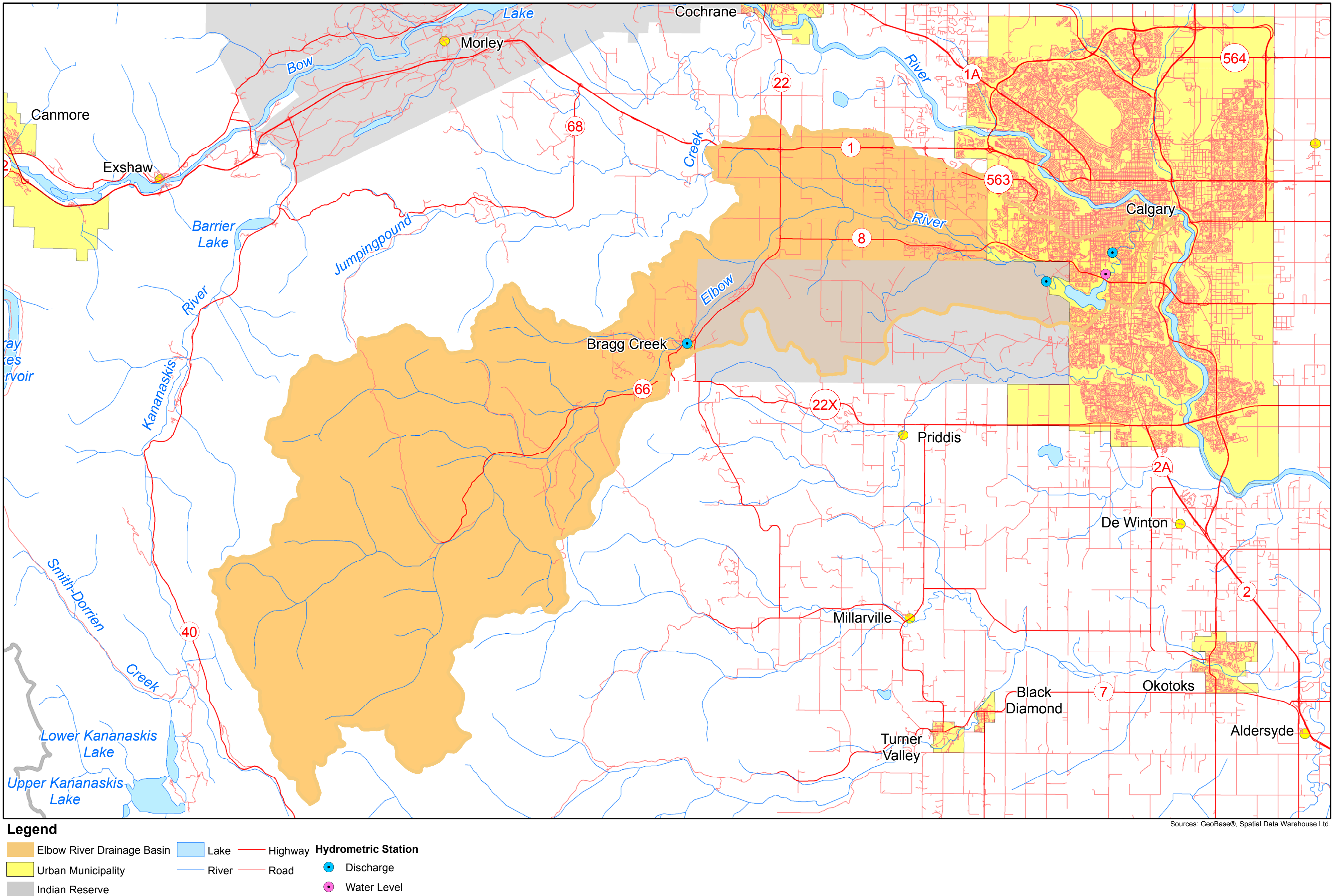
3.1.4 Hydrometric Data

Hydrometric Stations in the Elbow River Basin are listed in **Table 3.1,** and their locations are illustrated on **Figure 3.3**.

Table 3.1
Hydrometric Stations in the Elbow River Watershed

Station	StationName	Status	Drainage Area (km2)	Years of Record	From	To
05BJ001	ELBOW RIVER BELOW GLENMORE DAM	Active	1235.7	104	1908	2011
05BJ003	ELBOW RIVER AT FULLERTON'S RANCH	Discontinued	742	10	1914	1923
05BJ004	ELBOW RIVER AT BRAGG CREEK	Active	790.8	78	1934	2011
05BJ005	ELBOW RIVER ABOVE GLENMORE DAM	Discontinued	1220	45	1933	1977
05BJ006	ELBOW RIVER ABOVE ELBOW FALLS	Discontinued	437	29	1967	1995
05BJ008	GLENMORE RESERVOIR AT CALGARY	Active	1223.6	37	1976	2012
05BJ009	LITTLE ELBOW RIVER ABOVE NIHAHI CREEK	Discontinued	129	18	1978	1995
05BJ010	ELBOW RIVER AT SARCEE BRIDGE	Active	1189.3	32	1979	2011
05BJ011	ELBOW RIVER AT CLEM GARDINER BRIDGE	Discontinued	871	1	1979	1979



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PDF: Fig3.3 Elbow Basin Hydrom Stns 14-05-22

DATE: May 2014

PROJECT: CW2174

PROJECTION/DATUM: 10TM/NAD83

ANALYST: NH

Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

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Hydrometric Stations in the Elbow River Basin

Figure 3.3

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During the June 2013 flood, two of the gauges sustained damages:

- Elbow River at Sarcee Bridge – data is questionable due to rating curve issues; and
- Elbow River below Glenmore Dam – data up to loss is questionable due to rating curve issues; the stilling well was undermined and needs to be relocated.

3.2 Elbow River Basin Hydrology

Greater precipitation amounts occur in the mountains and foothills than are experienced in the prairies. This trend is reflected in the runoff measured at various locations along the Elbow River. **Figure 3.4** illustrates these runoff rates for the month of June; when annual maximum flood events charateristically occur. The slopes of the lines on **Figure 3.4** indicate the monthly runoff expressed as a depth (mm). The mountain basin produces runoff over double that measured at the Sarcee Bridge gauge above Glenmore Reservoir. Thus to estimate the runoff for an upstream catchment, it is appropriate to use the flow records for an upstream site. Using a downstream site to estimate the runoff at an upstream site by drainage area proportion would underestimate the upstream runoff.

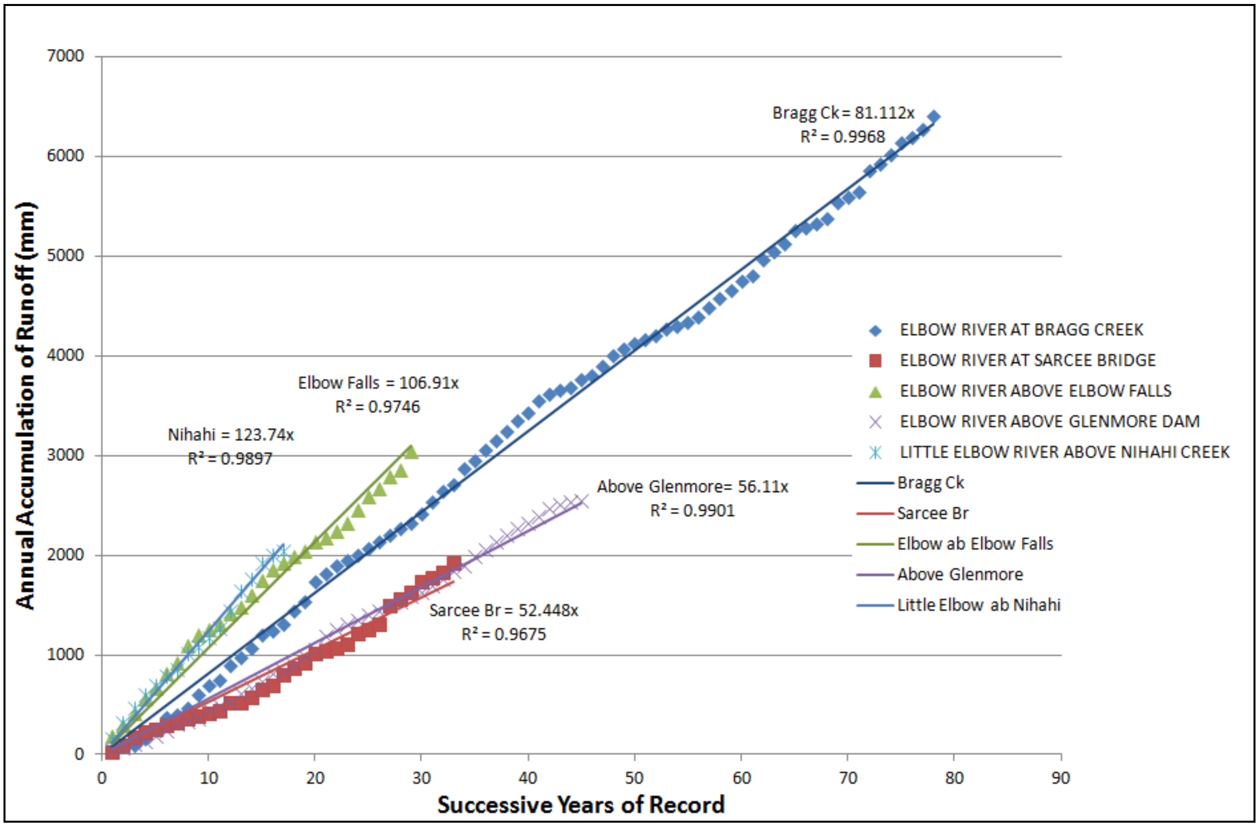


Figure 3.4: Variation in June Runoff Along the Elbow River

Floods are commonly characterized by the peak flood discharge that is estimated to have occurred based on measured water levels during the flood event. Floods on the Elbow River may have very sharp peaks, such as those which occurred during rainfall flood events in 2013, 2005 or 1995. **Figure 3.5** illustrates the relationship between the peak instantaneous discharge and the maximum daily mean discharge for the Bragg Creek gauging station. The general trend indicating peak discharges being approximately 1.5 to 1.6 times the maximum daily discharge.

For the 1995 event; however, the ratio would be almost 2.0.

It should be noted that the estimation of peak discharges is subject to uncertainty. This uncertainty may be due to several factors, including:

- The short duration of high water;
- Conditions may be challenging or unsafe (floating debris, difficulty accessing the stream to conduct a measurement, etc.);
- Gauging equipment might be lost or destroyed during an extreme flood;
- Considerable judgement might be required to estimate the peak discharge based on high water marks, as appreciable water might be flowing across the floodplain adjacent to the channel; and
- Changes may have occurred in the channel due to bank erosion and the scouring, transport and deposition of bed material during and following the flood event.

Therefore, simple extrapolation of a rating curve developed from limited high discharge measurements for lower magnitude events could lead to estimation of peak discharges that have an appreciable uncertainty.

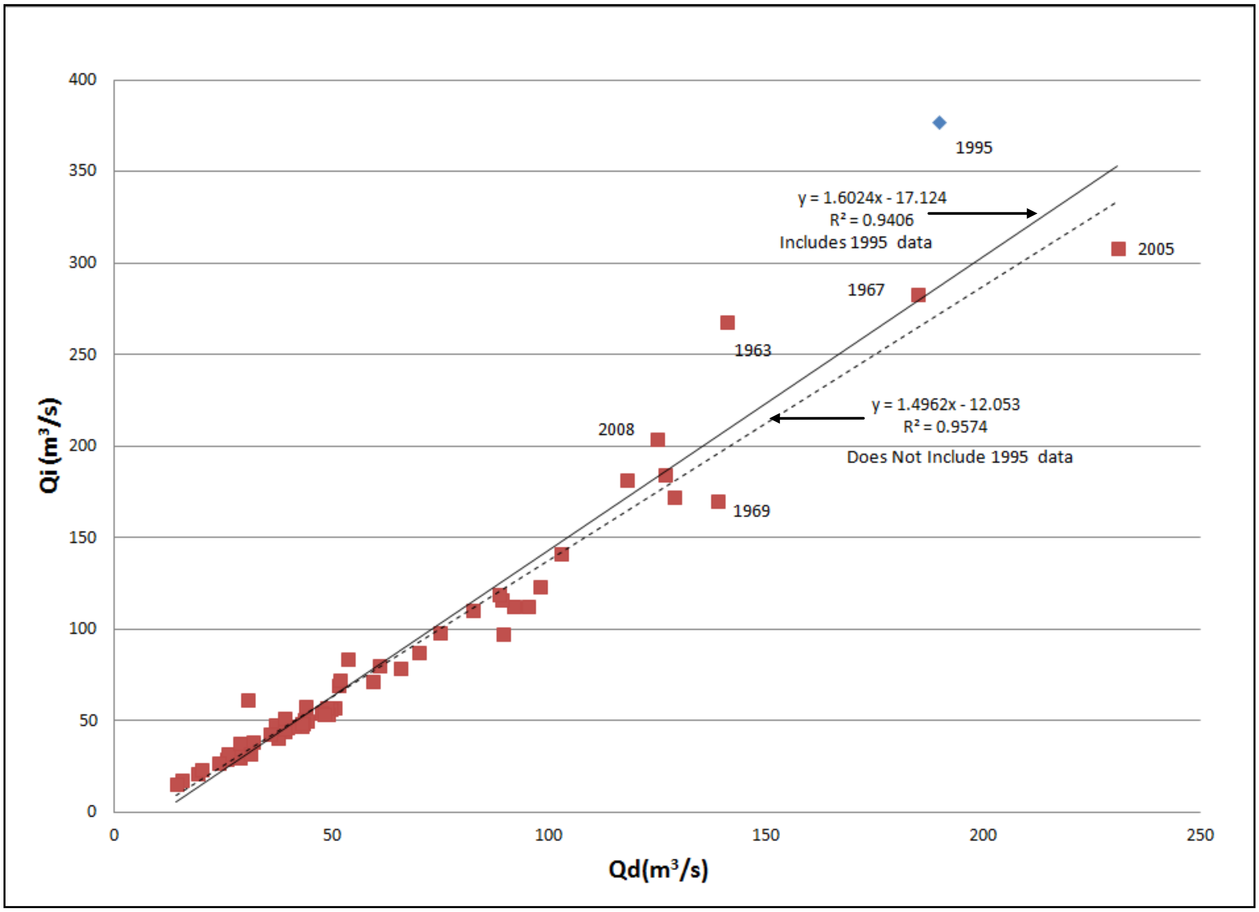


Figure 3.5: Relationship between Annual Peak and Maximum Daily Discharge at Bragg Creek

Flood discharges along the Elbow River result from three primary causes: snowmelt, rainfall with little or no snowmelt, or rain on snow. The latter characteristically produces the largest floods. Given the range of potential flood runoff inputs depending on the timing, rate and location of rainfall and snowmelt inputs, a wide range of runoff hydrographs can result. **Figure 3.6**, **Figure 3.7,** and **Figure 3.8** illustrate hydrographs at the same vertical scale for 1990, 1995, and 2005.

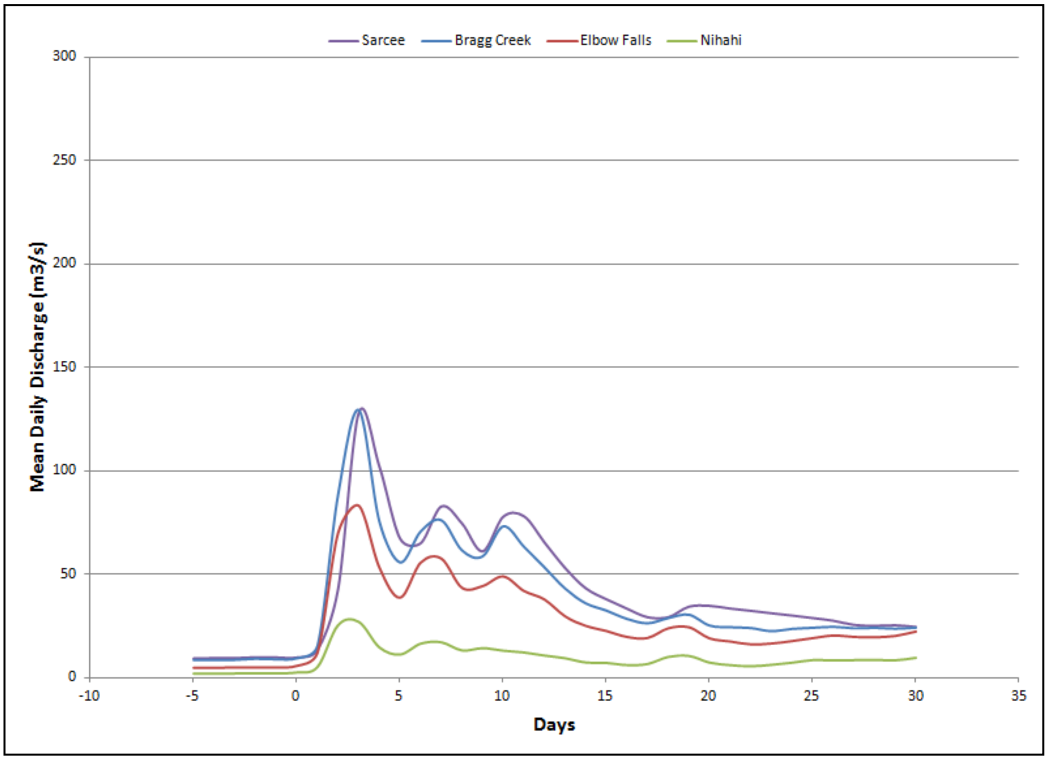


Figure 3.6: Elbow River Peak Discharge Hydrographs for 1990

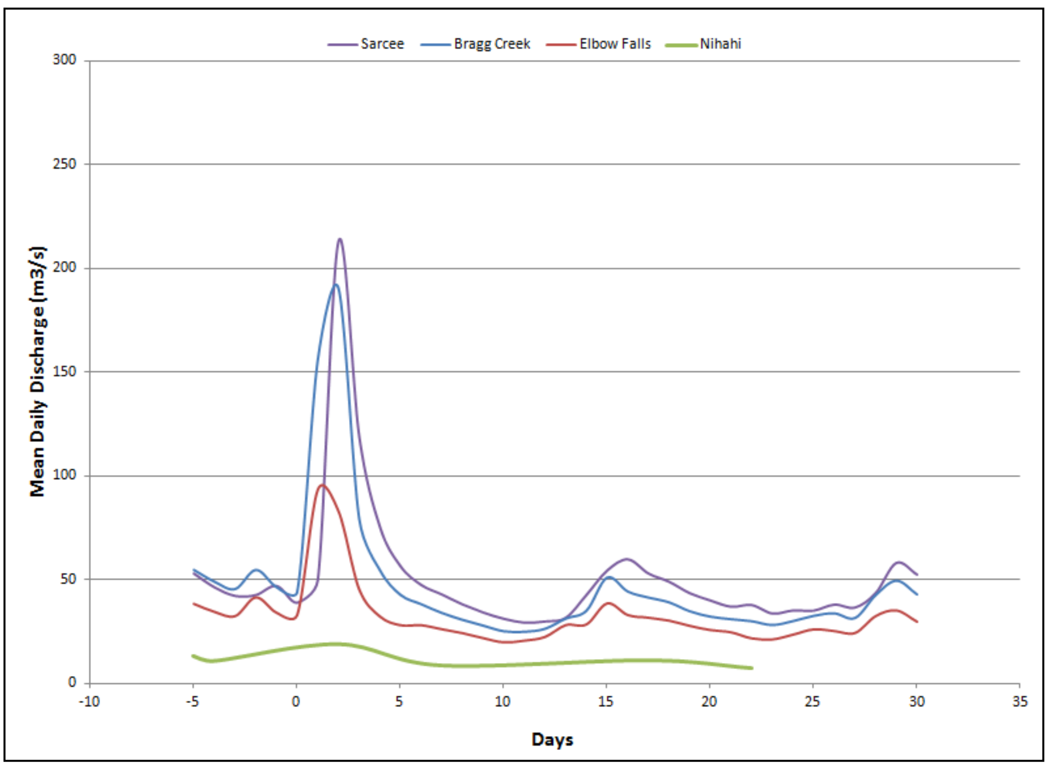


Figure 3.7: Elbow River Peak Discharge Hydrographs for 1995

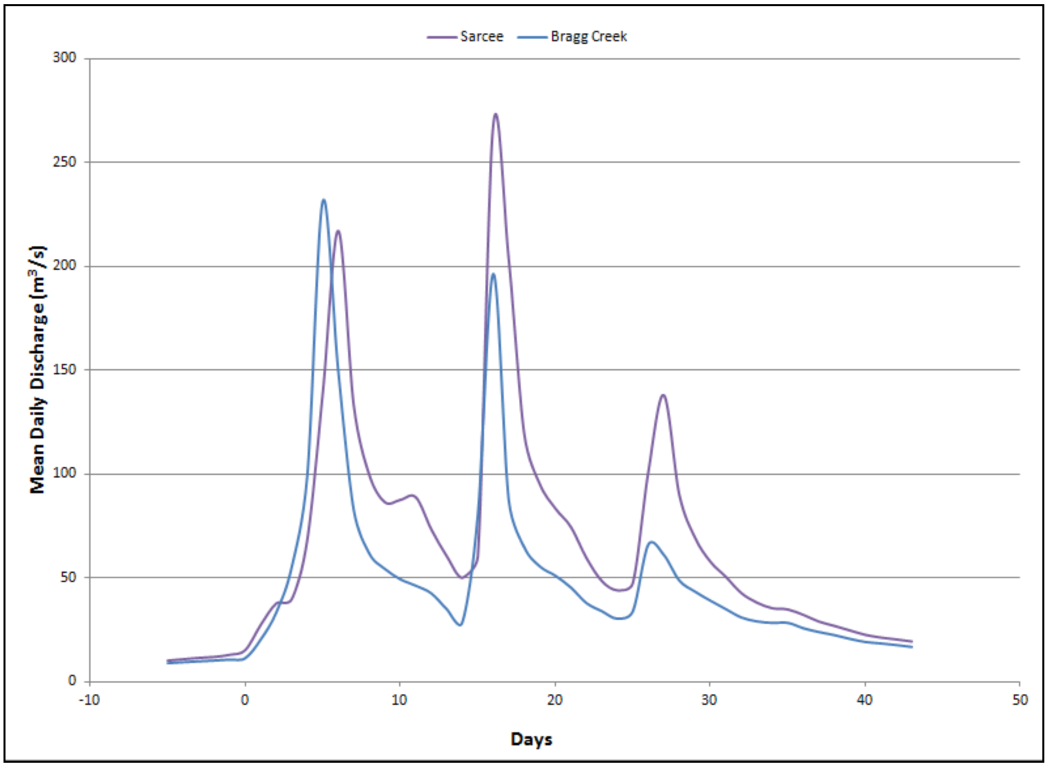


Figure 3.8: Elbow River Peak Discharge Hydrographs for 2005

For many of the hydrographs, the maximum daily discharge at Sarcee Bridge, immediately upstream of Glenmore reservoir, is larger than that at Bragg Creek. This might be the case for some years when some additional flow enters downstream of Bragg Creek, but that is contary to the opinion expressed in AGRA 1996, whereby AENV established that the flood frequency at Bragg Creek could be used for the reach of the Elbow River upstream of Glenmore Reservoir.

Given the variability in runoff processes which leads to irregular-shaped hydrographs, it is not surprising that a well-defined relationship between peak flow discharge and flood runoff volume might be difficult to determine. **Figure 3.9** illustrates the relationship between peak discharge and runoff volume for the Elbow River above Elbow Falls gauge. The three largest peak flow years depart from the data cloud for lower peak discharges.

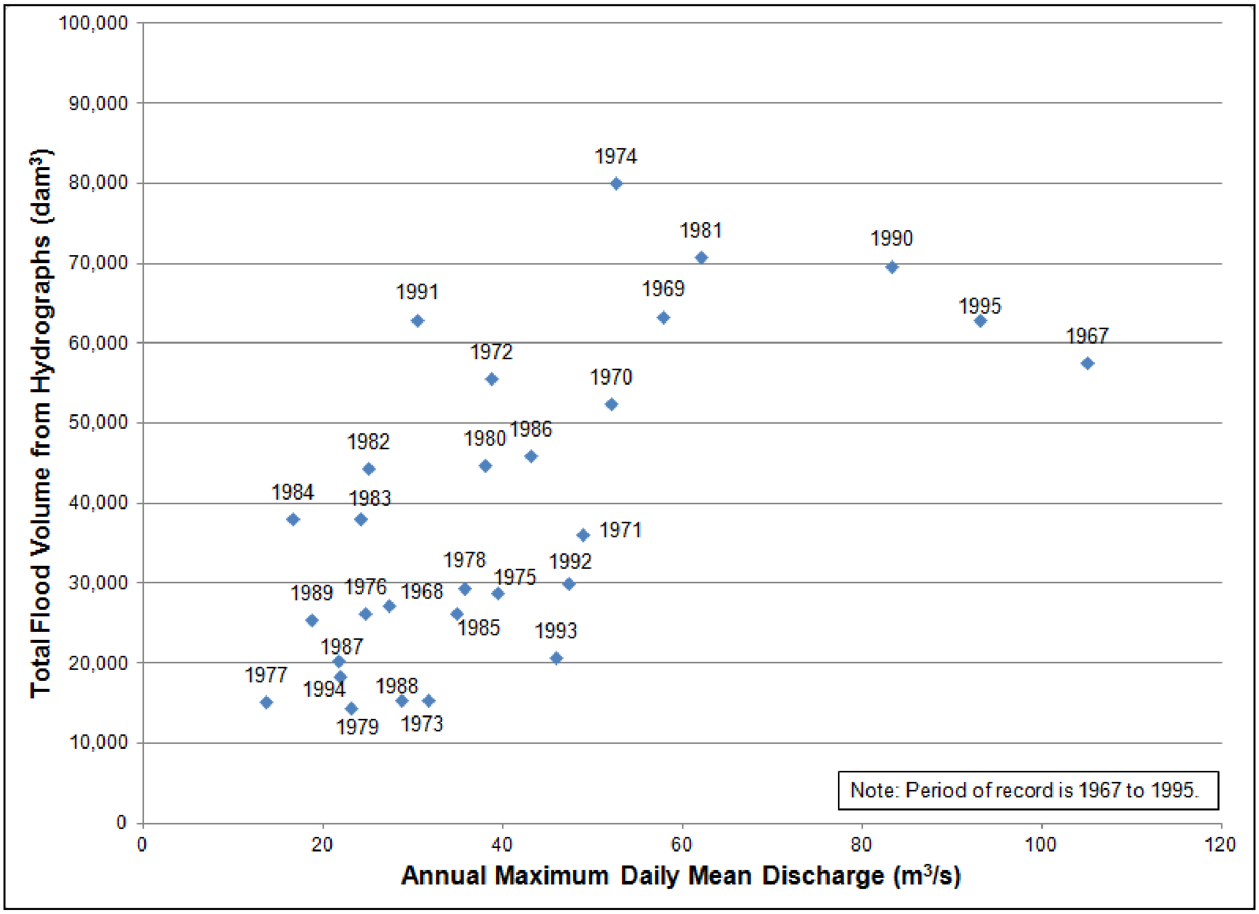


Figure 3.9: Flood Volume Comparison above Elbow Falls

The operation of Glenmore Reservoir in reducing downstream discharges has been discussed in several documents and flood studies including AENV (1983) and Golder (2010). The flood discharge reduction capability has been assessed in terms of the effect on the 1% AEP flood. For a peak inflow discharge of 737 m^3/s, Golder (2010) determined that the reservoir can reduce this inflow peak to a maximum outflow discharge of 699 m^3/s, or a reduction of 5%. Similar reductions were computed by AENV (1983), and both reports indicated greater reductions were possible at lower discharges. **Figure 3.10** illustrates the percent reductions in flows. A greater than estimated reduction in flows was achieved during the June 2013 flood.

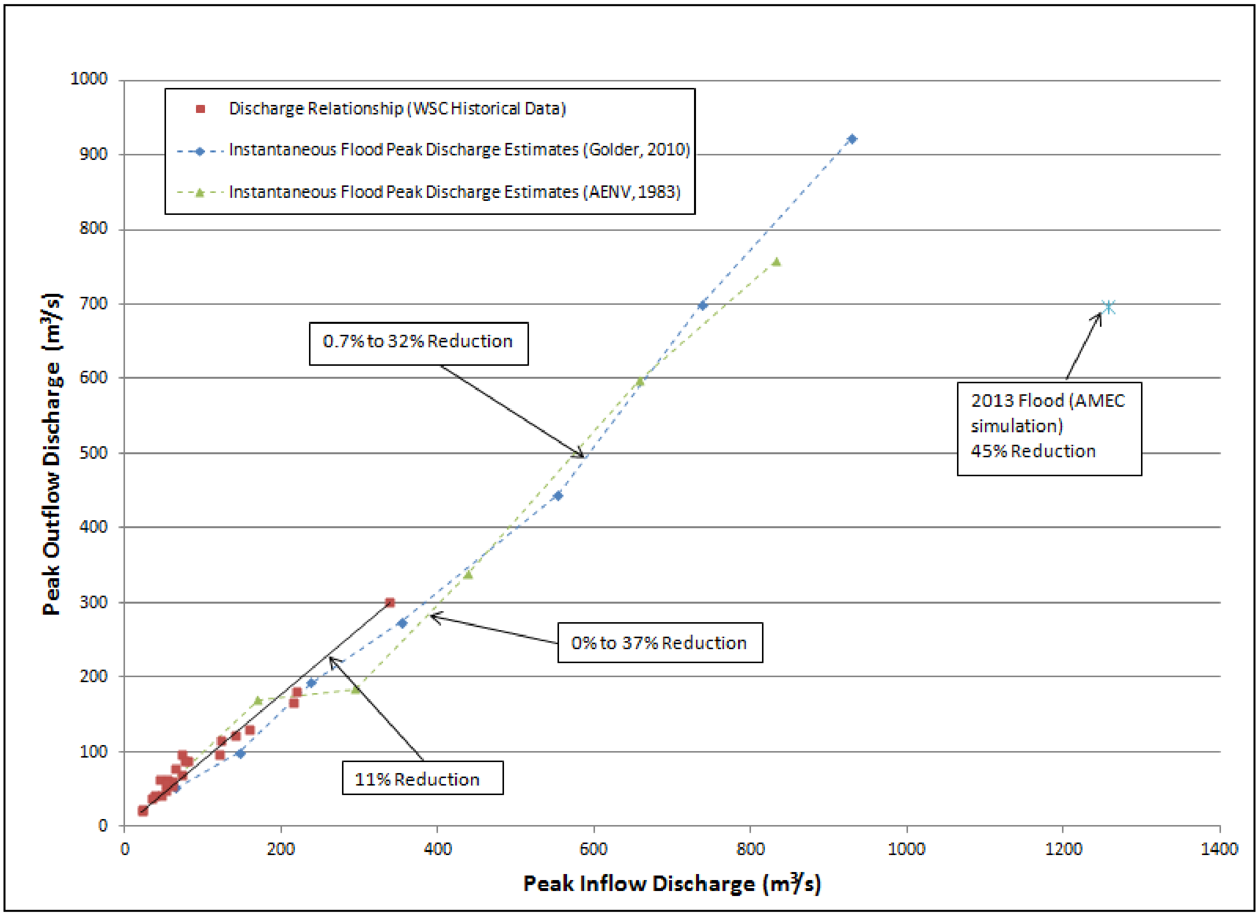


Figure 3.10: Flood Peak Reduction on the Elbow River at Glenmore Dam

3.3 Major Infrastructure Projects

3.3.1 Flood Storage Requirements

The City of Calgary established that a maximum release of 170 m^3/s from Glenmore Reservoir can be tolerated prior to flood damage occurring along the downstream river floodplain. This value is coincident with the capacity of the low level outlet (Dow Valves) at the Glenmore Reservoir.

The City of Calgary operating procedures allow Glenmore Reservoir to be drawn down by up to 5 m below its full supply level (FSL) of 1,076.85 m when it is estimated that extreme flood potential exists. The City of Calgary operating procedures also require that these valves are closed during an extreme flood if the reservoir rises above the crest elevation of 1,075.33 m; reaching the full closed position when the reservoir rises to 1,076.33 m, and the overtopping spillway discharge coincidentally reaches 170 m^3/s. The city requires a minimum of 25 hours to draw the reservoir down the 5 m assuming its starting level is at the FSL. In reality a portion of this storage should be drawn down well in advance of an actual flood event forecast (e.g., in the spring if significant snow pack exists in the upper watershed).

This procedure provides approximately 15,400 dam^3 flood storage which is available for attenuating the flood outflow rate below Glenmore Reservoir. The city significantly attenuated the 2013 flood utilizing nearly the full 15,400 dam^3 amount.

Adding additional upstream storage capacity (i.e., another reservoir) would position the City of Calgary to more effectively attenuate extreme floods. Including some amount of live storage for other purposes within this additional storage capacity would provide the city with more flexibility to draw down Glenmore Reservoir, as the additional storage could be made available for city use after the flood should the anticipated flood not occur as forecast.

Ongoing hydrologic assessment indicates that to fully attenuate extreme floods to a peak discharge of 170 m^3/s from Glenmore Reservoir requires more storage than is available at Glenmore Reservoir. Required flood storage volumes were estimated and are summarized in **Table 3.2.**

Table 3.2
Reservoir Flood Storage Requirements

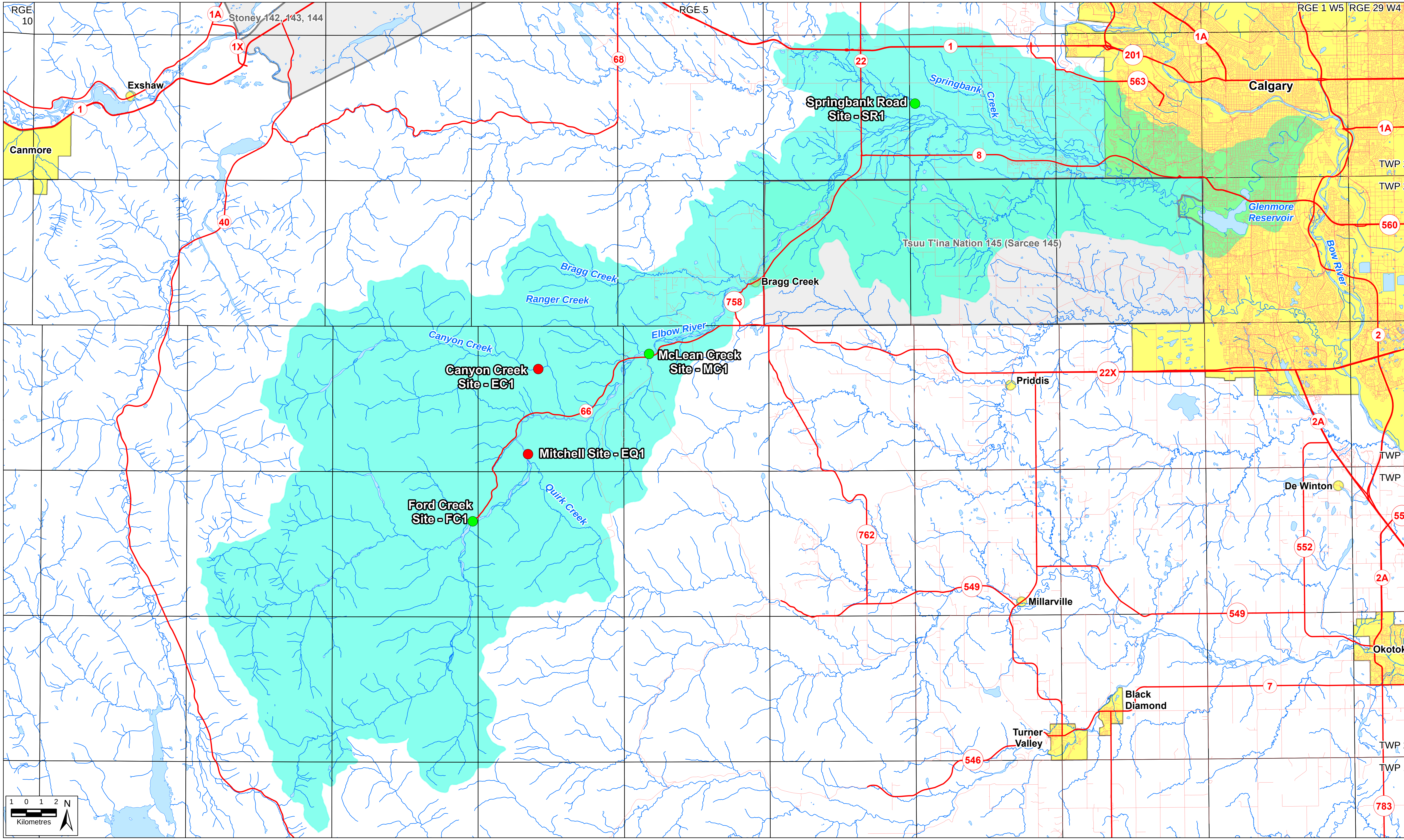
Annual Flood Probability	Peak Inflow (m^3/s)	Required Flood Storage Volume (dam^3)		
		Total	Glenmore	Difference
5% (20 yr)	440	16,800	15,400	1,400
1% (100 yr)	930	56,600	15,400	41,200
2013 flood	1,240	83,000	15,400	67,600
0.2% (500 yr)	1,625	107,500	15,400	92,100

Table 3.2 numbers indicate that Glenmore Reservoir has potential to manage all floods up to nearly the 5% AEP flood event (i.e., outflows not exceeding the target value of 170 m^3/s). Glenmore Reservoir also provides significant attenuation effect for larger floods (i.e., 2013 flood inflow peak was attenuated from 1,240 m^3/s to about 700 m^3/s).

The values noted in **Table 3.2** consider that the above noted flood volume difference can be contained within an additional storage site until after the flood has passed (i.e., include gate controls) otherwise somewhat larger storage volumes than indicated in **Table 3.2** would be required. **Table 3.2** also assumes that the flood was successfully forecast and that the Glenmore Reservoir was drawn down in a similar fashion to that accomplished for the 2013 flood.

3.3.2 Overview of Potential Storage Locations in the Elbow Basin

Investigations related to potential dam sites for irrigation and hydroelectric development in the Elbow River basin date back to the late 1800s and early 1900s. More recently, studies have recommended sites along the Elbow River for flood control purposes. **Figure 3.11** shows potential reservoirs identified by others and AMEC in the Elbow River basin.



Legend

- Elbow River Basin
- Lake
- Highway
- Urban Municipality
- River
- Road
- Indian Reserve

Potential Reservoir Location

- Recommended For Further Study
- Not Recommended

Source: GeoBase®, Watershed boundaries reproduced and distributed with the permission of Agriculture and Agri-Food Canada., http://www.envinfo.gov.ab.ca /Flood Hazard, © Department of Natural Resources Canada. All rights reserved., Spatial Data Warehouse Ltd.

Alberta Flood Recovery Task Force
Flood Mitigation Study

Potential Reservoirs in the Elbow River Basin

DATE: June 2014	ANALYST: NH
QA/QC: TR KK GG	PDF: Fig3.11 Potential Reservoirs Overview 14-06-02

Figure 3.11

amec

S:\Gis\Projects\CW2174_Flood_Mitigation\ArcGIS\Meeting May 30 2014\Fig3.11 Potential Reservoirs Overview.mxd

In 1986, WER Engineering Ltd., IBI Group, and Ecos Engineering undertook a joint study into flood plain management in the Elbow River basin. A summary report was issued as part of that study and it included:

- A comprehensive assessment of flood damages (economic assessment);
- Identification and assessment of alternatives for flood mitigation; and
- An evaluation of alternative flood plain management plans.

Along with other smaller mitigation measures, the study identified a potential dam site at McLean Creek (shown on **Figure 3.11** as MC1) with a potential storage volume of 24,600 dam^3 (low dam)/49 200 dam^3 (high dam) depending on the flow released from Glenmore Reservoir (and hence the height of dam required). The Ford Creek (FC1) and Mitchell (EQ1) sites (also shown on **Figure 3.11**) were also evaluated early in the 1986 study but were screened out. After the June 2013 flood, the FAP made recommendations for site EQ1 site as a potential dry dam site. The following sections provide an overview of how sites were selected for analysis, and a review of sites EQ1, MC1, SR1 and FC1.

3.3.2.1 Storage Site Identification

A primary objective of this study was to identify and assess potential storage sites within the Elbow River basin that would provide additional flood protection to the City of Calgary. For the purpose of this study it was established that, as a minimum, full 1% AEP flood protection would be provided (i.e., additional storage volume of 41,200 dam^3) as indicated in **Table 3.2**, and potentially up to the 2013 flood requirement (67,600 dam^3); the design standard to be later established based on economic and societal benefits analysis.

This component of the work was initiated by completing a comprehensive review of all potential dam sites within the Elbow River basin, including all sites which were previously identified by others and/or additional sites identified as a part of this work. To this end a detailed review of the most current topographic, geotechnical, hydrologic, photographic and other data was compiled and studied in detail considering that much of this now available data is far superior to that which was available for previous studies. Both on-stream (i.e., on the Elbow River) and off-stream storage concepts were considered, which included potential diversions upstream of the City of Calgary.

Criteria considered in this review were potential storage, environmental and social impacts, flood attenuation potential, and costs. Three preferred sites were identified with potential to provide significant flood protection; these are briefly described below.

1. Elbow River dam site at MC1 - This site was previously identified and recommended as a preferred site for flood mitigation purposes as part of the 1986 Elbow River Floodplain Management Study.
2. Off-stream dam site at SR1 - This is a new site which was identified as part of this study. It is located just west of Calgary. It would require a flood diversion weir across the Elbow

River and a diversion channel to transport flood water from the Elbow River to the off-stream storage reservoir.

3. Elbow River dam site at FC1. This site was previously identified and recommended as a preferred site for multi-purpose use by the PFRA in 1969. This site was further considered and documented as part of the Saskatchewan-Nelson Basin Board (SNBB) Study.

Previously identified site EQ1 was rejected for reasons described in the following section of this report.

Previously identified site EC1 was rejected as its potential storage volume was too small relative to that amount required for flood mitigation.

The location of these sites is illustrated on **Figure 3.11.**

3.3.2.2 Quirk Creek Site (EQ1)

The site at Quirk Creek was identified as a potential site for a dam in 1914 by Ducane, Dutcher and Company. The site was subsequently considered by Montreal Engineering in a 1967 flood study on the Elbow River and the Flood Advisory Panel in 2013. The Prairie Farm Rehabilitation Administration (PFRA) undertook office and field appraisal of the geological aspects at EQ1 in 1968[4] and found it to be geologically unsuitable.

To quote the report synopsis:

"The Mitchell Site and Ford Site are two dam sites topographically favourable for major storage along the Elbow River valley. However, at the Mitchell Site, a weak mass of rock located high on the east side of the valley between two rock slides would represent intolerable risks to a large dam upon creation of the reservoir and development of seepage pressures. Accordingly, the location warrants no further consideration as a potential site."

The report goes on to describe the debris fields from previous landslides near EQ1 as:

"highly variable and poorly graded, and voids are present. Saturation would inevitably lead to large settlements and adjustments within the mass."

And finally:

"An examination of the air photos indicates that some semblance of a scarp immediately downslope of the ridge, suggesting that a limited amount of movement may have occurred. It is felt that creation of a reservoir either immediately downstream or upstream would further reduce the stability of this slope. In view of the accepted margin of error associated with estimates of the stability of such slopes, no further consideration should be given to this location as a site for a conventional earth or rock-fill dam."

[4] *Elbow River Storage Investigations Geological Investigations of Elbow River Mitchell and Ford Sites, Alberta*. Canada – Prairie Farm Rehabilitation Administration. December 1968.

Figure 3.12 is a LiDAR image that clearly shows the rock slides. For the reasons given by PFRA and confirmed as a part of this study, the Mitchell or EQ1 site is not a suitable location for a dam.

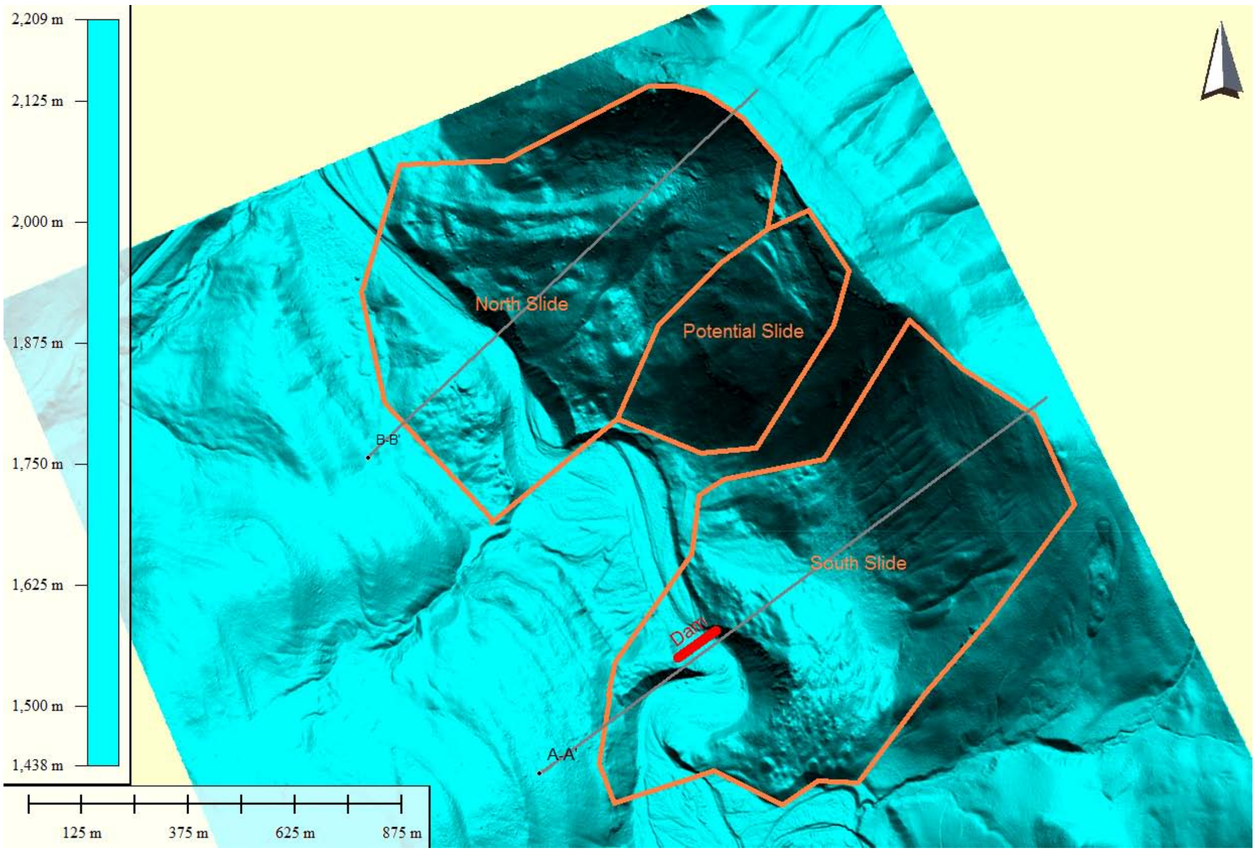


Figure 3.12: LiDAR Image showing rockslides

3.3.2.3 Elbow River Dam Site at MC1

This site is located approximately 11 km upstream of the Town of Bragg Creek and immediately upstream of the confluence of McLean Creek with the Elbow River. The dam site and reservoir location is illustrated in **Figure 3.11**.

The proposed earthfill embankment traverses a river gorge which is approximately 110 m wide at the base and is steep walled for a height of about 28 m. The river valley itself bends sharply to the northeast at this site, facilitating the construction of an auxiliary earth cut spillway on the right abutment and a combined permanent outlet conduit/spillway system on a plateau located on the left abutment. A six bay 3 m × 3 m gated conduit system through the dam, discharging into a spillway chute complete with hydraulic jump stilling basin is currently envisioned for this structure.

Valley bottom materials in the area consist of terraced modern alluviums composed of boulder to cobbly sands and gravels with fine-grained backwater deposits. Materials at higher elevations include colluvial deposits, glacial drift, and outwash deposits. The depth of valley bottom materials over bedrock is likely to be only a few metres. The depth of glacial deposits over adjacent bedrock topography is expected to be highly variable. The site rock exposures indicate that thickly bedded sand-stone lies above the more thinly bedded siltstones and mudstones, and that the bedrock is dipping in an east to southeast direction at about 5 to 10 degrees. The right side topography above the edge of the gorge is likely nominally capped with glacial drift materials, and the left gorge wall is capped with a substantial amount of glacial drift material.

The project concept considers development of a small permanent pool in the valley bottom extending from river bottom elevation 1,379.0 m to outlet structure intake invert elevation 1,398.0 m, thereby permanently containing approximately 4,000 dam^3 of water as dead storage. This storage would serve to prevent incoming larger bottom sediment from plugging the intake area, and would also replace the previously existing Allen Bill Pond. This concept also allows locating the permanent outlet structure on the left terrace, rather than in the valley bottom where it would be a much larger and more costly structure, and more prone to operation and maintenance challenges.

Resulting pond levels could be maintained to within 2 m surcharge above elevation 1,398.0 m for floods up to the 10% AEP event (i.e., maximum elevation of 1,400.0 m). The reservoir level would rise rapidly for larger flood events.

The small pond considered, results in a reservoir storage elevation of 1,423.0 m to achieve the additional 41,200 dam^3 live storage for 1% AEP flood protection, when considered in combination with Glenmore Reservoir storage. The proposed permanent outlet/spillway structure results in reservoir elevation 1,426.5 m to pass the 0.2% AEP flood (the estimated probability of the 2013 event) prior to activation of the proposed earth cut auxiliary spillway. A resulting top of dam elevation of 1,430.0 m has been estimated to provide probable maximum flood (PMF) protection to the dam system. The storage above elevation 1,423.0 m would provide downstream flood protection for floods greater than the 1% AEP event, but the resulting discharge from Glenmore Reservoir would exceed the “no damage” threshold of 170 m^3/s.

The resulting dam height is 50 m. The resulting reservoir would inundate approximately 8 km of existing Kananaskis Highway 66 including its bridge crossing of the Elbow River, and its relocation would be required.

Further information and conceptual design drawings are provided in **Appendix F**.

3.3.2.4 Off-stream Dam Site at SR1

This site is located approximately 18.5 km (linear distance) upstream of the Glenmore Reservoir as illustrated in **Figure 3.12.**

This concept considers diverting extreme flood flow from the Elbow River into an off-stream storage reservoir where it would be temporarily contained and later released back into the

Elbow River after the flood peak has passed. The storage reservoir could be designed as a dry pond, or could include a smaller permanent storage pond. The permanent pond component would serve to dissipate energy when flood water enters the reservoir, and could be used for multi-uses including recreational/environmental purposes and/or an additional water supply source for the City of Calgary. For the purpose of this conceptual assessment a multi-use storage containment of 9,000 dam^3 at elevation 1,198.5 m has been estimated providing a maximum pond depth of 10 m.

Project components include a diversion weir constructed across the Elbow River and a diversion channel excavated through the adjacent uplands to transport flood water into an off-stream reservoir storage site. The storage site facility includes a main embankment to temporarily contain the diverted water and a low level outlet structure incorporated into the embankment to later release the water back into the Elbow River after the flood peak has passed.

The diversion weir system would consist of a concrete overflow section across the Elbow River, a gated concrete sluiceway/fishway located adjacent to the left side valley abutment with its invert at the river thalweg level, and a gated diversion outlet structure located in the right valley abutment immediately upstream of the sluiceway. The outlet structure invert level would be located about 1.5 m above the river thalweg in order to exclude larger bottom sediment from entering the diversion channel. The sluiceway/fishway component is equipped with two 8 m wide radial gates. The outlet diversion structure is equipped with four 8 m wide radial gates. The sluiceway gates would typically be kept in the wide open position allowing free passage of sediment and fish during non-flood conditions. Partial closure would be required as a part of flood operations to provide for adequate flow rate diversion through the outlet diversion structure into the diversion channel, while allowing bottom sediment to pass under the gates (thereby staying in the Elbow River). The outlet structure gates would typically be kept in the full closed position during non-flood conditions. This conceptual design considers opening these gates when extreme flood conditions are anticipated (e.g., a 10% AEP flood or greater) diverting a portion of the flood flow into the off-stream storage site, thereby providing flood protection to the City of Calgary.

An earthfill containment berm will be required across the floodplain connecting the diversion weir to the south land form to prevent an extreme flood water creating a new channel through the floodplain, thereby bypassing the diversion area/sluiceway system.

Including the 15,400 dam^3 available at Glenmore Reservoir, a minimum of 41,200 dam^3 of flood retention storage is required at SR1 to provide a 1% AEP standard of flood protection. If the aforementioned 9,000 dam^3 permanent pond is taken into account, a minimum total live storage requirement of 50,200 dam^3 is required (or a reservoir elevation 1,208.5 m).

The dam system will include a gated low level outlet structure. This structure will consist of a conduit through the dam and include a gate well tower located near the dam centerline. This structure will be used to release stored water back into the river after the flood has passed. Channel improvements will be required along the creek connecting this outlet to the Elbow

River. The conceptual design considers a design discharge of 20 m^3/s which could release the contained flood water back into the Elbow River system over a period of approximately 1 month.

Further information and conceptual design drawings are provided in **Appendix G**.

3.3.2.5 Elbow River Dam Site at FC1

This site is located in the upper watershed approximately 30 km (linear distance) upstream of Bragg Creek where Highway 66 terminates and connects to Powderface Trail.

Although this site has been identified as a preferred site it offers no apparent advantages as compared to the MC1 site. A disadvantage of this site is its location within the basin, controlling only 30% of the watershed upstream of Calgary. It has been determined that unless the flood generating event is centered over this part of the basin it will not be as effective in protecting the City of Calgary (i.e., the storm could be centered over another area still generating volumes in excess of what can be managed at Glenmore Reservoir). This site is therefore not being further investigated at this time. The FC1 site could be revisited if future studies prove that both the MC1 and SR1 sites are unsuitable for implementation.

3.3.3 River Diversions

One very effective way of controlling flooding is to divert the source into another watercourse where there are few receptors (i.e., little infrastructure, housing etc). The idea is to divert flood flows away from built up areas via a diversion channel with sufficient capacity to pass the design flood flow. There are countless examples around the world where this has been successful. The most famous here in Canada is arguably the Red River floodway diversion around Winnipeg. The channel capacity of the Red River floodway is approximately 3,960 m^3/s. The original floodway diversion was finished in 1968 costing $63 million. Since completion, it has been estimated to have prevented $40 billion (in 2011 dollars) in flood damage in Winnipeg. A very important feature of the Red River floodway is that the channel has been engineered to pass the required flow for the entire length of the diversion.

Diversions of the Elbow River have been considered in the past. Two that have received significant publicity following the 2013 flood are a diversion into Priddis Creek and Fish Creek, and a tunnel diversion from Glenmore Reservoir into the Bow River. These are discussed below.

3.3.3.1 Priddis Creek

The Priddis Creek diversion concept has been considered in the past. A view of the concept of using the Priddis Creek valley was taken in the 1986 Elbow River Floodplain Management Study report which considered large scale flood mitigation options to protect the City of Calgary.

The 1986 report outlines a proposed route for the diversion with approximately 46 km of engineered channel at a cost of $68 million in 1986 (based on the Bank of Canada CPI calculator, this figure is approximately $130 million in 2014).

In a January 2014 report, Alberta WaterSMART made the following recommendation:

"WaterSMART recommends further investigation into the Priddis Diversion concept. Based on review of the 1986 Elbow River Floodplain Mangement (sic) Study and the potential to divert 345 m^3/s, this diversion makes it a (sic) ideal choice as it bypasses both Bragg Creek and the City of Calgary. Furthermore after a brief review of the topography surrounding the Priddis Valley, further storage on this diversion is practical, making it cost effective. Flooding of Fish Creek and other low lying areas along the diversion would be ideal to off-set property damage within the City of Calgary."

There is a logical location where the Elbow River and the upper reaches of Priddis Creek are only a few kilometres apart and the topography is amenable to a diversion at this location. However, there are two very significant reasons the Priddis Creek diversion is unlikely to prove the best solution for the City of Calgary.

The 1986 report looked at the diversion as an engineered channel. Any such diversion into Priddis Creek without substantially engineering the receiving watercourse would be severely harmful to the regime of Priddis and Fish Creeks. A flood risk mapping study was undertaken by Alberta Environment Regional Services River Engineering Team in 2004. The 1% AEP flood estimate for Priddis Creek upstream of the confluence with Fish Creek was 144 m^3/s. Though a detailed assessment has not been undertaken for this study, it can be assumed that the existing channel has reached a natural balance between natural erosion, aggradation and degradation processes taking place along the watercourse. Periodically adding 345 m^3/s to this system, or any factor thereof, would cause extreme changes in the channel morphology. Depending on the nature of the bed material, the large scale transport of bed material would occur affecting aquatic habitat. Transported bedload material would be deposited at the confluence of Fish Creek and Priddis Creek in Priddis.

At Priddis, downstream of the confluence, the 1% AEP estimate is 244 m^3/s. There is already a considerable floodway area with many properties at risk. In fact, conceptual flood mitigation measures are provided for Priddis later in this report. Using Priddis Creek to carry Elbow River overflow would significantly increase flood risk to properties already at risk. The Priddis flood study does not estimate flood frequency beyond the 1% AEP event. However, more than doubling the discharge through Priddis will require substantial buyouts or river channel engineering through the hamlet to ensure those at risk are managed in an effective way.

Recommendation 4.11: It is recommended that the concept of diverting flow from the Elbow River into the Priddis/Fish Creek basin be abandoned.

3.3.3.2 Calgary Tunnel

There is a feasibility study currently being undertaken independently by others for the City of Calgary tunnel diversion. However, as part of this overall study, AMEC analysed the effectiveness of the proposed 8.0 m diameter diversion tunnel from Glenmore Reservoir to the Bow River, with a stated peak flow capacity of 500 m^3/s. The purpose of this work was to further evaluate the quantity of upstream storage required on the Elbow River above Glenmore Reservoir.

A HEC-HMS reservoir storage and routing model was developed for the Glenmore Dam and Reservoir using available information provided by the City of Calgary. The June 2013 inflow hydrograph to Glenmore Reservoir (as estimated by City of Calgary through reverse reservoir routing) was provided as input to the model to compare the reservoir levels and downstream discharge with and without the 8.0 m diversion tunnel in place. In this computation, the general assumptions made by Stantec (2013) regarding the diversion flowrates were adopted:

- The inlet rim is situated at the lowest operating level (LOL) of the reservoir; and
- The full capacity of the tunnel is reached with 2.0 m of head above the inlet rim.

Discharge was assumed to increase linearly from the LOL up to 2.0 m of head and remain constant (500 m^3/s) thereafter.

The resulting reservoir stage and discharge hydrographs are presented in **Figure 3.13** and **Figure 3.14**. The simulated June 2013 Glenmore Reservoir stage and outflow hydrographs agree quite well with the observed data, which validates the estimated inflow hydrograph having a peak discharge of 1,240 m^3/s. Under existing conditions with no diversion, the peak discharge on the Elbow River downstream of the dam was approximately 700 m^3/s. This is just below the 1% AEP flood estimate of 737 m^3/s determined by Golder (2010).

With the diversion tunnel in place for the same inflow conditions, the peak reservoir level would have been reduced by approximately 1.1 m and the peak discharge to the Elbow River downstream of the dam would have been just over 180 m^3/s. The anticipated diversion flow hydrograph for this event is also shown having a maximum allowable discharge of 500 m^3/s.

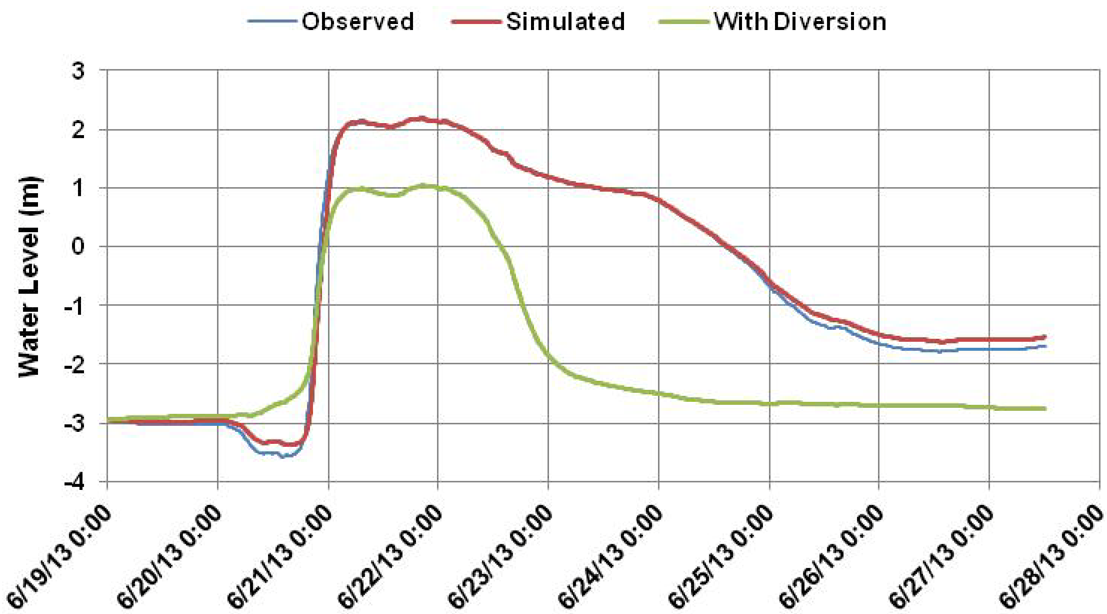


Figure 3.13: Glenmore Reservoir Water Levels for the June 2013 Flood

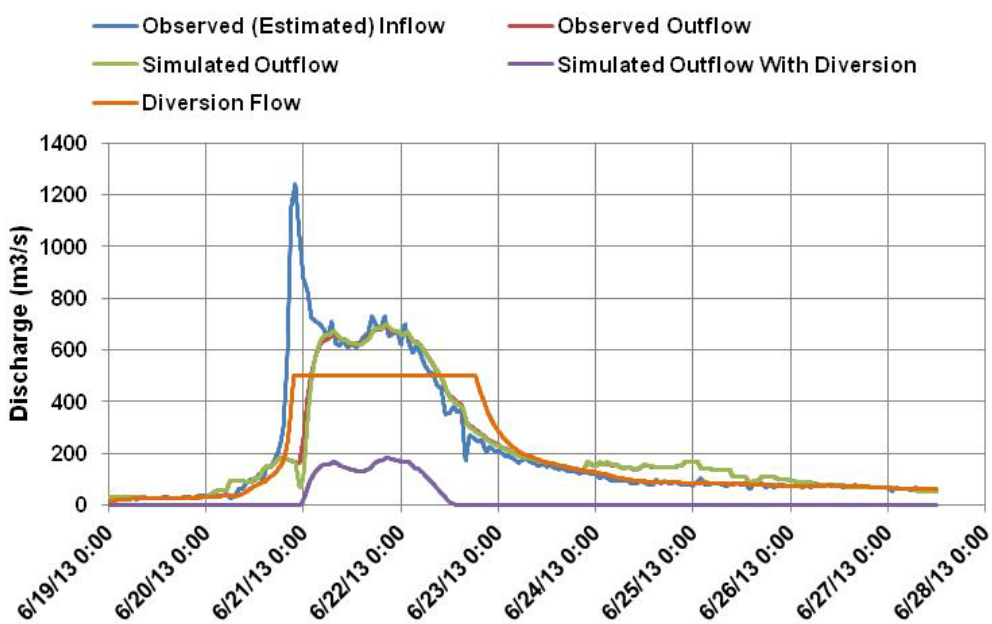


Figure 3.14: Glenmore Reservoir Hydrographs for the June 2013 Flood

Based on the above results, it is reasonably evident that with a 500 m^3/s peak discharge capacity diversion tunnel in place between Glenmore Reservoir and the Bow River. Additional upstream detention storage in the Elbow River Basin may not be required to prevent severe flooding on the Elbow River downstream of Glenmore Dam for an event of comparable magnitude to the June 2013 flood. It is acknowledged that the diversion tunnel would not mitigate flooding for upstream communities such as Bragg Creek or for development in flood-prone areas downstream of the outfall on the Bow River, where other measures such as dyking may be required.

It is also noted that the anticipated design capacity of the tunnel needs to be verified through conceptual and detailed design, which the City of Calgary is currently conducting under a separate study.

3.3.4 Selection of Preferred Major Infrastructure Project

This study does not have sufficient information available yet to make recommendations on the preferred major project for protecting major infrastructure along the Elbow River. The outcome of the City of Calgary's Glenmore tunnel diversion study will help the GoA make decisions on the best way forward for major infrastructure. However, in terms of comparing the two likely schemes identified by this study, namely MC1 and SR1, there are a number of key facts which can be taken into the decision making process:

- From an engineering perspective, and based on the information available at present, both MC1 and SR1 are viable flood storage sites.
- The design standard of protection is yet to be determined by the GoA. MC1 and SR1 are both conceptually designed to mitigate the 1% AEP flood. .
- Conceptual study results indicate that the cost of these projects will be in the order of $200 million each.
- It is more economic to build one larger project than two smaller projects. Either project could be enlarged to provide minimum 2013 protection for an additional $55 million or thereabouts.
- Potential exists for multi-use storage at both sites with little impact on project cost. This is in addition to flood storage, and/or can be included as flood storage. This multi-use storage could be of significant future benefit at little or no upfront/future cost. The need for and amount of such multi-use storage should be given early consideration as it impacts design and environmental assessments.
- Once land acquisition is taken into consideration, both schemes will have a similar magnitude of cost and therefore, both will be similar in terms of benefit cost ratio.
- Both MC1 and SR1 can help with overall water management in the basin and compensate for the loss of storage in Glenmore Reservoir due to siltation (estimated to have lost 17% since 1933).
- Construction risks are less with SR1 since the risk of a major flood occurring during construction presents a greater hazard for on-stream construction. For example, there is about a 5% chance that a 1:100-year (1% AEP) flood will occur during construction.
- There is likely more potential for accelerated construction at SR1 due to the smaller dam height and the ability to construct the constituent parts of the overall scheme in parallel schedules.

- The consequences of dam failure can be catastrophic. Selection of design engineers with dam experience and construction quality control cannot be over-emphasized.
- Land access/project sizing/environmental field study and regulatory process appear to be the primary schedule constraints as compared to engineering/construction. It appears that this will negate the typical schedule advantage of design-build over design-bid-build process.

Before a preferred site can be selected between MC1 and SR1, the GoA will need to determine the required design standard, the options available for multi-use storage and also will need to resolve land access issues to enable a full programme of geotechnical drilling and environmental surveys to be undertaken at SR1. At this stage, land access issues at SR1 prohibit AMEC from undertaking sufficient work to enable a recommendation on the best scheme to be made.

3.4 Options by Flood Risk Area

3.4.1 Bragg Creek

3.4.1.1 Stakeholder Engagement Response

The stakeholder engagement response came from Rocky View County. A bridge over Bragg Creek had just been replaced at a higher elevation (1% AEP level) which saved it from being washed out. There was lots of concern about the bridge that crosses Bragg Creek east to west at the hamlet. If that bridge were to be destroyed, there's no other way out of the area.
The bridge was closed down for 2 days as it was threatened by floodwater (a house hit it, but it still held). A smaller bridge further west on Bragg Creek to Hawkeye Estates was overtopped. There was generally severe disruption and damage to municipal infrastructure including the electrical and water supply, wastewater treatment and roads. The only warning to community were by media and the general provincial emergency management system. Most residents were "wandering around trying to figure out what to do. Door to door warnings helped".

3.4.1.2 Known Flood Pathways

Bragg Creek is primarily at risk of out of bank fluvial flooding from the Elbow River.
The movement of groundwater through the alluvial material which makes up the river valley needs to be taken into consideration in the design of flood defences for Bragg Creek.

3.4.1.3 Multi-Criteria Decision Making and Option Selection

The MCDM appraisal process showed that dykes and erosion protection were the best structural mitigation measure for Bragg Creek. The best non-structural measure is to flood proof the basements of dwellings where groundwater ingress is a problem.

3.4.1.4 Conceptual Design

A conceptual design of flood defences has been prepared for the protection of residential homes and properties located within flood fringe areas defined by ESRD flood risk mapping. The scheme includes a flood dyke (to the 1% AEP flood level plus 1 m freeboard) and French drain. Three flood risk Zones A, B, and C were identified and for each, a flood protection dyke and French drain were proposed as illustrated in **Appendix H**. The following sections provide the details of the flood defences.

- The earth embankment dyke is designed to have minimum 1.0 m freeboard over the ESRD 1% AEP flood level. The dykes have top width of 3 m and side slopes of 3H:1V as per standard design requirement of the US Army Corps of Engineers. The locations of dykes are shown on conceptual sketches in **Appendix H.**
- A preliminary seepage assessment related to groundwater behavior adjacent to the Elbow River under flood conditions estimates groundwater seepage rates on the order of 15,000 m^3/d would be expected after 2 days, along the dykes. A French drain is proposed for seepage collection along the flood dykes. The French drain included perforated high density polyethylene pipes wrapped with granular drain rocks. CSP wells with 200 m spacing were proposed for the installation of dewatering pumps for more rapid groundwater dewatering if necessary during an event. The French drain adjacent to Zone A is designed to release groundwater flow to river by gravity. Riprap protection is required for the outfall of the French drain to the Elbow River.

3.4.1.5 Recommendations

The need for local flood defences through Bragg Creek depends entirely on the preferred major flood prevention infrastructure. By constructing a dam upstream of Bragg Creek (at MC1) there would be no need to construct the flood dykes through the town. However, if the preferred project lies downstream of Bragg Creek, the town will benefit from the proposed defences. Also, given the approvals and construction time that a dam at McLean Creek may take (perhaps 5 to 10 years for project completion), there may be a preference for constructing the defences in the short term to provide immediate flood mitigation to this important residential and recreational area.

It is therefore recommended that once the preferred scheme for the City of Calgary has been identified, flood defences, if necessary, be constructed as soon as possible at Bragg Creek based on the conceptual design in **Appendix H**. To speed the process, the detailed design and planning for the defences should be initiated as soon as possible.

Recommendation 4.12: It is recommended that once the preferred scheme for the City of Calgary has been identified, flood defences, if necessary, be constructed as soon as possible at Bragg Creek.

3.4.2 Tsuu T'ina First Nation

3.4.2.1 Stakeholder Engagement Response

Just downstream of Bragg Creek, at Redwood Meadows, there are a number of properties that are known to be at risk of flooding on the Tsuu T'ina reserve. Other engineers are looking at improvements to the existing flood defences at Redwood Meadows which are known to have been damaged during the June 2013 event. Properties in Redwood Meadows are at risk from fluvial flooding from the Elbow River but also due to groundwater as there is direct hydraulic connectivity between levels in the Elbow River and groundwater levels. As such, there are a number of houses which are subject to basement flooding on occasion. There has been no response from Tsuu T'ina to the engagement questionnaire and; therefore, no recommendations can be made at this time.

3.4.3 Calgary

3.4.3.1 Scope of Study for Calgary

Although the City of Calgary is by far the largest conurbation with the most properties at risk of flooding in the Elbow River basin, the scope of work agreed at the onset of this study did not include specific local level flood mitigation schemes. The City of Calgary has both the resources and technical expertise locally to deliver mitigation measures on behalf of the residents and businesses. However, given the scale of flooding experienced in June 2013, and the major infrastructure proposed by Stantec on behalf of the Advisory Panel, AMEC were asked to include a review of proposals for dams in the upper Elbow River basin.

Meetings were held with staff from the City of Calgary and it is understood that they are evaluating the following solutions to alleviate known flooding hazards identified during the 2013 flood and previous events:

- Repair of pre-existing flood protection works;
- Selected new permanent dykes and flood-protection berms;
- Selected new temporary flood protection barriers;
- Amendments to existing storm water outlets to ensure protection from high river levels and ensure adequate stormwater control during periods of high river levels;
- Erosion protection measures for pathways and related facilities along river banks;
- Replace or repair of pedestrian bridges;
- Engineering feasibility assessment for a tunnel from Glenmore Reservoir to the Bow River;
- Selected groundwater control measures;
- Selected removal and reshaping of accumulated gravels;
- Enhancement of fish habitat and habitat compensation program delivery;
- Development (with the province) of new flood hazard area information and protocols;
- Improving storm and sanitary lift stations;
- Improving wastewater treatment plant flood resilience; and

- Education and engagement programs to advise Calgarians of risk so they can better prepare.

Evaluations by others within the City of Calgary include relocating vulnerable electrical trunk and feeder services (ENMAX).

3.4.3.2 Known Flood Pathways

The known flood pathways along the Elbow River within the City of Calgary are generally confined to the river channel and adjacent floodplain for the reaches of the river upstream of Glenmore Reservoir and immediately downstream of Glenmore Dam. Further downstream in the Mission community, the Elbow River can jump the north bank and flow along street northwards towards the Bow River. This pathway was identified in the 1983 flood study by Alberta Environment, and was examined in a report documenting a 2-dimensional mathematical hydraulic model of the breakout (Hatch, 2013). The City of Calgary constructed earthen berms as a flood defence in 1995 and 2013.

Overbank flooding also occurs at other locations between Mission and the river confluence with the Elbow River.

- A short distance downstream, below the 25th Avenue bridge, the river floods onto the right (east) floodplain in the Erlton district near the Lindsay park recreation facility. Erlton Flood Channel was constructed in the 1990s to collect overland flow along streets and convey the flow east to the Elbow River at the Macleod Trail (northbound) bridge.
- In 2013 floodwaters flowed north along Macleod Trail and along the western boundary of the Stampede grounds towards downtown. The LRT tunnel south of 25th Avenue SE was flooded, as was the LRT tunnel between 12th and 7th Avenues SE.
- The Stampede grounds were flooded. Calgary Exhibition and Stampede Park had constructed berms and other flood protection barriers along portions of the left river bank to protect their facilities.
- Floodwaters escaping the Elbow River ultimately affected the downtown area; however, flooding in the downtown area was not primarily attributed to water from the Bow River.

Flood discharges in excess of 170 m^3/s can result in overbank flooding downstream of Glenmore Dam. This discharge corresponds to an AEP of approximately 8% (i.e., there is an 8% probability in a given year that this discharge will be exceeded on the Elbow River).

3.4.3.3 Multi-Criteria Decision Making Assessment

In the assessment of structural and non-structural flood mitigation options for the Elbow River at the City of Calgary, the top ranked structural measures were levee/dyke, erosion protection and improve conveyance. Wet dam and dry dam scored lower.

The top-ranked non-structural options were buy-outs, managed retreat and flood-proofing. These were followed by land zoning (restricted development), warning/forecasting/management and building code changes.

3.4.3.4 Conceptual Design

AMEC is undertaking conceptual design of dams in the Elbow River basin which would be for the benefit of the City of Calgary. These conceptual designs are presented in **Appendix F** and **Appendix G**.

The City of Calgary is undertaking the evaluation and design of local flood mitigation measures along the Elbow River, so no further consideration is given.

3.4.3.5 Recommendations

There are a number of mitigation measures that will be proposed by both the City of Calgary and the SAFRTF which, at some point, will need to be measured against not only engineering feasibility but also the best economic, environmental and performance criteria. The MCDM analysis highlighted that a river diversion might be the best solution for the Elbow River downstream of Glenmore; however, the feasibility of a dam upstream at SR1 or MC1 would probably win out due to cost of construction and performance.

It is therefore recommended a complete economic appraisal be undertaken for all technically feasible projects including the 58th Avenue tunnel (being studied by the City) and dams at MC1 and SR1.

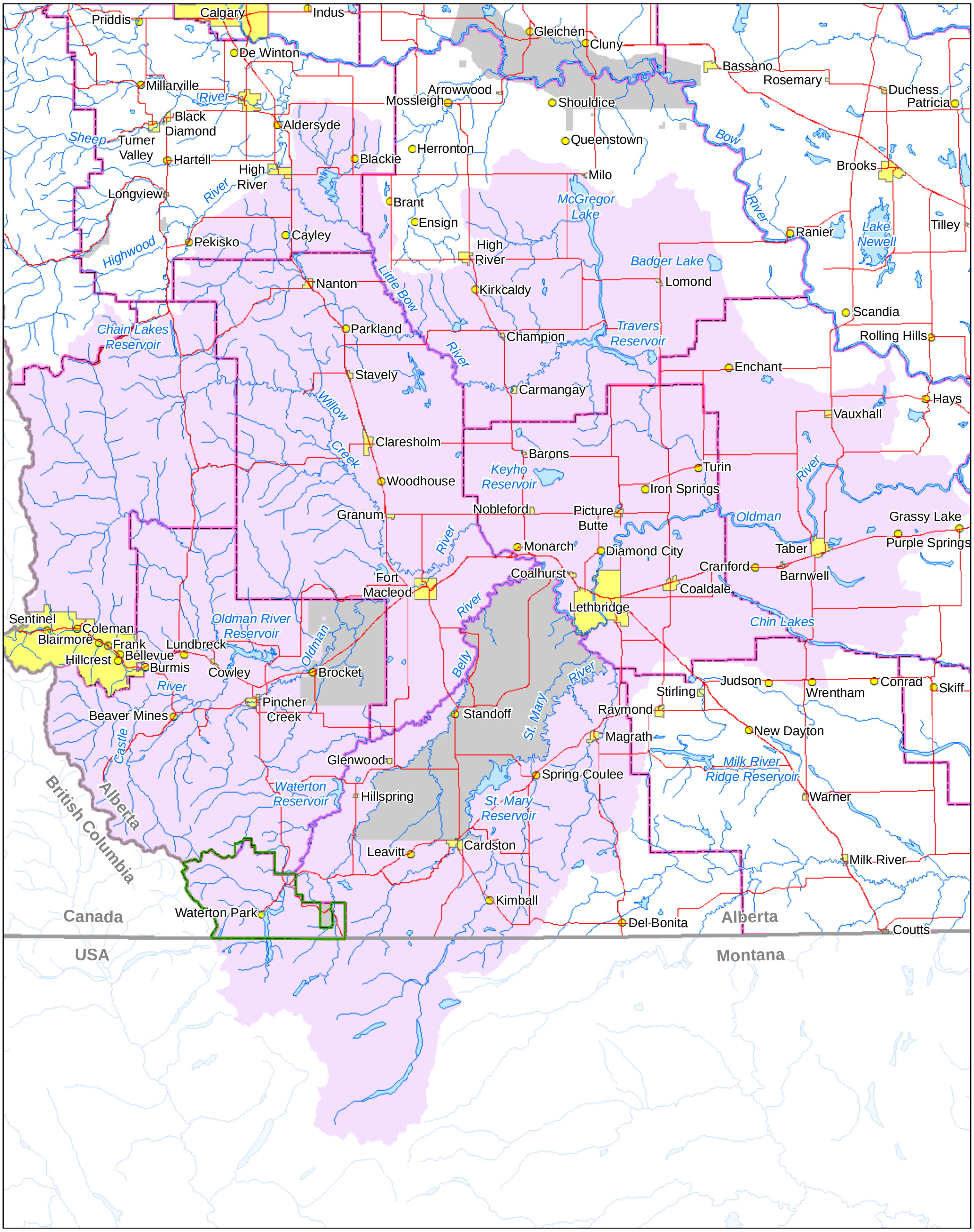
Recommendation 4.13: It is recommended a complete economic appraisal of feasible engineering flood mitigation options be undertaken following completion of the conceptual design for the Calgary (58th Ave) tunnel and the dams at MC1 and SR1.

4.0 OLDMAN RIVER BASIN MITIGATION MEASURES

4.1 Basin Description

The Oldman River basin is situated on the eastern slopes of the Rocky Mountains in southwestern Alberta. The source of the Oldman River is within the Rocky Mountains at the continental Divide. Southeast of its source and within the Foothills physiographic zone, the Oldman River is joined by the Crowsnest River flowing east from the Crowsnest Pass and by the Castle River flowing north. This confluence is the site of the Oldman River Dam, which became operational in 1992. Downstream of the Oldman River Dam, as the river emerges onto the Prairies, the Oldman River is joined from the north by Willow Creek near the town of Fort Macleod. Moving downstream the river becomes more entrenched within its valley, and is joined by the Belly River and the St. Mary River. The St. Mary River and the Belly River, as well as its tributary, the Waterton River, all have their sources in Montana, USA. The Waterton and St. Mary Rivers both have irrigation water supply dams. The City of Lethbridge is situated a short distance downstream of the St. Mary River confluence. There are no major tributaries along the Oldman River between Lethbridge and the mouth of the Oldman River, where it joins with the Bow River to form the South Saskatchewan River.

The drainage area of the Oldman River is approximately 16 200 km^2, and is illustrated on **Figure 4.1**. The basin extends east from the Continental Divide across the inner mountain zone, across the Foothills and onto the Prairies. Mountain peaks range in elevation from 2,500 to 3,500 m. River valleys near the source are near elevation 1,500 m. The river drops steeply to the Oldman River dam area, and then more gradually from there to the mouth. Over its 700 km length, the river drops approximately 940 m.



Sources: GeoBase®, Spatial Data Warehouse Ltd.

Legend

Oldman River Drainage Basin
Urban Municipality
Indian Reserve
Lake
Highway
Waterton Lakes National Park
Municipality Boundary
River

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PROJECTION/DATUM: 10TM/NAD83	ANALYST: TR

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Oldman River Basin

Figure 4.1

4.2 Water Management Issues

4.2.1 Irrigation and Regulation

Approximately 60% of the Oldman River basin is used for agricultural production, including about 40% of Alberta's total 640,000 ha of irrigated land. This is considered to be one of the most intensive agricultural regions in Canada because of the large area of irrigated crop land and high densities of livestock feeding operations. Other land use activities in the watershed, outside of urbanized areas, include forestry, mining, oil and gas extraction, and recreation.

The Oldman River basin currently has a total population of about 220,000 people and almost half live in Lethbridge, the largest city in the basin. The remainder live in rural areas and smaller towns including High River, Taber, Pincher Creek, High River, Nanton, Vulcan, Claresholm, Magrath and Cardston.

Three major on-stream water storage reservoirs are located in the Oldman River basin. These are the Oldman, St. Mary, and Waterton reservoirs. The smaller Twin Valley Reservoir is located on the Little Bow River downstream of High River. These reservoirs have a combined storage capacity of a little over 1.0 million dam^3. In addition, more than 25 off-stream reservoirs located within the sub-basin store another 430,000 dam^3 of water.

Many of these off-stream reservoirs are owned and operated by one of the nine irrigation districts located in the basin, and are important irrigation water sources during the summer growing season. They are also important recreational destinations for many residents throughout southern Alberta. The on-stream and off-stream water storage reservoirs are important to capture runoff water from the mountains during the relatively short snowmelt period in May and June. This stored water is used by a wide variety of users throughout the basin during much of the summer season when the natural flow in the rivers is often very low.

Prior to the Oldman Dam and Reservoir, water flow past the City of Lethbridge was often very low in July, August, and September. With the completion of the Oldman Dam and Reservoir in 1992, summer and winter flows were increased to meet agreed upon levels past Lethbridge and Medicine Hat. The Oldman Dam and Reservoir is also important to ensuring that apportionment flows to Saskatchewan are met.

4.2.2 St. Mary and Milk Rivers – International Water Sharing

The St. Mary River, a key tributary of the Oldman River, originates in the eastern slopes of the Rocky Mountains in Montana. This river is an important source of water for both Alberta and Montana, and along with the Milk River, has been the subject of ongoing negotiations and discussion since the early 1900s.

The International Joint Commission (IJC) was set up by Canada and the United States to help resolve all trans-boundary water issues between the two countries. This resulted in the 1909 Boundary Waters Treaty and later the Order of 1921, which provided a specific sharing agreement for sharing of the St. Mary and Milk Rivers.

This agreement affects the volume of water that is available for use in the Oldman River basin. Montana feels it should receive a larger share of the St. Mary River water, and continues to challenge the 1921 Order to the IJC. Discussions are ongoing between Alberta and Montana to see if a compromise settlement is possible.

4.2.3 Water Use

In the Oldman River basin, about 2.2 million dam^3 of water is allocated for various uses, and about 1.1 million dam^3 is actually used on average. This is about 51% of the total allocation and 34% of the median natural flow of the river (AMEC, 2009). Irrigation is the dominant water use in the Oldman basin, accounting for about 88% of the total volume of water allocated. Of Alberta's 13 irrigation districts are sourced from water in the Oldman River. Combined with private irrigation schemes, 9 divert water directly from rivers, streams, and reservoirs, about 285,000 ha of land is irrigated in the basin. Municipal use accounts for about 3% of allocation, commercial and livestock use about 1% each, and other uses about 7%. Industry and petroleum use is barely measurable.

Specialty crop production has spurred the development of major food processing industries in the Oldman River basin and other regions in southern Alberta.

4.2.4 Drought

Droughts have been a reality in the Oldman River basin since before European settlement began. They are an ongoing occurrence of the semi-arid climate of this region which could have significant impacts on the economy and quality of life in the region.

Dryland and irrigation producers are usually the first to feel the impacts of a drought, such as occurred in part of the Oldman River basin in 2000 and 2001.

During that event, on-stream and off-stream storage reservoirs in the Southern Tributary Sub-basin were reduced to about 26% of capacity going into the 2000/2001 winter season – much lower than normal. Low precipitation in the 2000/2001 winter season reduced water supply for the 2001 summer season to about 50% of the total water demand. To cope with the drought, irrigation districts and other water users reached a water sharing agreement.

While management of the 2001 drought was considered a major success, it is recognized that this was an ad hoc solution to a very short drought situation.

4.2.5 Flood and Drought Mitigation

It is unlikely that a single action can prepare the Oldman River basin for a flood, or a multi-year drought. A successful strategy will require implementation of a number of integrated actions that need to be in place well before these events occur.

Effectively managing a drought or a flood requires a strategy that optimizes the management of water. Short-term storage of excess water during a flood, or long-term storage of water for a drought may be able to utilize essentially the same storage infrastructure. This would optimize the effectiveness of the infrastructure, and save significant costs compared with construction of single-purpose infrastructure for floods and droughts separately.

During the 1995 flood, existing storage reservoirs in the Oldman River basin were credited with saving the two bridges crossing the Oldman River at Lethbridge, and reducing the impact of the flood waters on downstream communities. During the 2013 flood, the Twin Valley reservoir downstream of High River was credited with reducing the impact of Little Bow River flood flows on the downstream Travers Dam.

Construction of new on-stream and off-stream reservoirs at key locations in the sub-basin should be considered for both drought and flood protection.

4.2.5.1 Water Storage Opportunities Study

Water supply in the South Saskatchewan River Basin (SSRB) is naturally subjected to highly variable flows and frequent low flows. Capture and release of surface water runoff is critical in the management of available water supply. In addition to supply constraints, other factors such as the potential impact of climate change, the existing infrastructure, the level of water allocations and the water licensing and regulatory framework impact water security in the basin.

In March 2013, a steering committee led by Alberta Agriculture and Rural Development (AARD) retained AMEC to conduct a water supply study to identify and evaluate opportunities for new water storage development in the SSRB in Alberta.

The water storage opportunities study will evaluate and summarize existing reports and basin modelling information on reservoir storage opportunities within the Bow River, Red Deer River, Oldman River and South Saskatchewan River basins. It will also provide technical evaluations of new storage development options.

The objectives of the study are:

- To provide a summary of current and future water requirements in the SSRB, including license purposes, priorities, amounts, frequency and magnitude of deficits, and the ability of users to manage water deficits.
- To provide a summary of the current and future water supply in each of the four basins.
- To provide an overview of existing reservoirs within the SSRB, including information on licensees, licensed purpose, capacity, priority and current uses and their role in water management.
- To summarize current operation practices and requirements of existing reservoirs and outline potential opportunities for their re-management.
- To present a rationale for additional storage.

- To compile a summary of potential sites within the SSRB and criteria and weightings to compare sites.
- To model and evaluate the outcomes and results of key potential sites for their ability to:
  - Improve security of water to existing users.
  - Support downstream aquatic environment.
  - Support future needs of First Nations.
  - Mitigate impacts of climate change.
- To review recent work on the Bow River basin (the Bow River Operational Model) and assess the results for new storage opportunities identified in that study in the context of this project.
- To provide a comprehensive set of conclusions and recommendations which may influence policy and provide advice to decision makers on future water storage development in the basin; and finally,
- To provide a summary of information gaps and recommendations for further work.

After reviewing the water supply issues and the need for new storage development in the four basins of the SSRB (Red Deer River, Bow River, Oldman River and South Saskatchewan River), as a first priority the study has focused on assessing options for storage opportunities in the Oldman River Sub-basin. To date, three potential sites for new storage in the Oldman River basin have been identified:

- Expansion of off-stream storage in Chin Reservoir;
- Construction of a new reservoir on the lower Belly River (Belly River Project); and
- Development of the Kimball site on the upper St. Mary River (Kimball Project).

A fourth site located near the mouth of the St. Mary River (Lower St. Mary Project), has been identified as an option in the event that none of the previous sites proved to be promising. The water supply study is ongoing and scheduled for completion by 31 March 2014.

4.3 Areas at Risk of Flooding

The areas at greatest risk from flooding or flood damage are the communities situated along various watercourses, agricultural operations and transportation infrastructure crossing major streams. For many of the communities potentially affected by flooding, the GoA has conducted flood risk mapping studies. These communities include:

- Crowsnest Pass;
- Pincher Creek;
- Fort Macleod;
- Lethbridge; and
- Cardston.

Climate change studies predict the occurrence of more severe weather events, including floods. Whether or not climate change is the cause, southern Alberta has experienced numerous floods over the past two decades, often caused by high rainfall combined with spring snowmelt. These floods caused significant damage to public and private infrastructure in various parts of the sub-basin.

While the 2013 flood has been one of the most devastating on record, floods in 1995, 2002, 2005, 2010 and 2011 have also caused significant damage in various regions of the Oldman River basin.

The 2010 and 2011 floods across southern Alberta resulted in severe overland flooding caused by excess rainfall and snowmelt, combined with runoff from the Milk River Ridge in southwestern Alberta and the Cypress Hills of southeastern Alberta. These flood events caused significant damage throughout this part of the province to public and private infrastructure (highways, roads, irrigation canals, storage reservoirs, farm buildings and homes). Thousands of hectares of agricultural land were flooded and many livestock were threatened. In both 2010 and 2011, irrigation canals and off-stream reservoirs could not handle the excess flood waters, and serious overland flooding resulted in many downstream areas. This was a particular issue with the St. Mary River District main canal which runs from the Milk River Ridge Reservoir (near Cardston) to south of Medicine Hat.

To prevent the Milk River Ridge reservoir from overtopping, excess water was diverted into this canal. This resulted in one St. Mary River District reservoir, near Medicine Hat, being in danger of breaching, which caused serious concerns for the safety of downstream residents in and around Medicine Hat.

Three irrigation districts share responsibility for the operation of the St. Mary River District main canal system, and have proposed that one or more emergency spillways be constructed at key locations along the 200 km canal. This would allow excess water to be diverted into the Oldman River, and the main canal to act as both an irrigation and drainage channel during flood events.

4.3.1 Managed Retreat in the Aftermath of the 1953 Flood

The history of settlement in the Oldman River valley at Lethbridge is instructive in terms of lessons learned and the mitigation measures instituted by the City of Lethbridge following major floods. The floods of 1902 and 1908 had discouraged settlement in the river bottom. Nevertheless, according to Johnson (1989), in 1912 the City of Lethbridge purchased 160 acres of land from the CPR in the river valley and subdivided it into small leases. People were encouraged to settle in the area and by the early 1950s, a total of 83 families, including 509 children, lived there.

Then the flood of 1953 hit. It was the largest flood to hit the City of Lethbridge since the flood of 1908. The 1953 flood was one of the most disastrous in economic terms. As reported by Johnson (1989), it closed the City-owned power plant for a week and reduced the community water supply by half. Canada (1955/1957/1962) reported $15,000 in damages were sustained by the City of Lethbridge, $25,000 in damages to Lethbridge Sand and Gravel Co., and a total of $365,000 in damages to other irrigation, railway, highway and communities as far east as Medicine Hat.

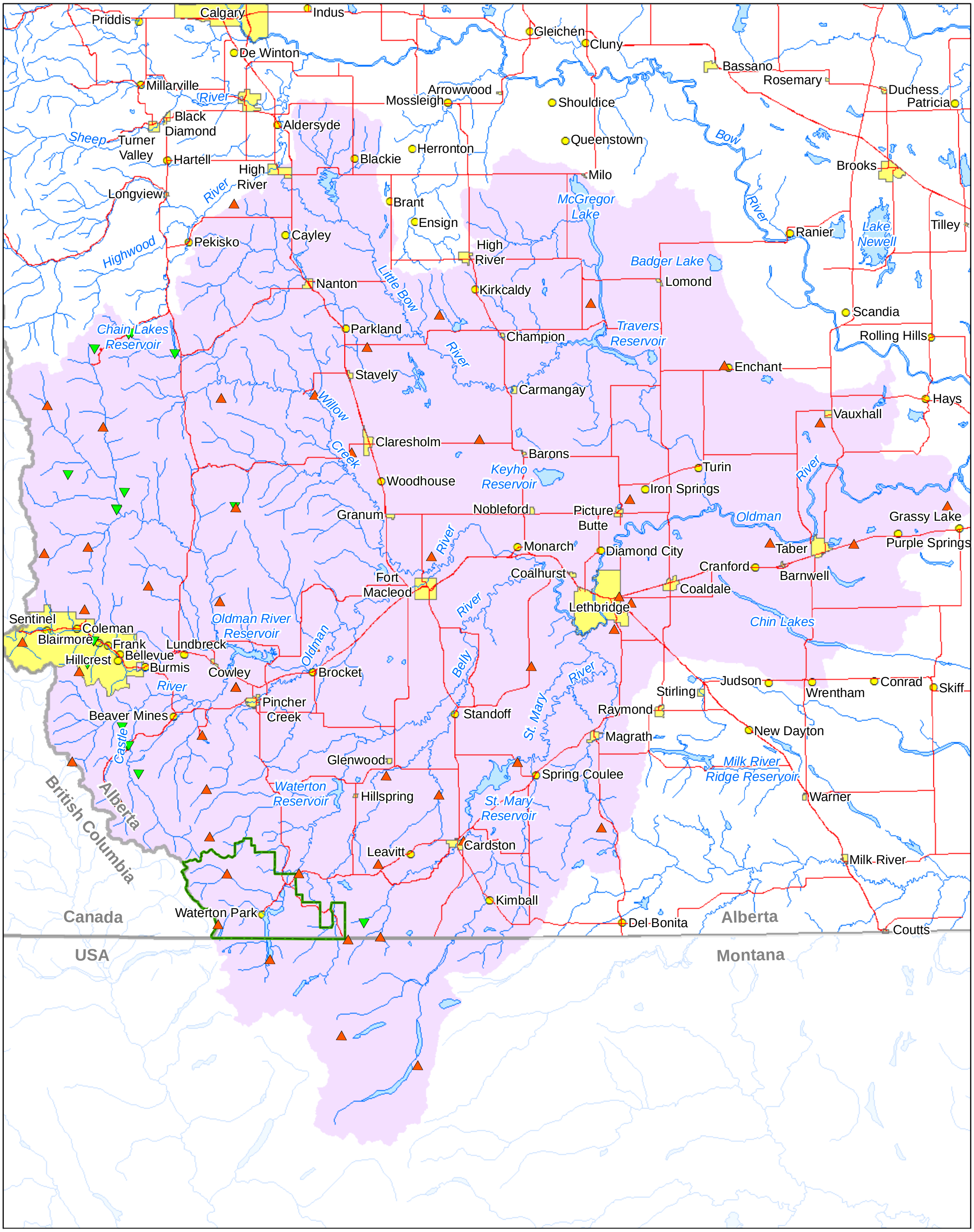
The 1953 flood forced the midnight evacuation of over 150 people by police, militia and firemen. This disaster convinced the City of Lethbridge council to zone the river bottom as parkland/recreation. According to Johnson (1989), people were encouraged, and sometimes pressured, to leave. Although the pull-out was gradual, only one or two homes remained by 1960 when Indian Battle Park was named, and all habitation was removed by the mid-to late-1970s.

4.4 Data Collection and Review

Climate and hydrometric data have been gathered to aid in understanding the characteristics of flooding in the Oldman River basin. Climatic data includes precipitation temperature, etc. **Figure 4.2** illustrates the locations of climatic stations in the Oldman River basin.

ESRD also monitors snow pack in the Oldman River basin as a part of its water supply and flood forecasting mandate. **Figure 4.3** illustrates the locations of snow survey monitoring sites in the Oldman River basin.

Streamflow is monitored at numerous locations in the Oldman River basin. **Figure 4.4** indicates the locations of the hydrometric stations currently used for flood forecasting purposes.



Sources: GeoBase®, Spatial Data Warehouse Ltd.

Legend

- Oldman River Drainage Basin
- Urban Municipality
- Waterton Lakes National Park
- Lake
- River
- Highway
- Meteorological Station (ESRD)
- Meteorological Station (AFS)

PDF: Fig4.2 Oldman Basin Met Stns 14-05-22			
DATE: May 2014	PROJECT: CW2174		
PROJECTION/DATUM: 10TM/NAD83	ANALYST: NH		

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Meteorological Stations in the Oldman River Basin

Figure 4.2

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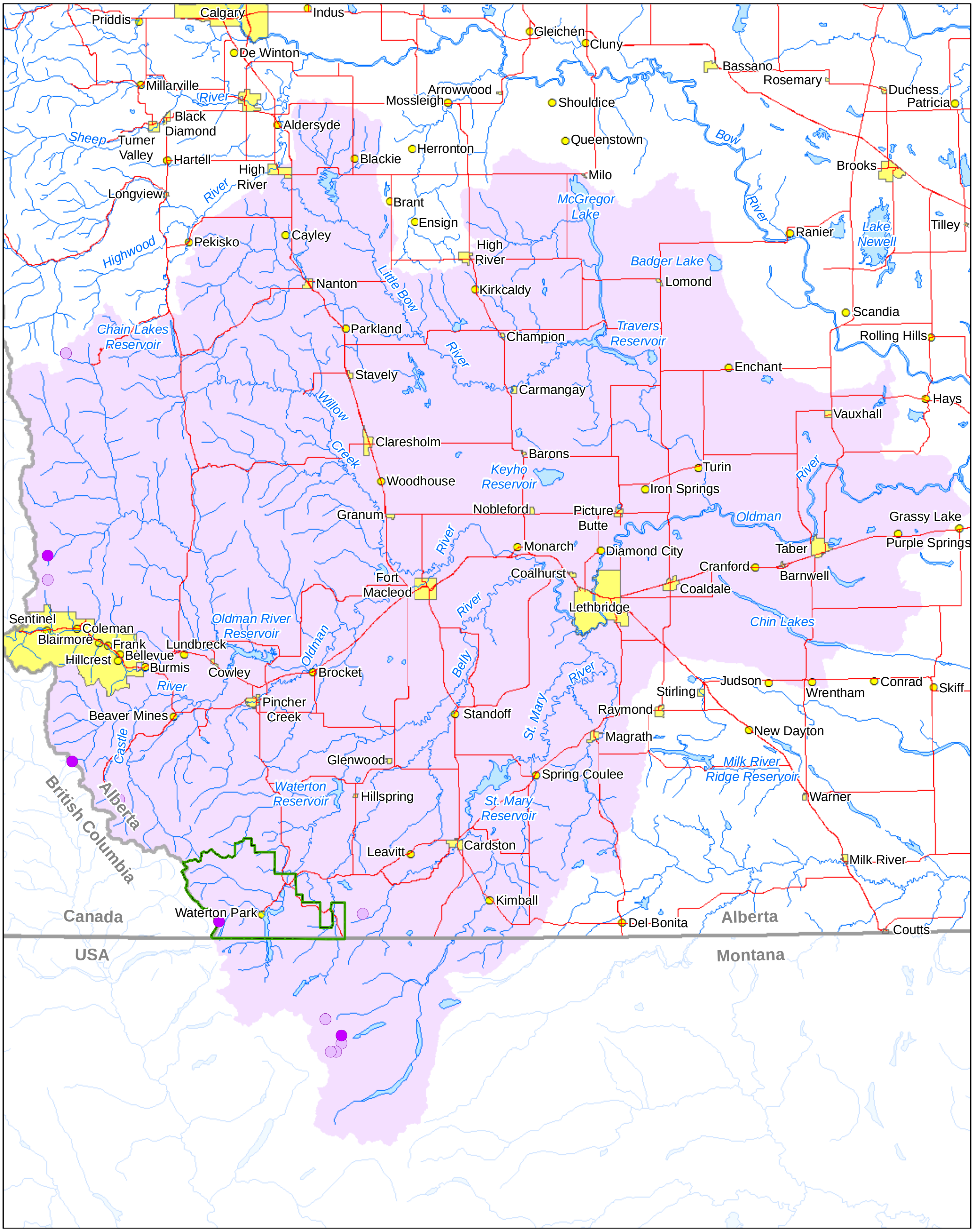

Sources: GeoBase®, Spatial Data Warehouse Ltd.

Legend

Oldman River Drainage Basin	Urban Municipality	Lake
	Waterton Lakes National Park	River
Highway	Snow Pillow	
	Snow Course	

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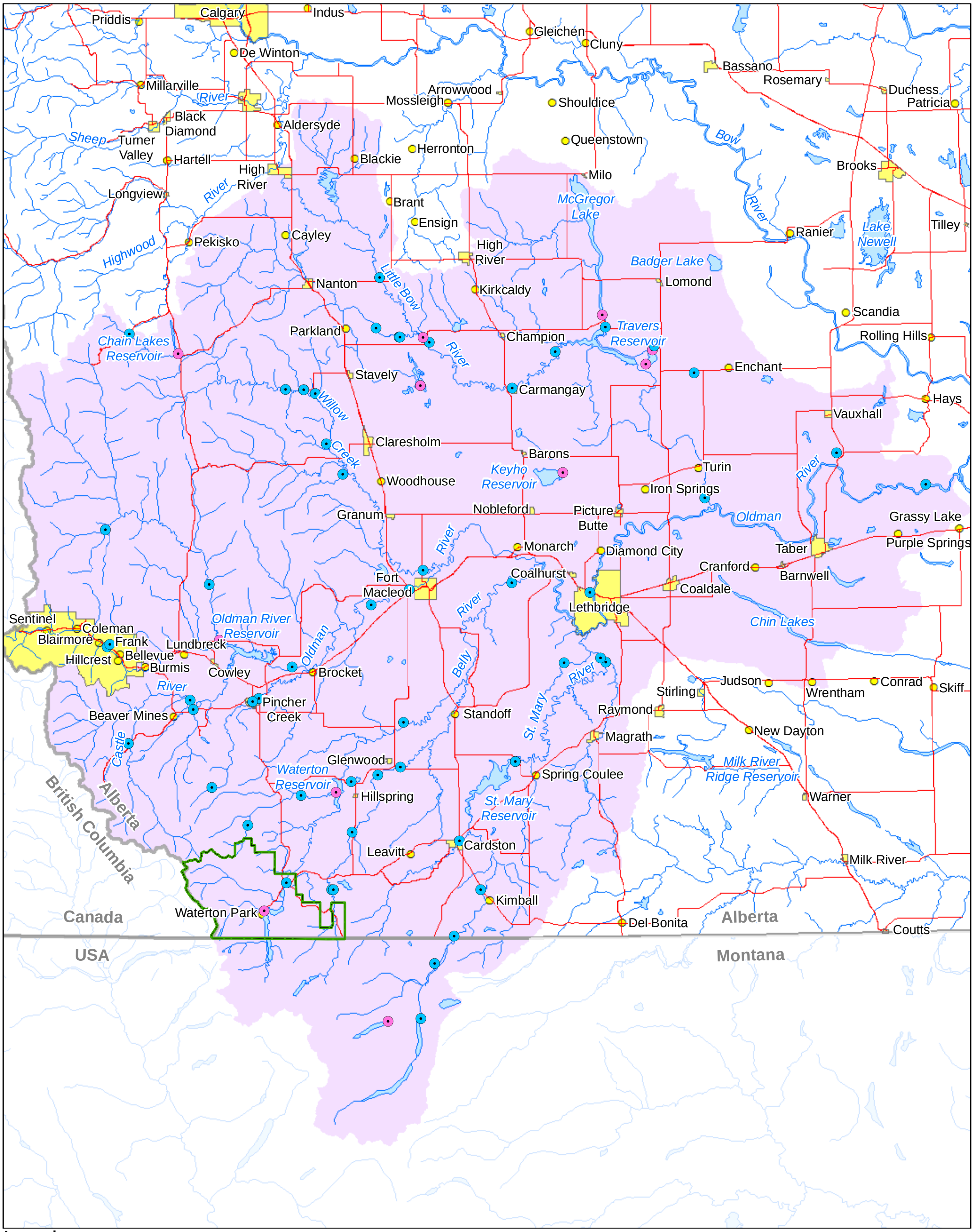
Snow Survey Stations in the Oldman River Basin

Figure 4.3



Sources: GeoBase®, Spatial Data Warehouse Ltd.

Legend

- Oldman River Drainage Basin
- Urban Municipality
- Waterton Lakes National Park
- Lake
- River
- Highway
- **Hydrometric Station**
  - Discharge
  - Water Level

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PROJECTION/DATUM: 10TM/NAD83	ANALYST: NH	

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Hydrometric Stations in the Oldman River Basin

Figure 4.4

4.5 Basin Hydrology

The systematic period of recorded river discharges starts around 1908. Prior to that date there is anecdotal information concerning floods that occurred in c.1870, 1887, 1897, 1899, 1902, and 1908. Since the start of hydrometric monitoring, floods within the Oldman River basin occurred in 1923, 1937, 1942, 1948, 1953, 1964, 1975, 1995, 2005, 2010, and 2013.

For many streams in the Oldman River basin, the flood of 1995 was the largest flood on record. **Figure 4.5** illustrate recorded flood discharges and flood frequency estimates for selected streams and communities in the Oldman River basin. The sources of the flood frequency estimates are indicated below.

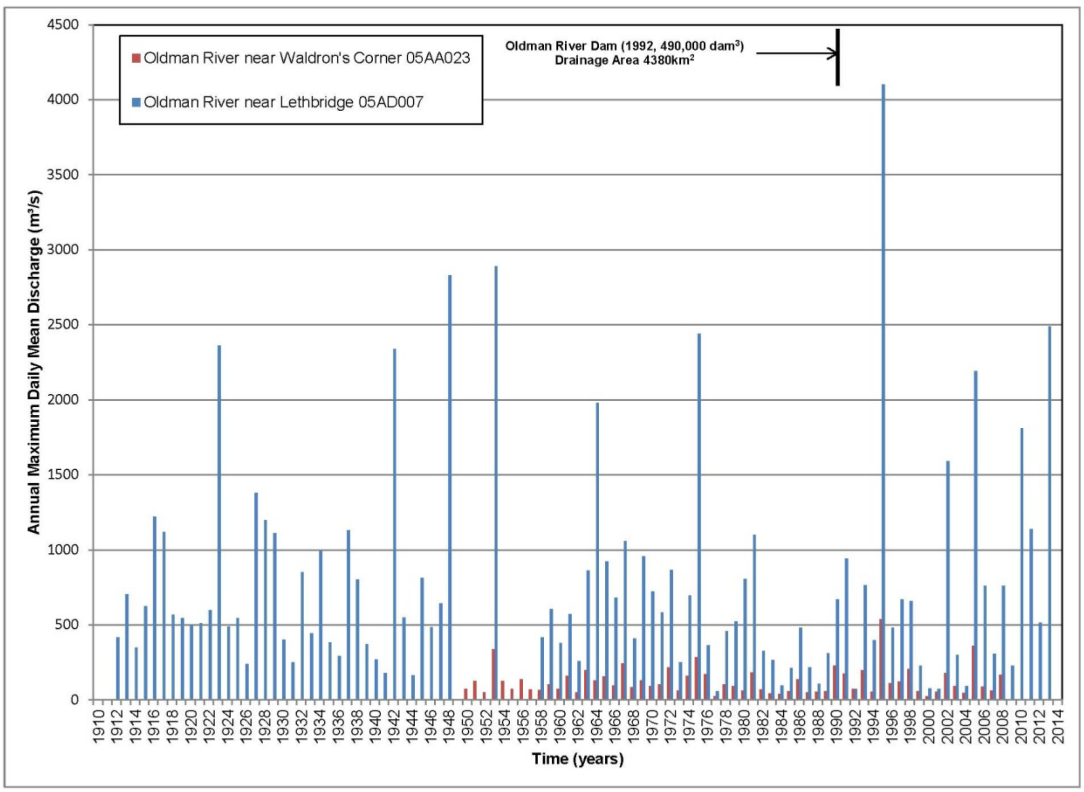


Figure 4.5: Historical Flood Discharges Along the Oldman River

Table 4.1 summarizes the results from recent floodplain mapping studies conducted for major communities in southern Alberta.

Table 4.1
Source of Flood Frequencies from Floodplain Mapping Studies in the Oldman River Basin

(Crowsnest River at Frank	Pincher Creek at Pincher Creek	Lee Creek at Cardston	Oldman River at Fort Macleod	Oldman River at Lethbridge
AMEC, 2007b	Philips, 1993	Stanley, 1992	AENV, 1991	AMEC, 2007a

Historic recorded drainages at Frank (Crowsnest Pass), Pincher Creek, Cardston, and Lethbridge are shown on **Figure 4.6**, **Figure 4.7**, **Figure 4.8**, and **Figure 4.9**, respectively.

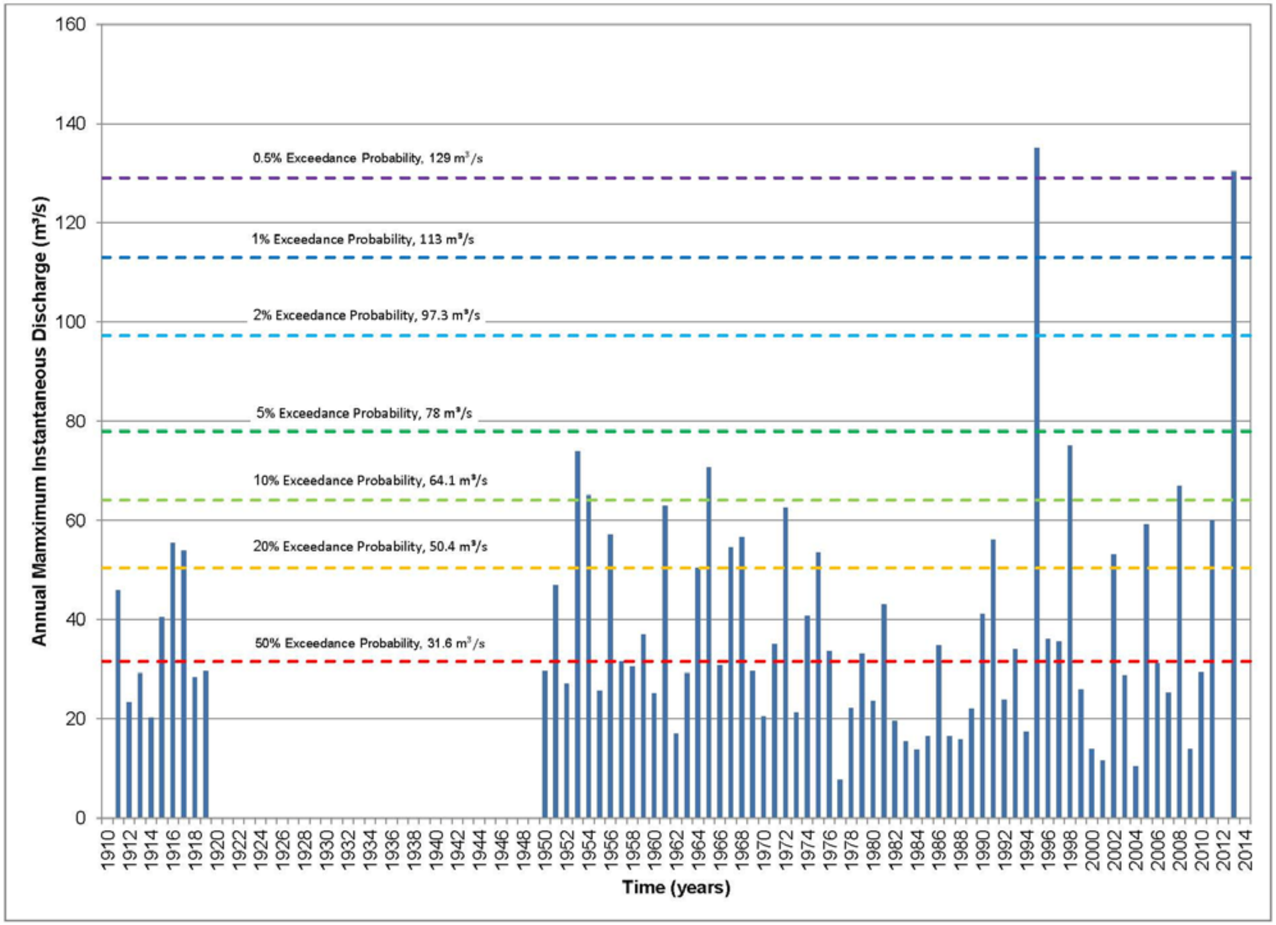


Figure 4.6: Historic Recorded Discharges at Frank (Crowsnest Pass)

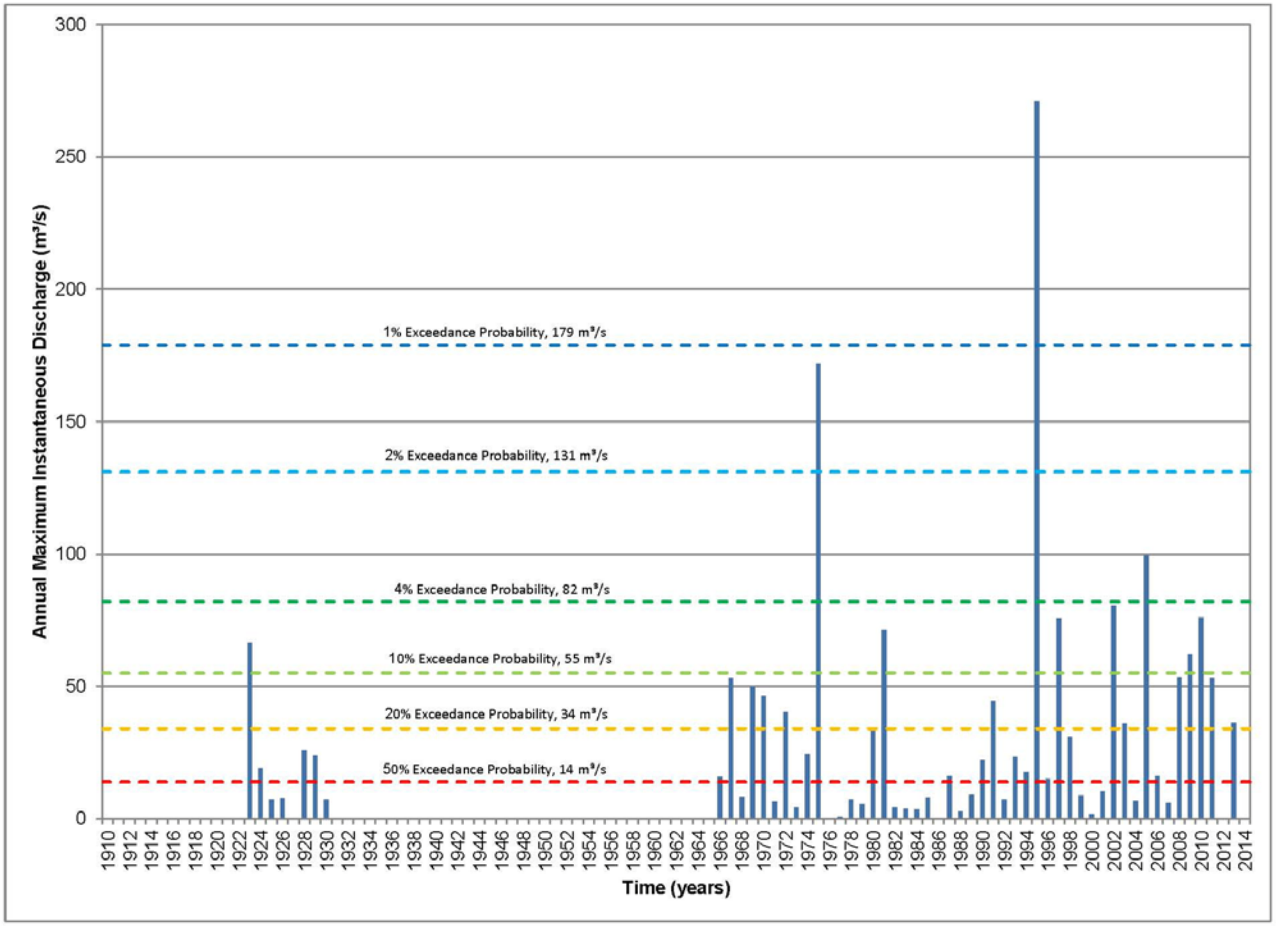


Figure 4.7: Historic Recorded Discharges at Pincher Creek

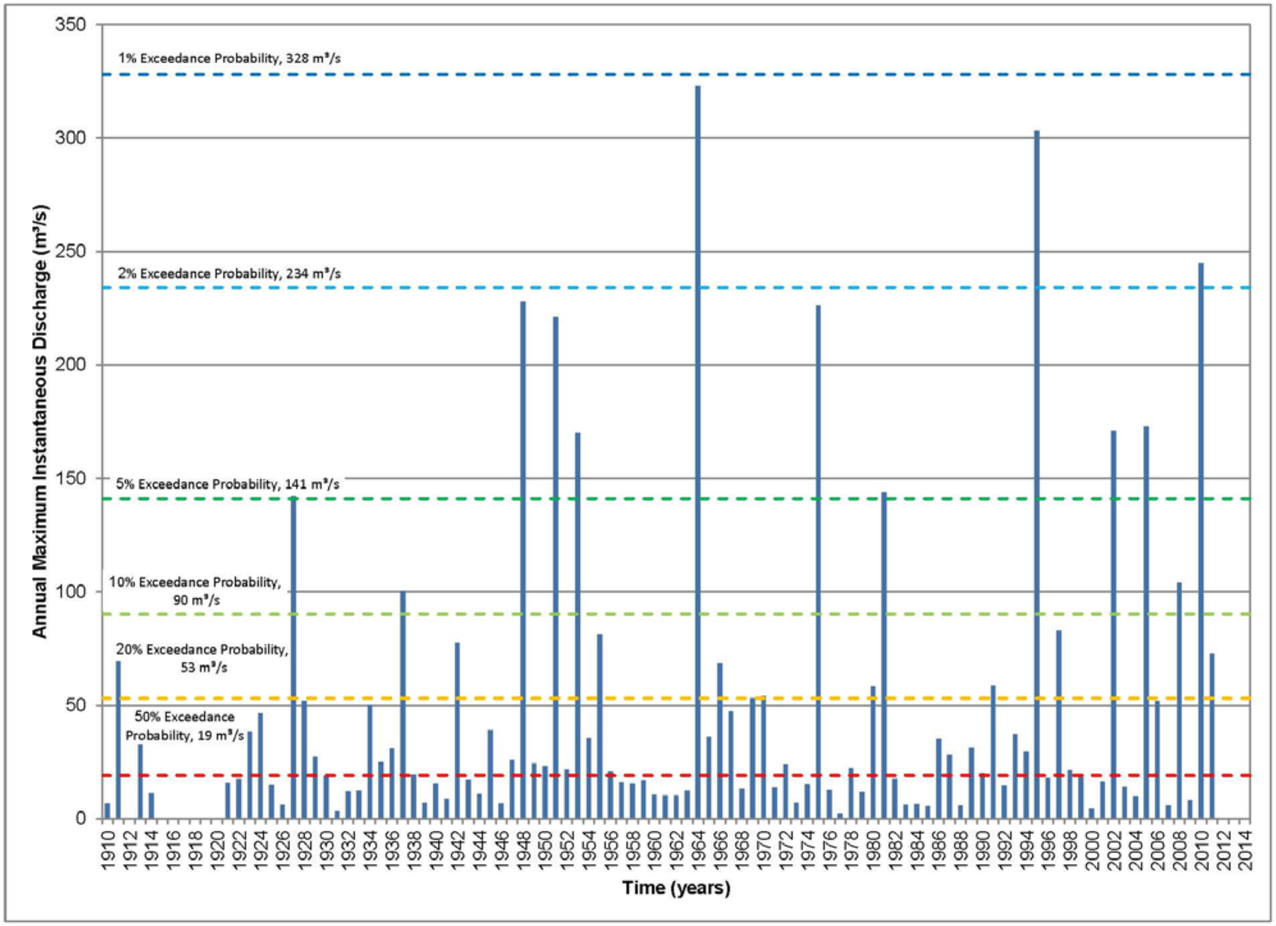


Figure 4.8: Historic Recorded Discharges at Cardston

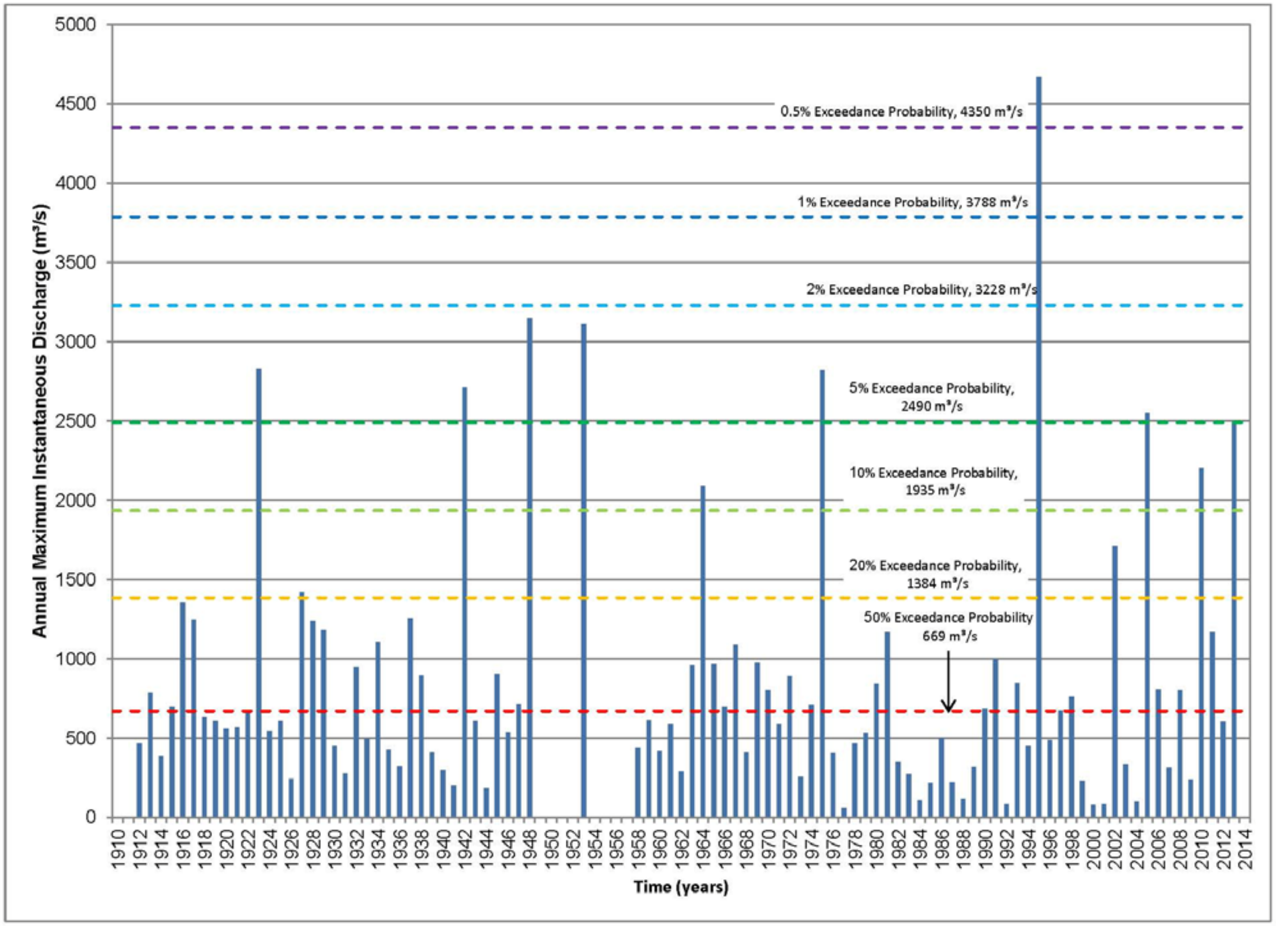


Figure 4.9: Historic Recorded Discharges at Lethbridge

4.6 Options by Flood Risk Area

4.6.1 Crowsnest Pass

4.6.1.1 Stakeholder Engagement Response

The Municipality of Crowsnest Pass estimated the cost associated with the 2013 flood was about $2.5 million. Most of the flood damage was caused by tributaries entering the Crowsnest River, rather than the river itself. There was some damage (erosion) to a municipal road and one of the walking bridges was washed out. Some residential damage occurred along Lyons Creek due to water backing up at the CPR bridge because of a log jam. A forest fire in 2004 may have increased runoff and debris load during the flood.

Some sections of the Crowsnest River have limited mitigation measures in place, mainly rip rap along some sections. This appeared to be effective in preventing damage along those areas of the river. There is little mitigation for the creeks flowing into the Crowsnest River.

The municipality recognizes the need to develop a more robust system to mitigate future flood events, including:

- Stockpiling sand bags and sand;
- Dealing with affected people and developing an evacuation plan; and
- Implementing additional flood mitigation works before the next flood event.

Restoration work is required in preparation for a future flood. The municipality suggested that the size of the channel under the CPR rail line be increased to prevent upstream residential flooding.

4.6.1.2 Known Flood Pathways

The headwaters of the Crowsnest River are located in the Flathead and High Rock Ranges of the Rocky Mountains. In response to historic flood events beginning in 1923, the Crowsnest River was channelized between Blairmore and Coleman. Flooding along all streams in the study area generally occurs during the open water season, as a result of mountain snowmelt runoff combined with rainfall events. High flows are most likely to occur in May and June.

Flood pathways in the Crowsnest Pass are best described by considering the mainstem of the Crowsnest River and the tributary channels that feed into the Crowsnest River. Based on information provided in AMEC (2007b), which examined flooding along the river from Crowsnest Lake to downstream of Hillcrest, areas along the Crowsnest River that are subject to flooding are generally those where bankfull capacity is reduced allowing for high water levels to inundate adjacent floodplain areas. Examples include:

- Upstream and downstream of the Allison Creek confluence;
- The floodplain north of the river between Coleman and Blairmore;
- Old Frank townsite between Highway 3 and Cold Creek confluence; and

- Area upstream of East Hillcrest Drive.

Tributary creeks would generally be flashier in terms of response to rainfall events compared to the Crowsnest River that would have flows moderated to some extent by Crowsnest Lake. Flooding along the creeks is affected by conveyance through road and railway crossings. While the modeling conducted by AMEC did not account for debris blockage, such an occurrence is acknowledged to be problematic at some locations (e.g., a jam occurred on the CPR crossing of Lyons Creek in June 2013; **Figure 4.10**). Characteristically the creek channels approaching the river are somewhat confined; however, overbank flooding can occur in the lower reaches immediately upstream of the river. This is especially true for McGillivray Creek and Nez Perce Creek at West Coleman and Coleman, respectively and to a lesser extent for the lower reaches of Gold Creek and Drum Creek.

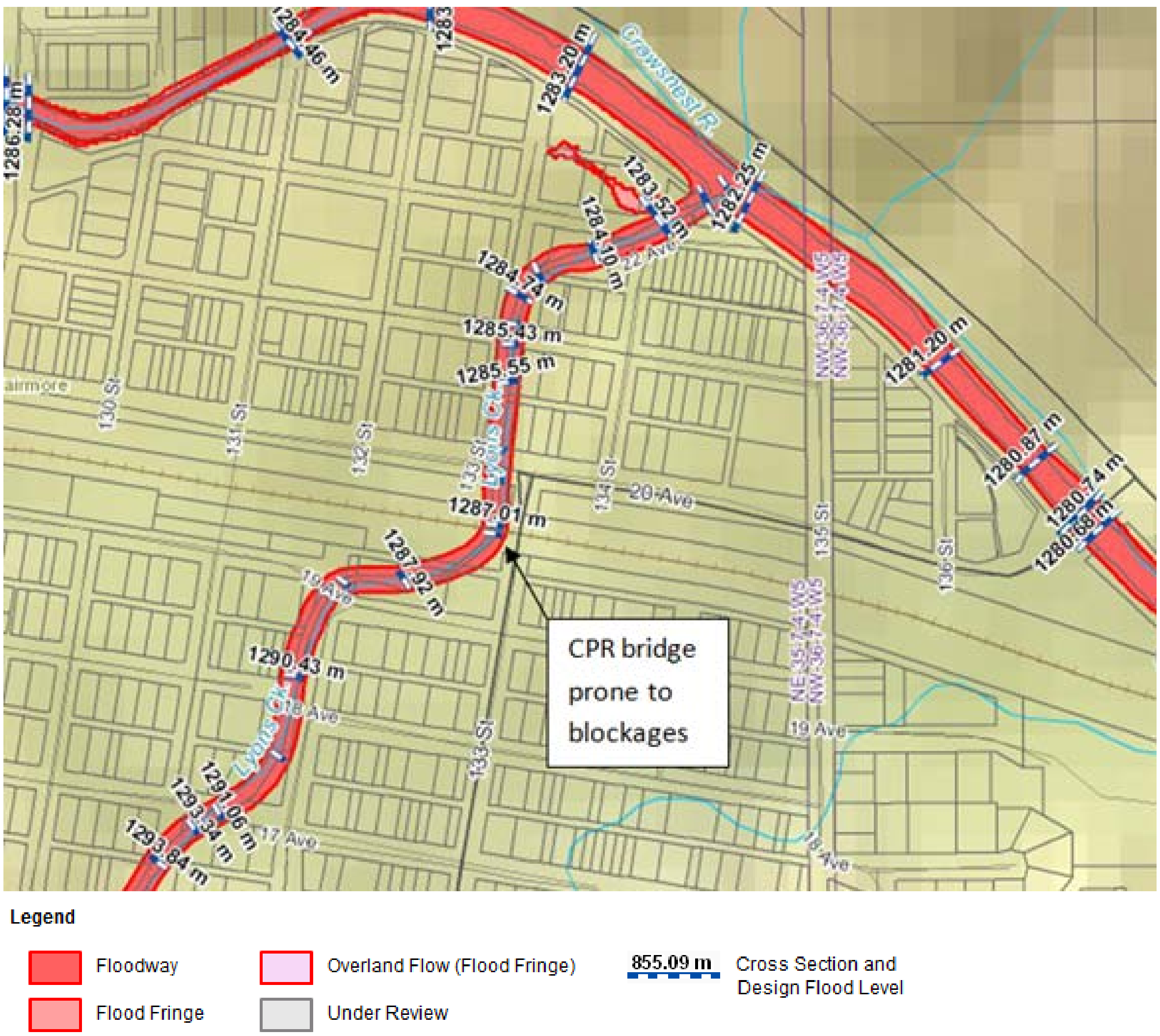


Figure 4.10: CPR Crossing at Lyons Creek that blocked in June 2013

4.6.1.3 Multi-criteria Decision Making and Option Assessment

At Crowsnest Pass, the best structural measure was considered to be improvements to conveyance to crossings including the CPR bridge over Lyons Creek. The preferred non-structural measure was to undertake flood proofing to houses that are at risk of damage from overland flow routes. Because the primary problem identified by the MD and the MCDM analysis was to do with conveyance problems at major structures, no conceptual design of mitigation measures was possible within the time frame of this project.

4.6.1.4 Recommendations

A more detailed analysis of structure capacities is required before specific recommendations can be made for conveyance improvements. It is known that the CPR bridge at Lyons Creek is problematic and investigations should be made into how the conveyance through this area can be improved.

4.6.2 Pincher Creek

4.6.2.1 Stakeholder Engagement Response

The MD of Pincher Creek has been impacted by floods in 1995, 2005, 2010, and 2013. The MD estimates the total damage for the 2013 flood was $1 million to $10 million. Pincher Creek overflowed its banks mainly as a result of obstacle and debris build up at a few key locations. There was also some river bank erosion. Indianfarm Creek, located immediately east of the town, also overflowed its banks at the Therriault Dam site.

There are some flood mitigation works along Pincher Creek, including permanent earth and aggregate berms at key locations. The town has implemented zoning policies that limit development in the flood plain, which reduced potential damage from the flood. The town has an emergency response plan that was put into effect during the flood.

The MD recommended that earlier notification would have been helpful to more effectively alert residents and businesses about the impending flood. They suggested that some form of headwaters protection should be investigated to reduce future flood impacts.

4.6.2.2 Known Flood Pathways

The flooding characteristics within the Town of Pincher Creek have been assessed by Philips (1993). Pincher Creek has its headwaters in the eastern slopes and foothills of the Rocky Mountains. Floods typically occur in the open water season, either from a combination of spring rainfall and snowmelt runoff or as a result of major summer rainstorms. High flows are most likely to occur in May or June. Flood flows are confined to the creek channel in the upstream reach at the west end of town. Downstream from the centre of town to Highway 6 some overbank flooding is possible. Downstream of Highway 6 to beyond the confluence of Kettles Creek, widespread overbank flooding can occur. This is especially true of Highway 785, where the road crossing appears to severely restrict flow, resulting in local ponding upstream of the crossing. Within Kettles Creek itself, isolated overbank flooding can occur in some areas, while the crossing of MacLeod Street (Highway 785) crossing appears to severely restrict flow, resulting in local ponding upstream of the crossing.

4.6.2.3 Multi-criteria Decision Making and Option Assessment

The MCDM appraisal showed that dykes and erosion protection were closely ranked asthe preferred structural mitigation measure. Both were selected as the preferred method because there are already dykes in place in much of Pincher Creek and there are signs of erosion particularly at the Kettle Creek confluence.

The preferred non structural mitigation measure was to restrict land development in the floodway and flood fringe areas.

4.6.2.4 Conceptual Design

A site visit was undertaken on 26 February 2014 to find areas where there may be opportunities to improve the existing flood dykes or to provide erosion protection.

The site visit noted the following:

- From Highway 507 to upstream of Kettle Creek confluence, the buildings appear to be located on higher ground above the flood plain areas. No areas of concern were noted.
- On Kettle Creek there was some minor scouring of the watercourse but no significant impacts to any land or buildings. The Kettle Creek/Pincher Creek confluence point has some erosion which left unchecked may have an impact on land and buildings on the left (north) bank. This erosion is caused by flows from Kettle Creek. A small amount of rip rap armouring on the left bank would probably be sufficient at this location.
- A park area located just upstream of the Highway 6 bridge has a pathway/dyke. There are two low spots in the levee which facilitate drainage across the structure. These could be infilled with the drainage maintained using a gated culvert. At the south end of the pathway, the dyke should be increased.

4.6.2.5 Recommendations

Conceptual design sketches are provided in **Appendix I**. However, it is recommended that a thorough condition survey be undertaken for the existing defences. This was not possible during this contract due to time constraints and winter weather.

Recommendation 4.14: It is recommended that development be restricted in the floodway and flood fringe areas in Pincher Creek subject to a site specific flood risk assessment demonstrating that the development lies outside the 1% AEP flood area.

Recommendation 4.15: A thorough condition survey should also be undertaken for the existing flood defences in Pincher Creek. The survey should include an assessment of the standard of protection offered by the existing defences and raised where appropriate. The left bank of Pincher Creek should be armoured at the confluence with Kettle Creek.

4.6.3 Fort MacLeod

4.6.3.1 Stakeholder Engagement Response

The information was provided by Alberta Transportation and comments from a Fort MacLeod representative during an interview with the Oldman Watershed Council.

The town and immediate area along the Oldman River were affected by floods in 1995 and 2013. The Highway 2 bridge crossing the Oldman River was shut down during the 2013 flood because of erosion around the pilings at the north end. Two other crossings on the Oldman River were also affected. Infrastructure in Fort MacLeod (river valley) has been damaged several times from high water. The town expressed concern that some flood damages were caused by excess water being released from the Oldman River Dam.

There is not a large amount of infrastructure within the flood fringe in Fort MacLeod. There are a few buildings and the Daisy May Campground in the area between Lyndon Road and the river which are within the flood fringe area.

4.6.3.2 Known Flood Pathways

The Oldman River has its headwaters in the Livingstone Range of the Rocky Mountains. Flows have been regulated by the Lethbridge North Irrigation District system since 1923 and by the Oldman River Dam since 1991. The selected design discharge reflects regulation by the Lethbridge North Irrigation District system but not the Oldman River Dam. Flooding in the study area can be caused by severe summer rainstorms, heavy spring snowmelt runoff or ice jam activity during breakup. Open water flooding is the design case for the floodplain mapping conducted by AENV (1991).

The floodplain mapping conducted by AENV (1991), indicates that overbank flooding can occur along the entire length of the reach examined, from upstream of Highway 2 to downstream of the confluence of Willow Creek. Generally the floodplain is approximately 1 km wide upstream of Fort Macleod and close to 1.5 to 2.0 km wide downstream of the town.

4.6.3.3 Multi-Criteria Decision Making and Option Assessment

At Fort MacLeod the MCDM appraisal showed that erosion protection was the best structural mitigation measure. Erosion on the left riverbank at Highway 811 is impacting the bridge abutment. The preferred non-structural option was managed retreat; however, this is limited to the area between Lyndon Road and the river where the Daisy May Campground is situated.

This area lies within the flood fringe and, should the opportunity arise to change the use of this land to park or other water compatible use, retreat from this area should be considered.

4.6.3.4 Conceptual Design

Conceptual design sketches for the armouring of the left bank at Highway 811 are provided in **Appendix J**. The river training works at this location are essential to prevent the river from outflanking the left bridge abutment. The periodic inspection and maintenance of these is important.

4.6.3.5 Recommendations

It is recommended that the left bank abutment at Highway 811 Oldman River Bridge be armoured as per the drawings in **Appendix J**.

Recommendation 4.16: It is recommended that the left bank bridge abutment at Highway 811 Oldman River bridge be armoured.

4.6.4 Cardston

4.6.4.1 Stakeholder Engagement Response

No information is available, as there was no response to the stakeholder engagement.

4.6.4.2 Known Flood Pathways

Lee Creek originates in the Rocky Mountains of Montana but the majority of the watershed is located in the Foothills and western prairie zones of southwest Alberta. Floods in the study area are usually caused by a combination of heavy rainfall events and mountain snowmelt runoff. Although peak flows can occur throughout the year, the highest flows which cause flooding typical occur in the open water season between mid-May and the end of June.

Channel widening and modification works undertaken in 1983 have increased the conveyance capacity of Lee Creek from that of the natural channel. Floodplain mapping undertaken by Stanley Associates (1992) indicates that ponding can occur upstream of 9th Avenue (Highway 501), upstream of Highway 2 bridge, and upstream of the Highway 5 (First Avenue) bridge. The extent of flooding indicated in the Stanley (1992) mapping might not be indicative of present conditions, including filling of areas adjacent to the creek for commercial and industrial development has occurred over the past two decades.

4.6.4.3 Multi-criteria Decision Making and Option Assessment

At Cardston the MCDM appraisal showed that conveyance improvement was the best structural mitigation measure. It is known that the channel was widened and improved in 1983 and some consideration should be given to whether this channel needs to be dredged to remove silt. The Cardston flood mapping study was undertaken in 1992. The best way to determine if the channel requires attention is to update the flood mapping study with new hydraulic modeling of the watercourse and floodplain development as they exist today.

The best non-structural mitigation measure was to restrict development within the mapped flood fringe. There are parcels of undeveloped land within the Lee Creek flood fringe, and development should be restricted on these to prevent adding properties to the flood hazard area.

4.6.4.4 Conceptual Design

Whilst on the site visit to Cardston, erosion was noticed on the right bank of Lee Creek just downstream of Highway 501. The erosion will soon compromise an access road. Sketches for recommended remediation measures are provided in **Appendix K**.

4.6.4.5 Recommendations

It has not been possible to undertake updated survey and hydraulic modeling within the time frame of this project. It is recommended that the flood study for Cardston be updated with new modeling and mapping to reflect the current development in the town.

Recommendation 4.17: The hydraulic model and flood mapping for Cardston should be updated to determine if dredging of the channel is necessary to improve conveyance.

4.6.5 Lethbridge

4.6.5.1 Stakeholder Engagement Response

The City was affected by flooding in 1995, 2005, and 2013. The estimated damage for the 2013 flood event was less than $1 million. The cost estimate for the 1995 flood was much higher and estimated at between $1 million and $10 million. The Paradise Golf Course, campground, recreation areas and parklands were impacted by the 2013 flood. Some basements were flooded because of overland flow – not caused by the Oldman River. The bridges crossing the Oldman River were closed as a precaution during the 2013 flood, but were never in danger. This is in contrast to the 1995 flood, which saw very high water levels, and damage sustained to the Highway 3 bridge.

The City of Lethbridge has limited development on the Oldman River floodplain since 1955. As a result, damages sustained from flooding are limited. The water treatment plant and wastewater treatment plants are located in the river valley, but are protected and damage has been limited. The City did receive advance warning of the flood waters, and initiated a warning system for residents and restricted access to the flooded areas.

The City of Lethbridge recognizes the need to improve the warning system for residents. Debriefing after the flood event identified other improvements that the City will assess. They will consider increasing the standard of protection provided by existing berms at the water treatment plant, and harden electrical systems so that operations can be restored quicker. More improvements to the surface drainage system need to take place in key parts of the City.

4.6.5.2 Known Flood Pathways

The Oldman River has its headwaters in the Livingstone Range of the Rocky Mountains. Flows have been regulated by the Oldman River Dam since 1991 and by the St. Mary Dam since 1951. Flooding in the study area typically occurs during the open water season as a result of heavy rainfall events. High flows are most likely to occur in May and June.

Floodplain mapping along the Oldman River at Lethbridge was undertaken by AMEC (2007a). The mapping extended over 29 km of the river from approximately 5 km upstream of the mouth of the St. Mary River to approximately 6 km downstream of the Highway 3 Bridge. The 1% AEP flood used in the study is 3,320 m^3/s above the St. Mary River confluence and 3,788 m^3/s below the confluence. For the design flow event, inundation generally covers the entire valley floor. Under those conditions affected facilities include golf courses, the City's water treatment plant and sand and gravel mining operations.

4.6.5.3 Recommendations

No specific recommendations are made at this time for the City of Lethbridge.

4.6.6 Piikani First Nation

4.6.6.1 Stakeholder Engagement Response

The estimated cost of damages associated with the 2013 flood event is $4 million. In 1995, there was flooding along the entire length of the Oldman River through the Piikani Reserve. During the 2013 flood, the water level in the Oldman River was about 2/3 the level of the 1995 flood. During the 1995 flood, the north abutment of the Summerview Bridge was lost. During the 2013 flood, the entire bridge was lost.

The Reserve has implemented zoning policies to limit development in the river valley, which has helped limit flood damages. They work closely with the MD of Pincher Creek to assist residents. After the 1995 flood, the Reserve moved their water control building to higher ground.
An emergency warning system is in place, which allowed for successful evacuation where needed.

4.6.6.2 Recommendations

The Reserve recommends installation of rock armour in the Oldman River to protect their water wells, and other river erosion controls to protect the water supply and treatment facilities.
The Reserve recognizes the need to install storm drainage in the town of Brocket.

Due to the timing of the Piikani engagement meeting and the completion of this study, AMEC cannot make specific recommendations for erosion protection for the Oldman River through the Piikani Reserve. It is therefore recommended that further investigations are undertaken with regards to erosion control through the Piikani Reserve and also with regards to the provision of storm water drainage in Brocket.

Recommendation 4.18: It is recommended that further investigations are undertaken with regards to erosion control through the Piikani Reserve and also with regards to the provision of storm water drainage in Brocket.

4.6.7 Kainai First Nation

4.6.7.1 Stakeholder Engagement Response

The Kainai First Nation has been impacted by floods in 1964, 1974, 1985, 1995, 2002, and 2013. They estimate the total cost of the flooding to be $500 million to $1 billion, but acknowledge that detailed calculations have not been carried out. The 2013 flood was less severe than other flood events. The 2002 flood was considered the most severe, and impacted water supply infrastructure and many businesses and residents in Standoff. The 2013 flood did result in some roads being washed out and flooding of basements. Overtopping of the Belly River occurred at several locations along the western boundary of the Reserve. There was evidence of sediment and debris in the water, and some river bank erosion. The river bank erosion threatened homes, roads and water treatment facilities at Standoff.

There are minimal flood mitigation infrastructure on the Reserve. The band does have a policy of not allowing new construction in the valley of the Belly River, but does not have a policy that requires existing residents to move out of the valley. The band has an emergency response plan in place, but recognizes that it needs to be more comprehensive. They monitor snow pack information from ESRD to assess flooding potential. Potentially affected residents are warned of an impending flood through phone calls and local radio announcements.

4.6.7.2 Recommendations

The band provided the following recommendations:

- Erosion on the Belly River through the Reserve should be assessed, and additional erosion control measures be installed where necessary.
- Washed out roads should be re-built with better quality materials. Bridges should also be raised and armour added at the bridge abutments.
- Improved access to homes in low-lying areas is required, as is better flood proofing (berms) of those homes.
- Responsibility for road maintenance should be better clarified between the band and the province.
- Improved coordination is required with ESRD and the irrigation districts regarding the release of water from the upstream reservoirs.

- A better warning system is required in case the Waterton Dam were to fail. There is only a 4-hour water flow lag-time between the Waterton Dam and Standoff.

5.0 ECONOMIC APPRAISAL

5.1 Introduction

An economic appraisal enables the comparison of widely differing options in order to identify those which provide overall best value for money. It also provides a basis on which long-term management decisions can be made such as balancing capital costs with maintenance. Good decision making relies on the provision of high quality economic information derived from the application of thorough economic appraisal techniques.

Benefit cost analysis will normally be a significant factor in determining which flood defence schemes should go ahead.

In reality, there are some situations where a positive or negative economic appraisal is not the main determining factor as to whether a scheme should go ahead. There may be overwhelming social, environmental or legal obligations to fulfil. In these cases, it still makes sense to undertake an economic appraisal to underpin the decision and to help government decide whether a change in policy or regulation is required.

5.2 Calculating the Benefit Cost Ratio

This section is not intended to be a detailed description of the benefit cost calculation for flood mitigation scheme appraisal. It is a general description of the process and data necessary to achieve meaningful results.

A flood defence project appraisal needs to consider the benefit cost ratio of a proposed scheme. The benefit cost ratio is determined by the ratio of:

$$NPV_{DA} / NPV_{cost}$$

Where:

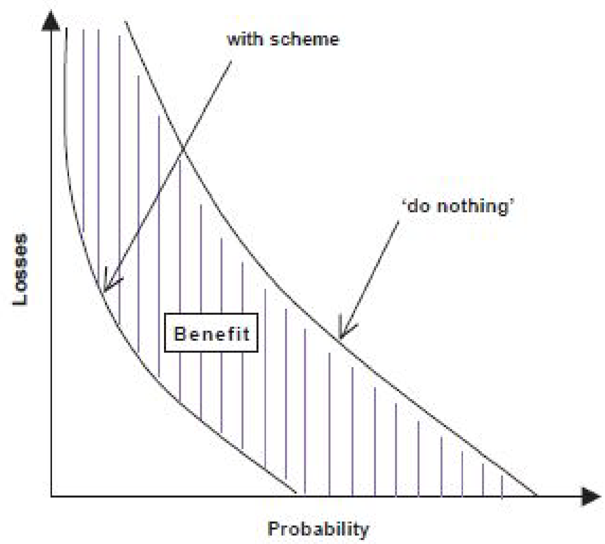
- **NPV_{DA}** is the net present value of flood damage avoided as a result of implementing a flood mitigation scheme. It is generally the cost difference between the damage that would be experienced if a scheme were, or were not, in place.
- **NPV_{cost}** is the net present value of the capital cost of construction and the annual or programmed maintenance to keep the structure or scheme operational.

Both are measured over the design life of a scheme and discounted at an agreed rate over that period. Debate can be had over the appropriate discounting factor and often it varies depending on the type of investment and the length of discounting period. For the SAFRTF work, the value of 4% has been recommended as an agreed discount rate for flood defence schemes[5].

To calculate the NPV_{DA}, the following is required:

- An estimate of annual average flood damage (AAD);
- An estimate of damage avoided as a result of a proposed scheme; and
- An estimate of costs for the design life of the project (capital + maintenance).

Figure 5.1 shows how the benefit of a scheme is calculated as the area between the loss/probability curve for the “do nothing” and “with scheme” scenarios.



Source: Flood and Coastal Defence
Project Appraisal Guidance: Economic Appraisal MAFF, December 1999

Figure 5.1: Calculating the Benefit of a Flood Mitigation Scheme

5.3 Estimating the Damages

Determining the annual average damages requires an estimate of damage for each flood probability. There are three ways to estimate damages for a given flood event:

1. Field survey to estimate potential flood damages. An estimate of damage for each flood probability must be made by taking a comprehensive inventory of assets and threshold levels.
2. Application of stage-damage curves per structure (or asset) to assess potential damage. Previous studies have estimated flood depth versus damages in different types of buildings from residential to commercial and industrial. This is a more generalised approach and can

[5] Agreed with the SAFRTF at a consultant meeting at IBI Group offices in Calgary on 6 March 2014.

be supported by GIS analysis of flood depth compared to LiDAR ground levels. This approach is more general than approach 1 but is sufficiently accurate to estimate damages for flood mitigation scheme feasibility studies.

3. Application of stage-damage curves by zones or area to assess potential damage. This method is similar to method 2 but a more zoned approach is taken. It can be an expedient means to estimate damages where there are a large number of similar properties. However, it is unsuitable where there are a variety of building types and uses.

It has not been possible during the limited timeframe of this project to undertake damage assessments for all areas where schemes are proposed. However, an estimate of damages in the Elbow River was undertaken in 1986 by W-E-R (WER, 1986). A comprehensive inventory of properties was taken during the study.

5.3.1 Estimated Flood Damages in the Elbow River Basin

Total flood damages for each return period of flooding were estimated for the study area. The damages included direct damage to residential, commercial, industrial, institutional facilities and highways as well as indirect damages. **Table 5.1** shows the total damages estimated for various probabilities of flooding. The damages were translated to 2014 values using the online Bank of Canada inflation calculator[6]. An annual rate of inflation of 2.34% was used.

Table 5.1
Calculated Value of Damages

AEP or Return Period	Damages in $ million (1986)	Damages in $ million (2014)
5.8% or 1 in 17 years	13.8	26.4
5% or 1 in 20 years	25.6	48.9
2% or 1 in 50 years	58.0	110.9
1% or 1 in 100 years	74.7	142.8

Figure 5.2 below shows the flood damages against probability for the Elbow River at Calgary using adjusted 1986 values.

[6] http://www.bankofcanada.ca/rates/related/inflation-calculator/

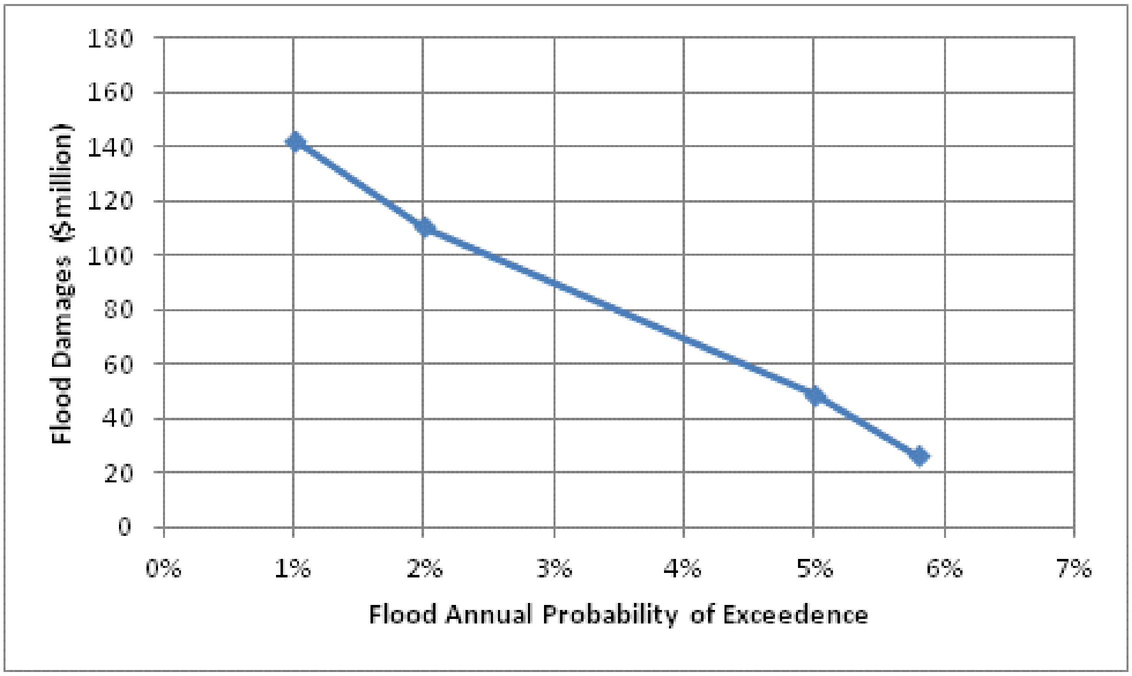


Figure 5.2: Flood Damage Probability Curve for the Elbow River (Calgary)

This information (adjusted for inflation) was used as a basis for an estimate of present day AAD. The 1986 report estimated AAD at $2.925 million which translates to $5.591 million in 2014. An additional 20% is added to this figure as an allowance for development downstream of Glenmore Reservoir since 1986. The AAD is therefore estimated to be $6.710 million

Assuming a design life of 100 years for a major dam, and a 4% discount rate (the 1986 study used 6%), the present value of damage avoided would be in the region of $171 million.

5.3.2 Estimated Flood Damages at Other Sites

It is not possible within the deadlines of this project to make an estimate of flood damage avoided at sites other than the Elbow River in Calgary. Other information may be available regarding flood damages at other locations; however, this data has not been researched to date.

It is recommended that a major study be undertaken to estimate flood damages using a common methodology selected from **Section 5.2**. This project could be undertaken on a province wide basis and the results used prior to investing in infrastructure projects recommended in this report.

Recommendation 4.19: It is recommended that a major study be undertaken to estimate flood damages using a methodology or approach similar to the 1986 Elbow River Floodplain Management Study Report.

5.4 Estimating the Present Value Costs of a Scheme

In estimating NPV_{cost} of a scheme, a sufficient level of preliminary engineering is required to adequately estimate capital costs and maintenance. The cost of construction of a dam at MC1 and SR1 has provisionally been estimated at $239.6 million and $159.7 million, respectively. These figures include a 25% contingency allowance and 20% for regulatory processes and engineering. These are construction costs only and therefore, the SR1 estimate does not include costs associated with land acquisition.

Detailed cost estimates are provided with the drawings in **Appendix F** (MC1) and **Appendix G** (SR1).

There are considerable uncertainties at both sites with respect to the design given that the design standard has been assumed as 1% AEP and the multi-use storage is to be determined. Over a 100-year design life, consideration must be given to maintenance, and both regular and planned rehabilitation. Major investment in rehabilitation can be expected during the life of the dam. An allowance of 20% of capital cost is made in Year 50 to allow for long-term rehabilitation. An annual allowance of 1% is made for annual maintenance.

With capital and maintenance cost included, the PV_{cost} estimated for MC1 and SR1 are $290.7 million and $193.8 million, respectively. The PV_{cost} calculation does not include for land acquisition at SR1.

5.5 Benefit Cost Ratio

The benefit cost ratio is determined by NPV_{DA} / NPV_{cost}. For a scheme to be favourable on economic grounds, this ratio should ideally be greater than 1.0. Given the information provided above, the estimated benefit/construction cost ratio is therefore 0.6 and 0.9 for MC1 and SR1, respectively. These figures demonstrate that even once land acquisition is taken into consideration, there is likely to be an economic preference for SR1.

It is recommended that a robust economic appraisal be undertaken prior to the investment in a flood control dam on the Elbow River. Based on the assumptions and limited data available for this report, it is likely that an economic case can be made to invest upwards of $200 million on flood defence infrastructure in the Elbow River basin.

Recommendation 4.20: It is recommended that a robust economic appraisal be undertaken prior to the investment in major flood control infrastructure in the Bow River, Elbow River or Oldman River basins.

6.0 CLOSURE

This report has been prepared for the exclusive use of the SAFRTF. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

Geoff Graham, B.Sc. (Hons) MCIWEM C.WEM
Associate Water Resources Specialist

Reviewed by:

John R. Slater, P.Eng.
Vice President
Water Resources and Civil Projects Division

Contributing Authors
Gary Beckstead, M.Sc., P.Eng.
Brent Paterson, P.Ag.
Ken Kress, P.Eng.
Matthew Graham, M.Sc., MCIWEM, CEnv

Permit to Practice No. P-4546

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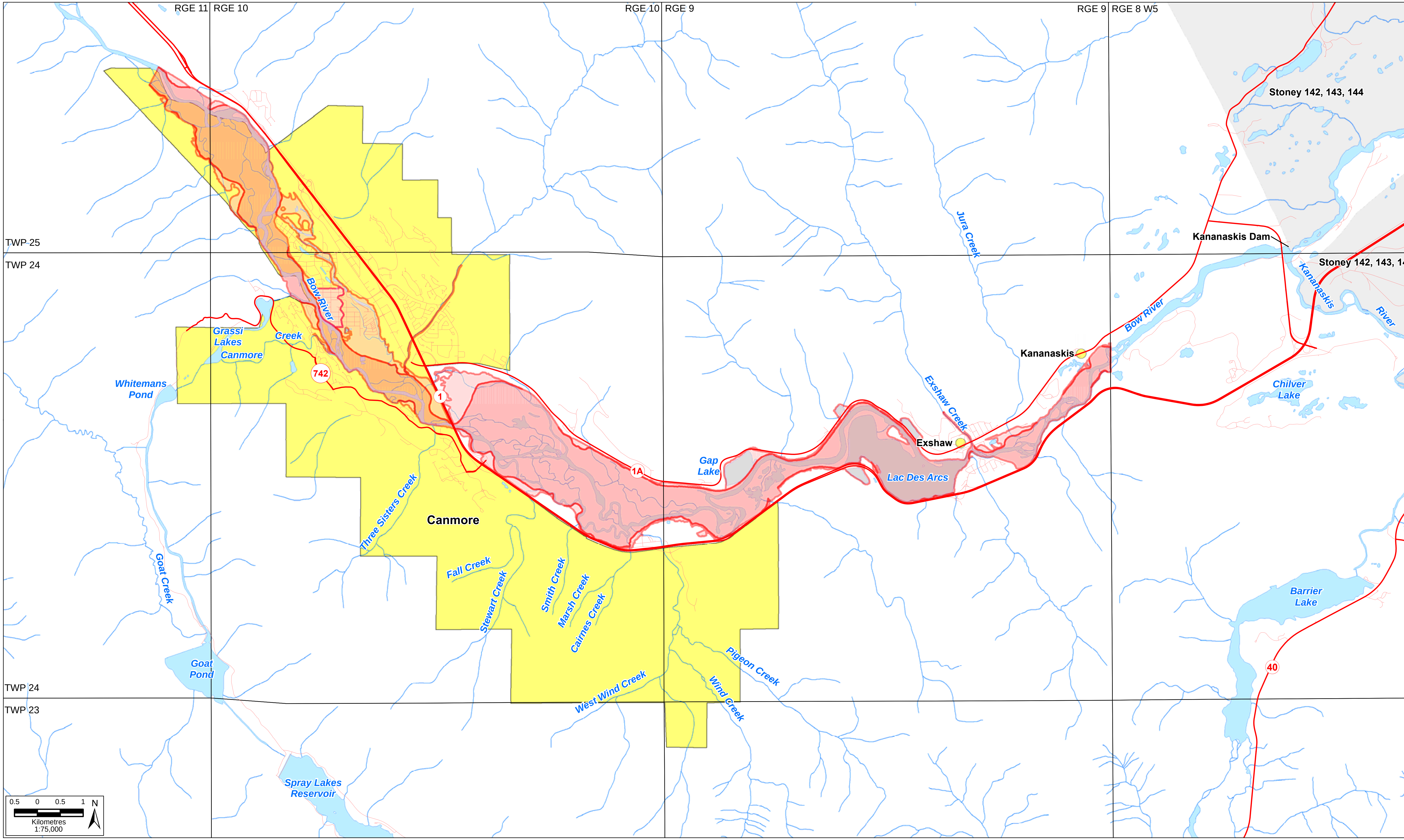
Appendix A

Flood Maps Based on ESRD Flood Hazard Mapping



Legend

- Township and Range
- Urban Area
- Native Reserve
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Canmore, Exshaw, and Kananaskis

DATE: May 2014	
ANALYST: NH	QA/QC: TR KK GG
PDF: FigA1 Canmore Exshaw Kananaskis 14-05-22	

Figure A1

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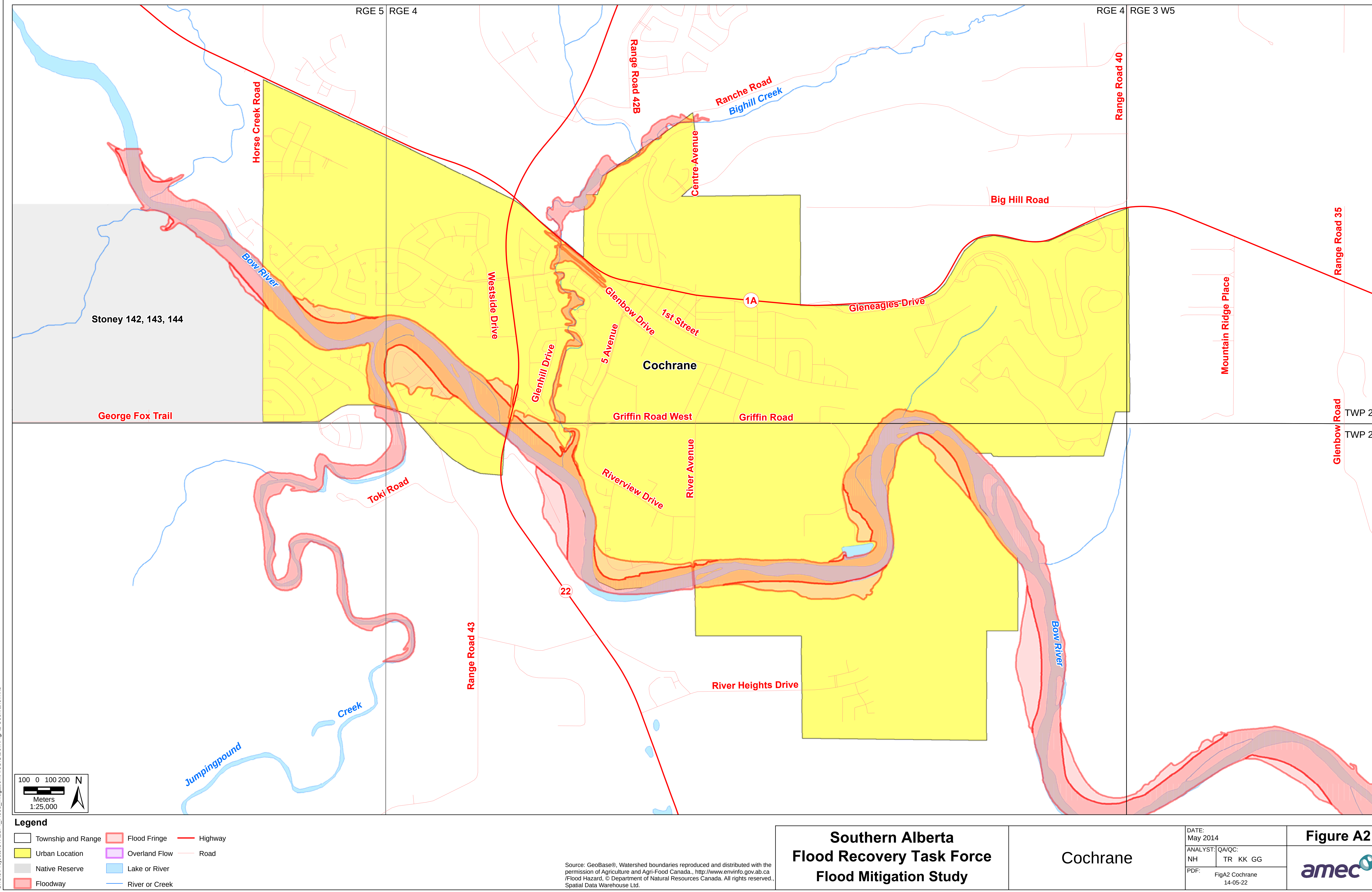

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study	Cochrane	DATE: May 2014	Figure A2
		ANALYST: NH QA/QC: TR KK GG	amec
		PDF: FigA2 Cochrane 14-05-22	

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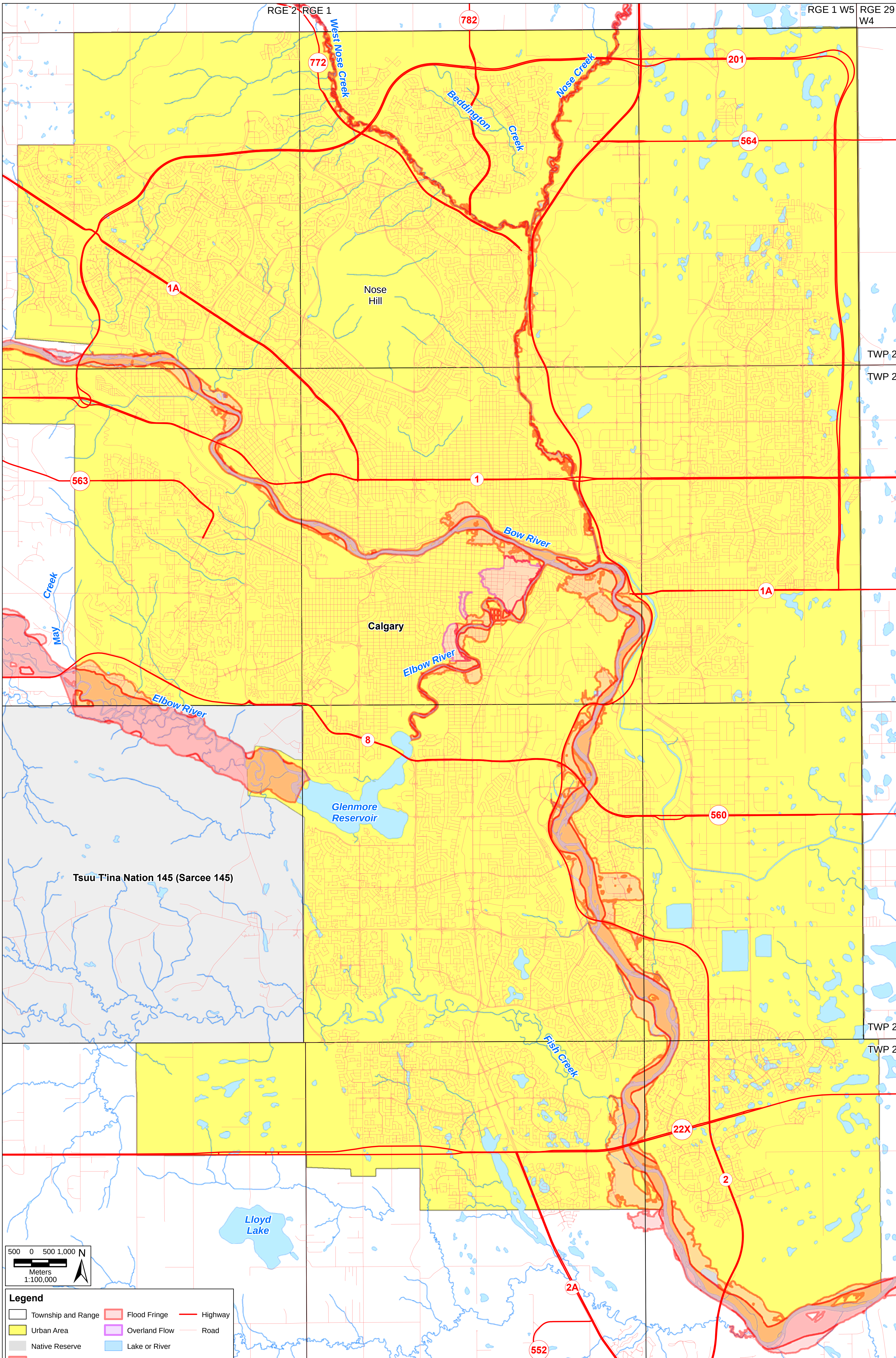

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Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

Calgary

DATE: March 2014	
ANALYST: NH	QA/QC: TR KK GG
PDF: Figx Calgary 14-03-03	

Figure A3

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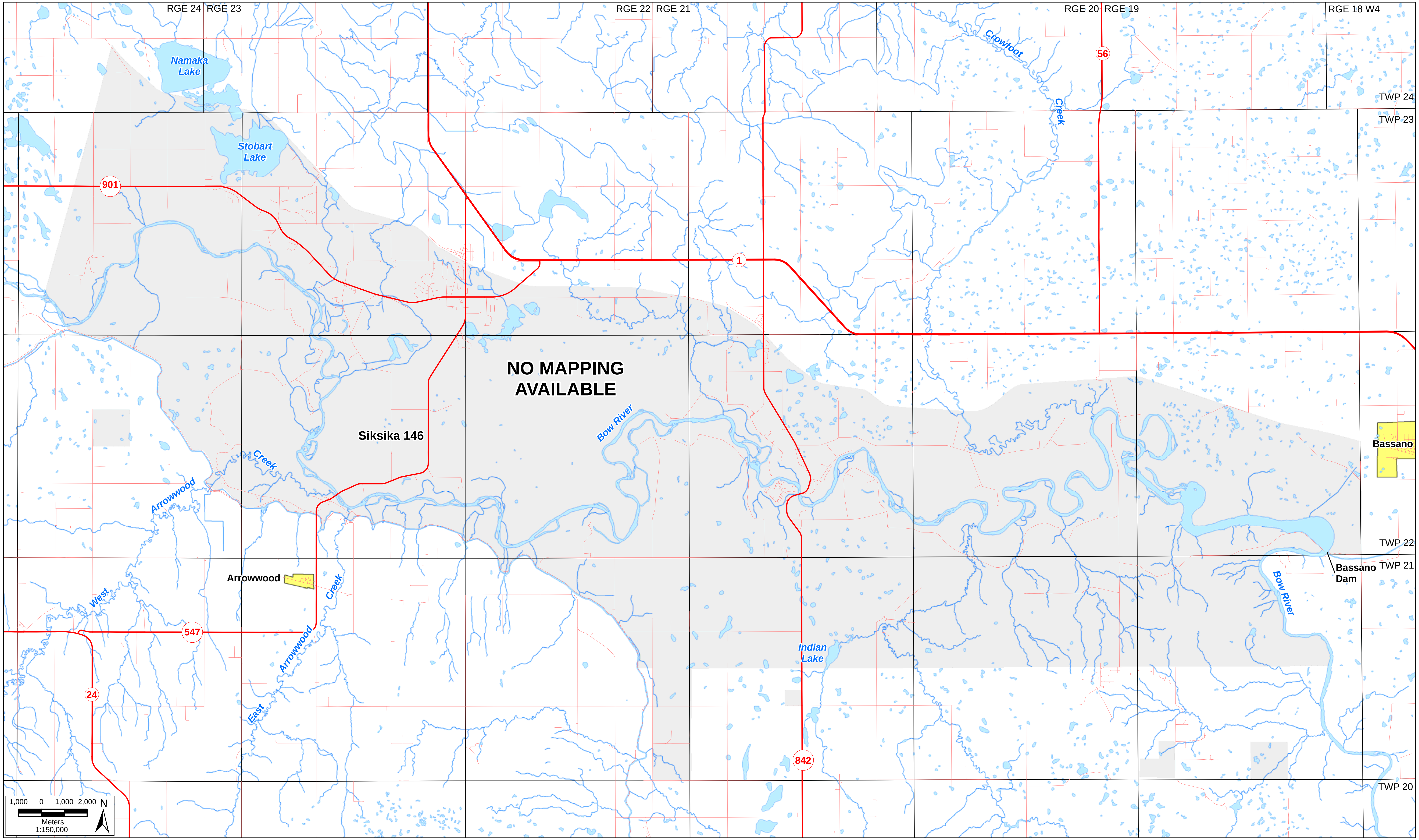

Legend

Township and Range	Flood Fringe
Highway	Urban Place
Overland Flow	Road
Native Reserve	Lake or River
Floodway	River or Creek

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Siksika Nation

DATE: May 2014

ANALYST: NH

QA/QC: TR KK GG

PDF: FigA4 Siksika Nation 14-05-22

Figure A4

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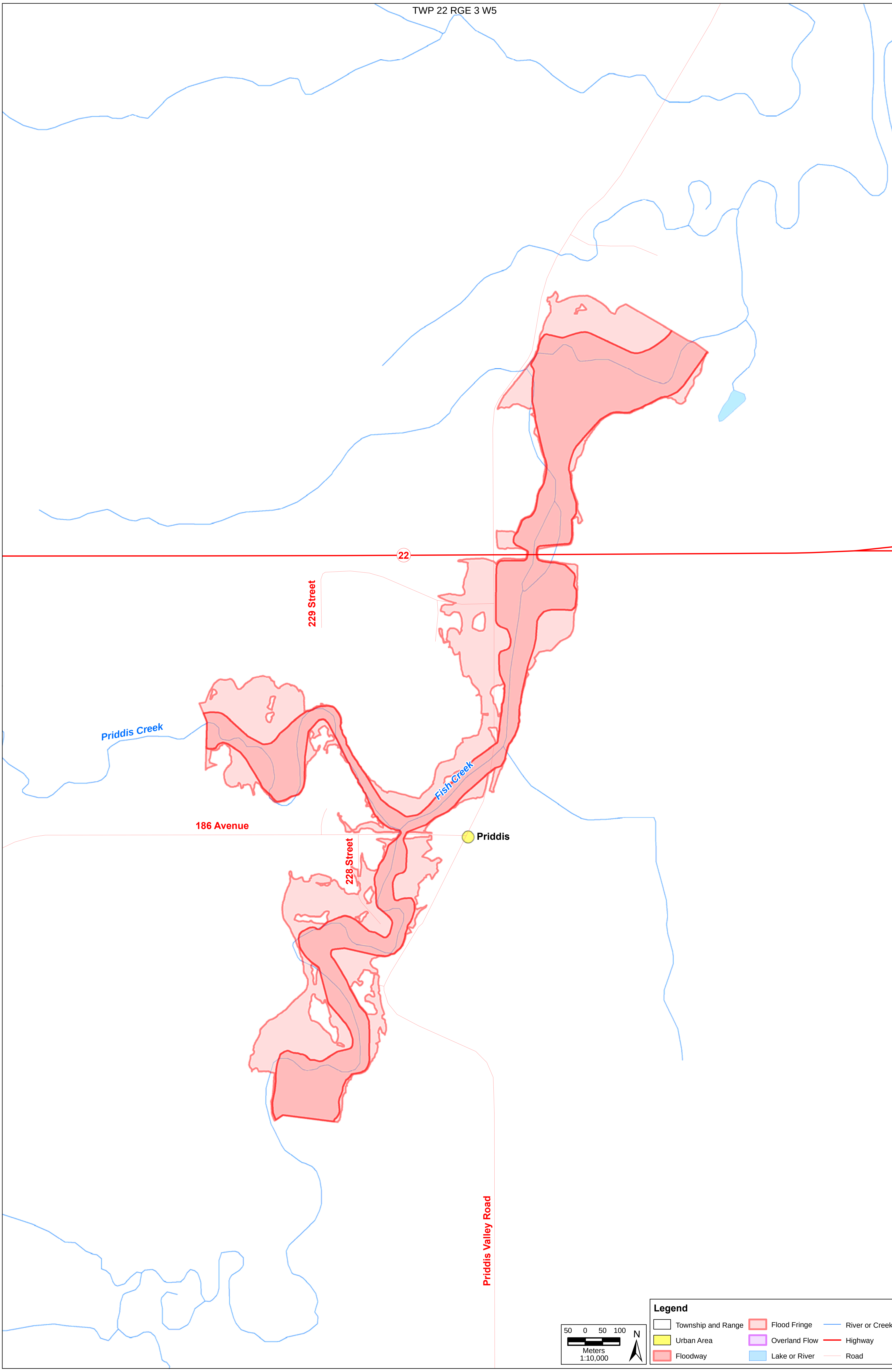

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Priddis

DATE: May 2014	
ANALYST: NH	QA/QC: TR KK GG
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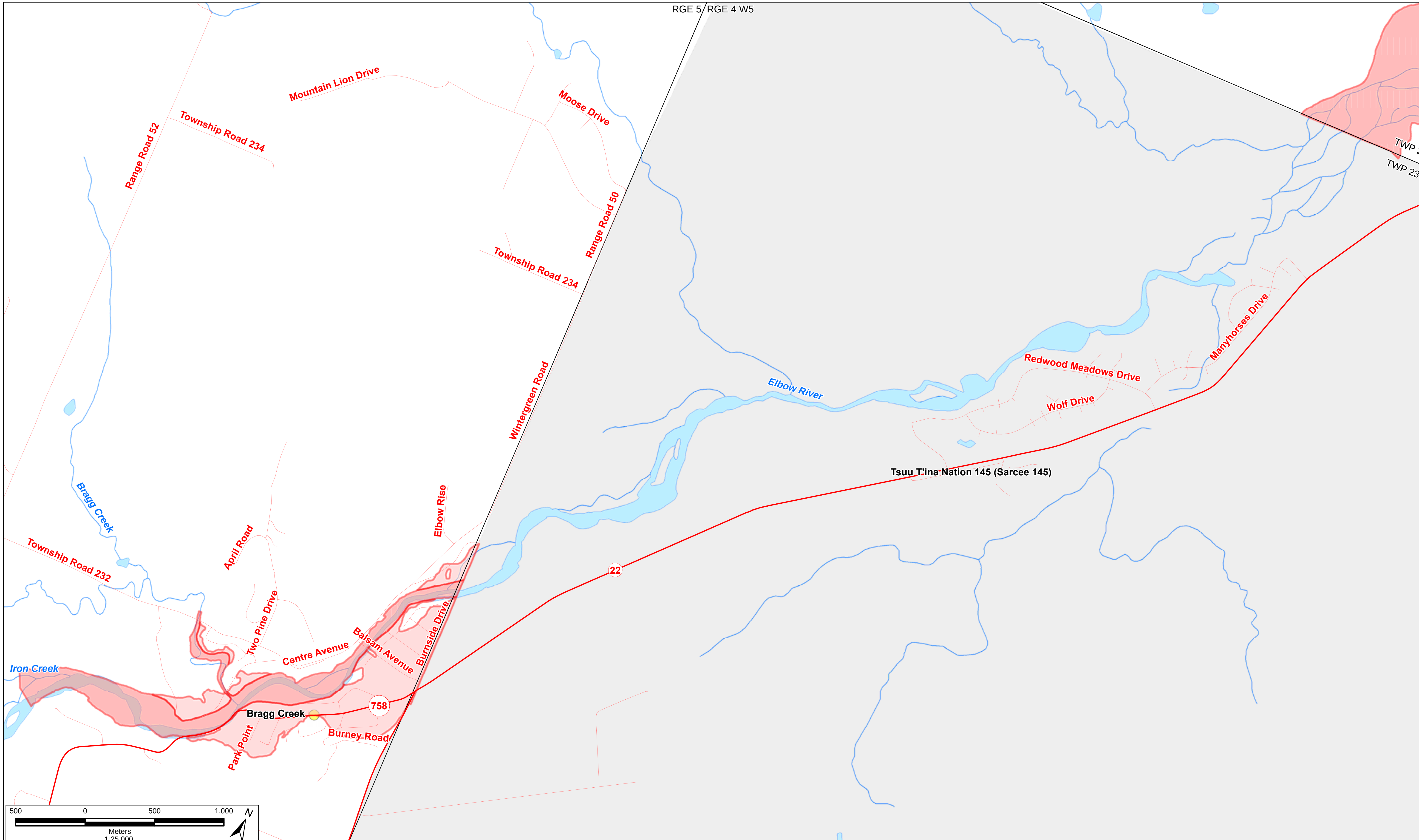

Legend

Township and Range	Flood Fringe
Urban Place	Overland Flow
Native Reserve	Lake or River
Floodway	River or Creek
Highway	Road

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Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

Bragg Creek and Redwood Meadows (Tsuu T'ina)

DATE: May 2014
ANALYST: NH
QA/QC: TR KK GG
PDF: FigA6 Bragg Creek Redwood Meadows 14-05-22

Figure A6

amec

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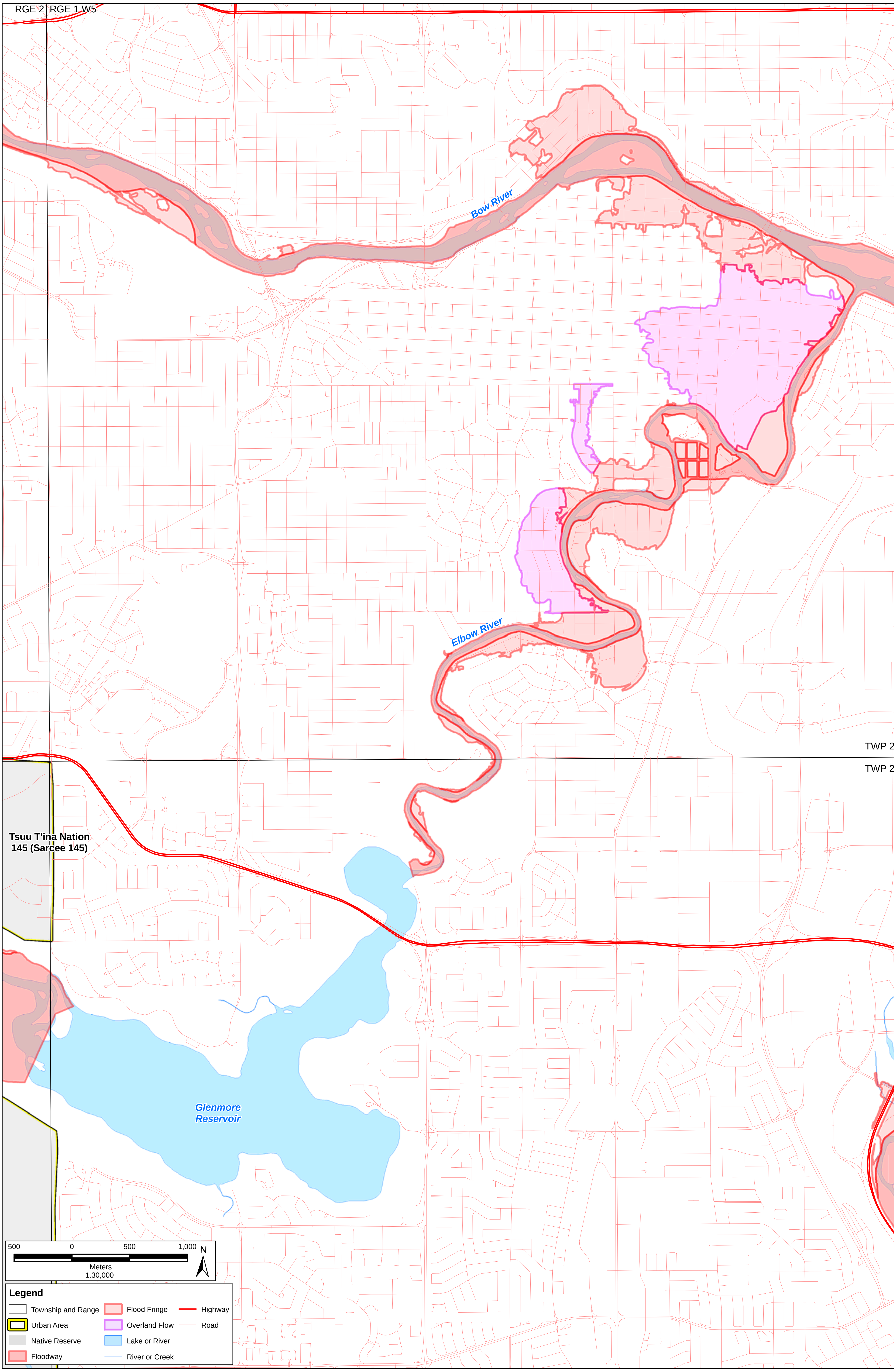


S:\Gis\Projects\CW\2174_Flood_Mitigation\ArcGIS\Elbow\FigA7 Glenmore Downstream.mxd

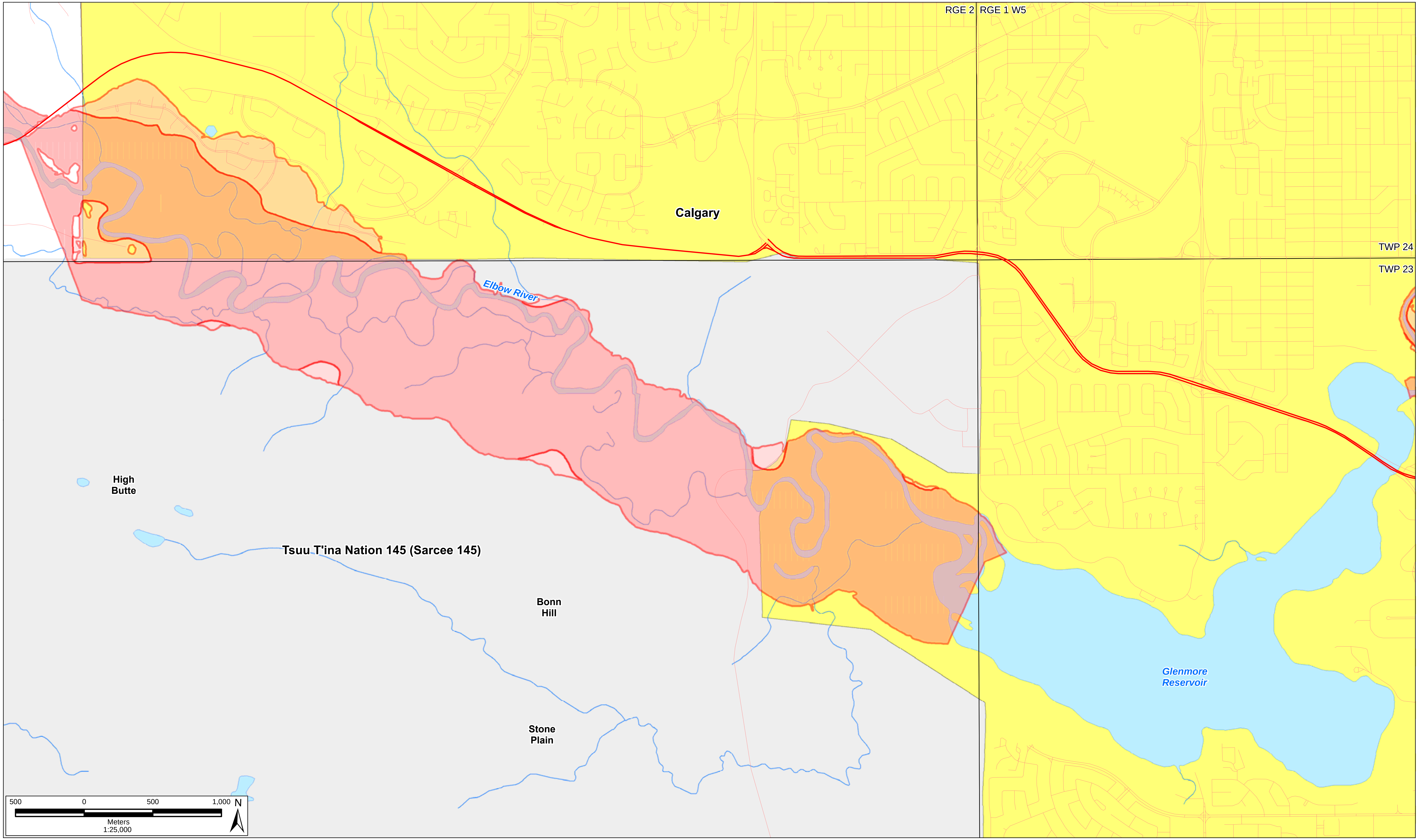
Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

Downstream of Glenmore Dam

DATE: May 2014
ANALYST: NH
QA/QC: TR KK GG
PDF: FigA7 Glenmore Downstream 14-05-22

Figure A7

amec



Legend

- Township and Range
- Urban Place
- Native Reserve
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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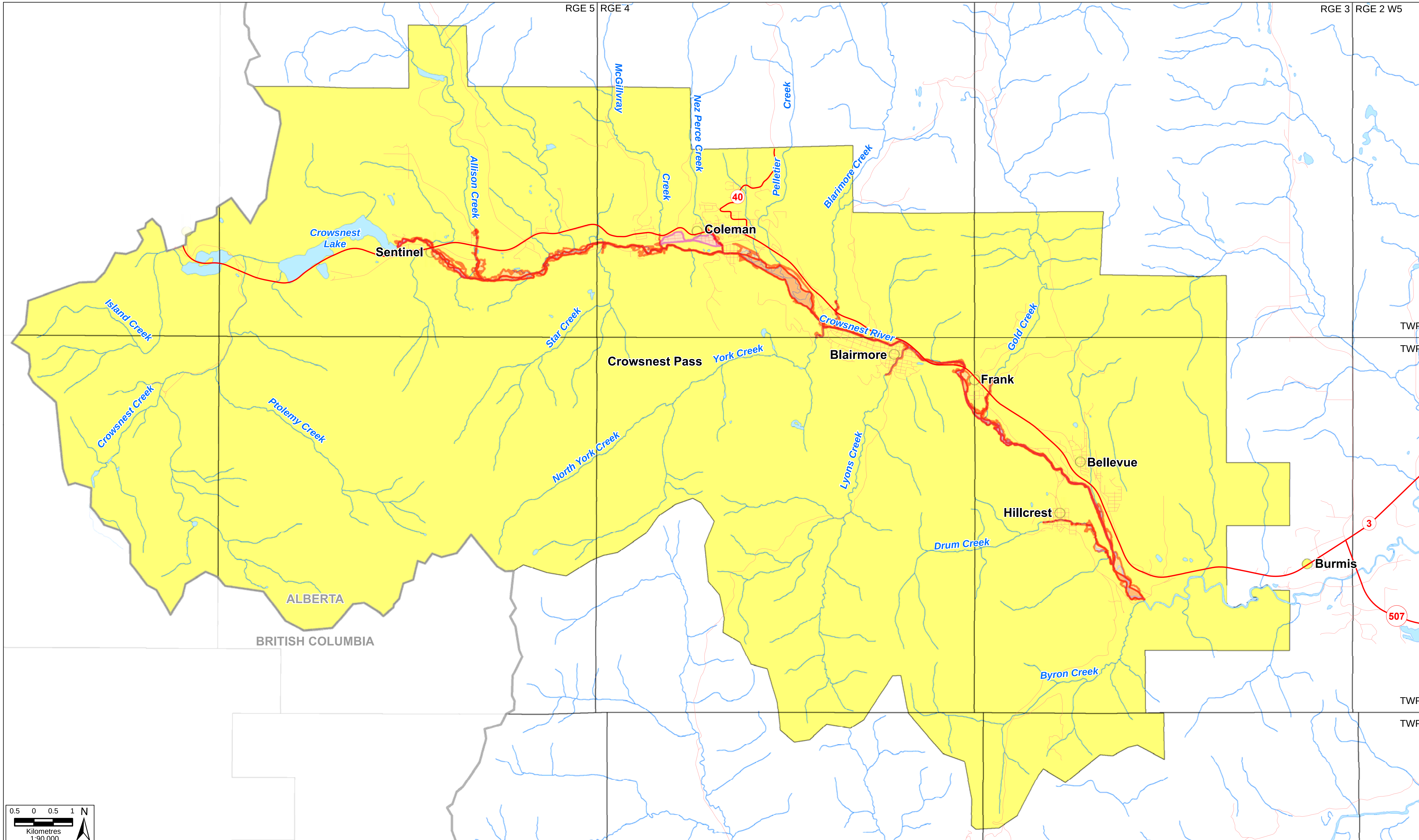
Southern Alberta Flood Recovery Task Force Flood Mitigation Study	Upstream of Glenmore Dam	DATE: May 2014 ANALYST: NH QA/QC: TR KK GG PDF: FigA8 Glenmore Upstream 14-05-22	**Figure A8** amec

S:\Gis\Projects\CW2174_Flood_Mitigation\ArcGIS\Elbow\FigA8 Glenmore Upstream.mxd



S:\GisProjects\CW2174_Flood_Mitigation\ArcGIS\Oldman\FigA9 Crowsnest Pass.mxd

Legend

- Provincial Boundary
- Township and Range
- Urban Area
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Crowsnest Pass

DATE: May 2014

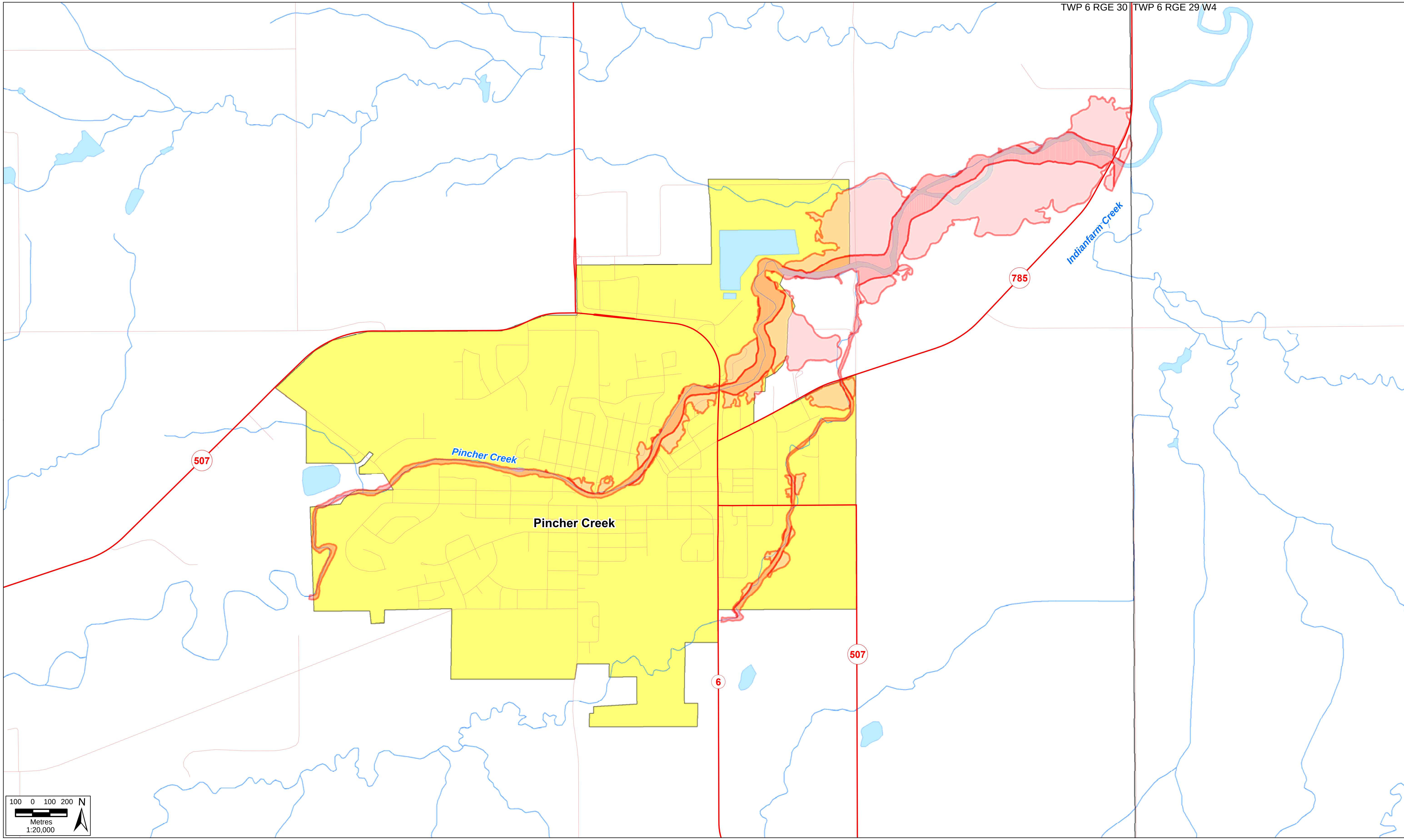
ANALYST: NH

QA/QC: TR KK GG

PDF: FigA9 Crowsnest Pass 14-05-22

Figure A9

amec



Legend

- Township and Range
- Urban Place
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Pincher Creek

DATE: May 2014	
ANALYST: NH	QA/QC: TR KK GG
PDF: FigA10 Pincher Creek 14-05-22	

Figure A10

amec

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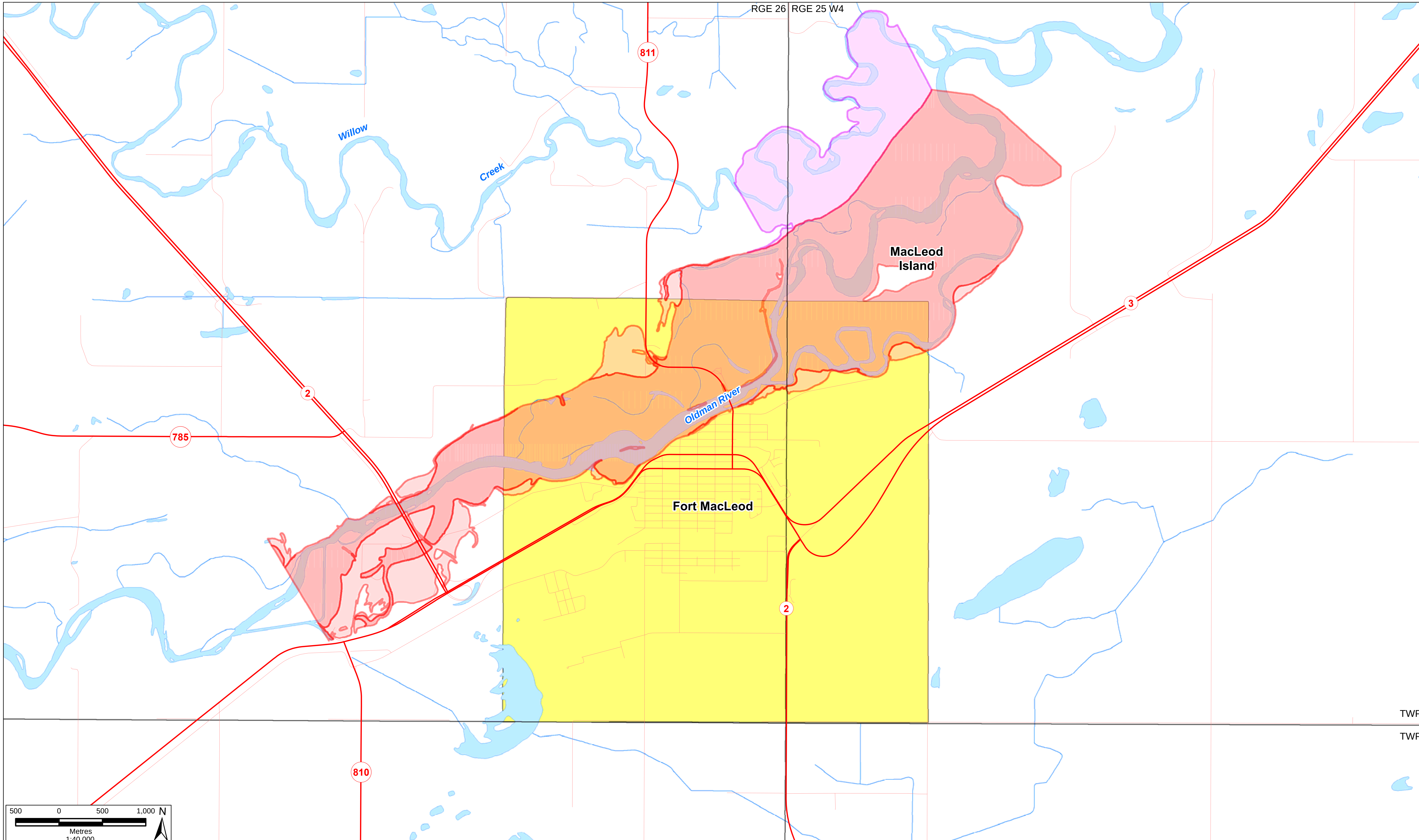

Legend

- Township and Range
- Urban Place
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

Southern Alberta
Flood Recovery Task Force
Flood Mitigation Study

Fort MacLeod

DATE: May 2014	
ANALYST: NH	QA/QC: TR KK GG
PDF: FigA11 Fort MacLeod 14-05-22	

Figure A11

amec

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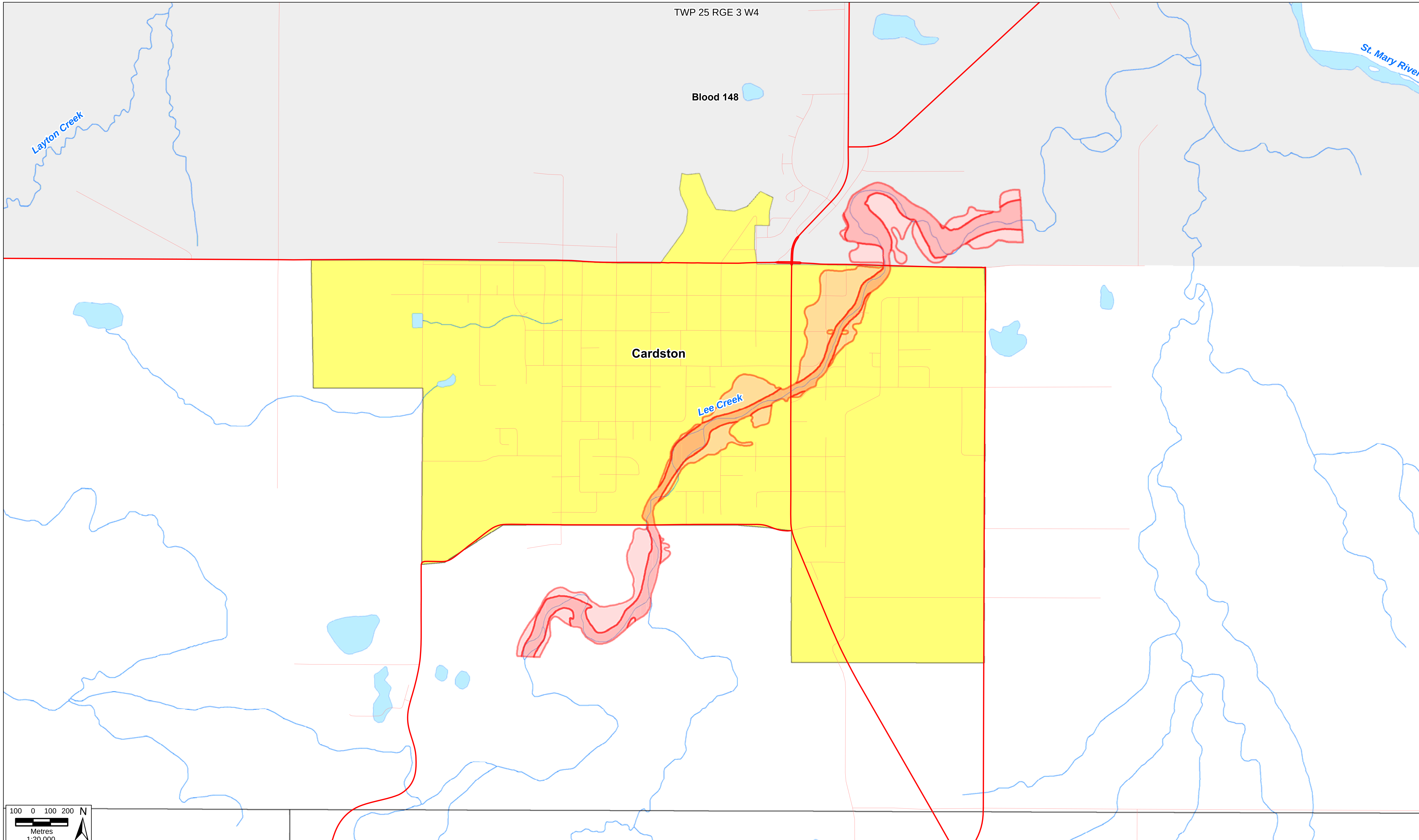

Legend

- Township and Range
- Urban Area
- Native Reserve
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

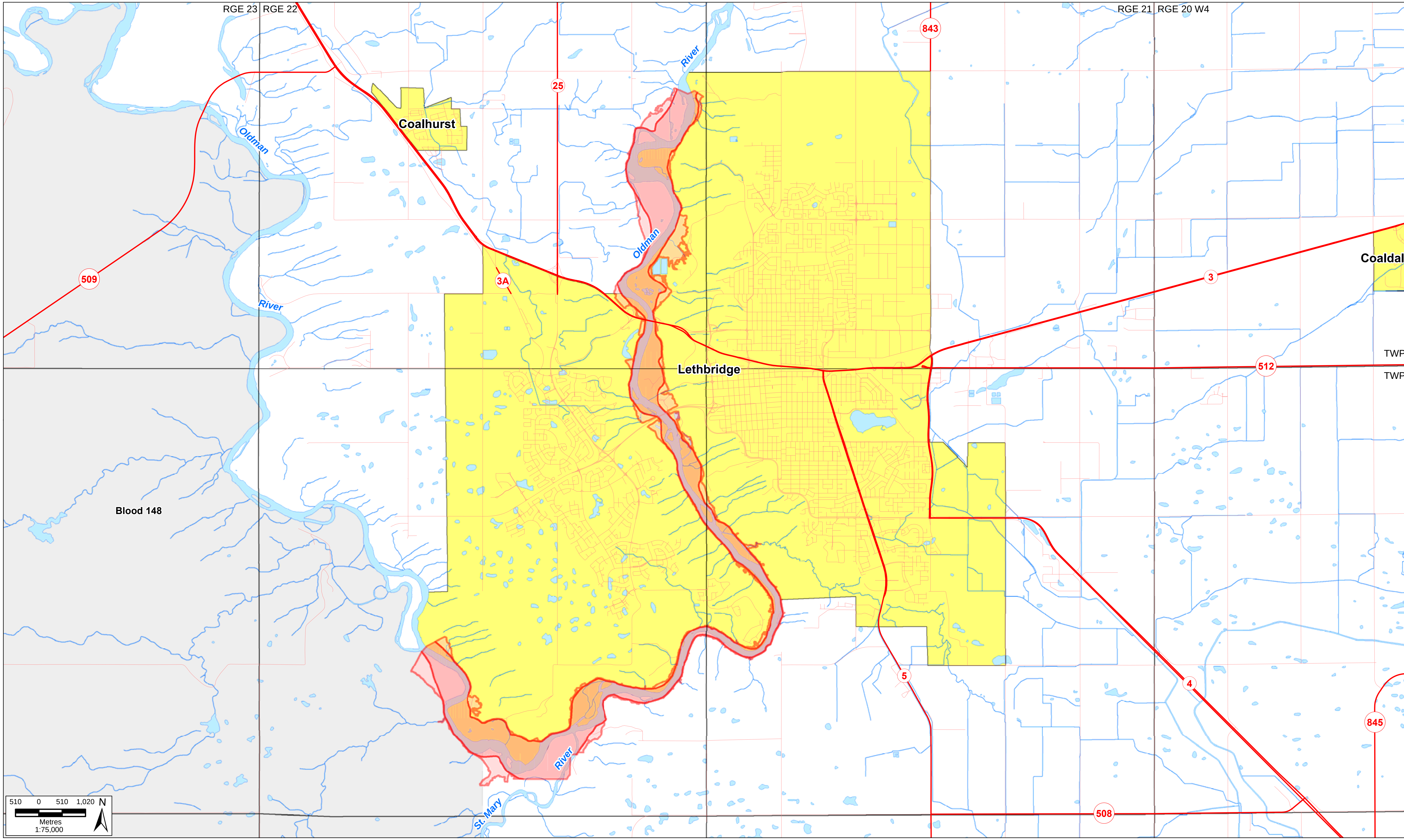
Cardston

DATE: May 2014
ANALYST: NH
QA/QC: TR KK GG
PDF: FigA12 Cardston 14-05-22

Figure A12

amec

S:\Gis\Projects\CW2174_Flood_Mitigation\ArcGIS\Oldman\FigA12 Cardston.mxd



Legend

- Township and Range
- Urban Place
- Native Reserve
- Floodway
- Flood Fringe
- Overland Flow
- Lake or River
- River or Creek
- Highway
- Road

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Southern Alberta Flood Recovery Task Force Flood Mitigation Study

Lethbridge

DATE: May 2014

ANALYST: NH

QA/QC: TR KK GG

PDF: FigA13 Lethbridge 14-05-22

Figure A13

amec

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Appendix B

Multi-Criteria Decision Making Assessment Process

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Option Ranking by Area & Weighting Scheme

Rank Legend

Structural Options:

Most Preferred						Least Preferred
1	2	3	4	5	6	7

Non-Structural Options:

Most Preferred					Least Preferred
1	2	3	4	5	6

Note: A ranking of 6 or 7 may indicate failure of one or more mandatory conditions.

			Structural Options							Non-Structural Options					
Basin	**Area**	**Weighting Scheme**	**Wet Dam**	**Dry Dam**	**Levee / Dyke**	**By-Pass Channel**	**Erosion Protection**	**Improve Conveyance**	**Sediment/Debris Control**	**Managed Retreat**	**Warning / Forecasting / Management**	**Land Zoning (Restricted Development)**	**Buy-Outs**	**Flood Proofing**	**Building Code Changes**
Bow River	Canmore	AMEC	6	7	2	4	5	1	3	2	6	3	1	5	4
		Equal Weighting	6	7	1	4	5	1	3	2	6	2	1	5	4
		Exclude Cost	6	7	3	4	5	1	2	2	4	3	1	6	5
		Exclude Environment	6	7	2	4	5	1	3	2	5	3	1	6	4
Bow River	Exshaw	AMEC	5	5	3	5	3	1	2	6	4	1	2	5	3
		Equal Weighting	5	5	3	5	4	1	2	6	3	1	2	3	3
		Exclude Cost	5	5	3	5	4	1	2	6	1	2	3	5	4
		Exclude Environment	5	5	3	5	3	1	2	6	4	1	2	5	3
Bow River	Kananaskis Country	AMEC	6	6	4	4	3	1	2	2	3	4	1	6	5
		Equal Weighting	6	6	4	4	3	1	2	2	3	4	1	6	5
		Exclude Cost	6	6	4	4	3	1	1	2	3	4	1	6	5
		Exclude Environment	6	6	4	4	3	1	2	2	3	4	1	6	5
Bow River	Cochrane	AMEC	5	4	1	6	2	7	2	5	3	4	5	2	1
		Equal Weighting	4	4	1	4	2	7	2	5	3	4	5	1	1
		Exclude Cost	5	4	1	6	2	7	2	5	3	4	5	1	2
		Exclude Environment	5	4	1	6	2	7	2	5	3	4	5	2	1
Bow River	City of Calgary	AMEC	4	5	1	6	2	3	6	2	5	4	1	3	6
		Equal Weighting	4	5	1	6	2	3	6	4	5	2	1	2	5
		Exclude Cost	3	5	1	6	2	4	6	3	4	5	1	2	6
		Exclude Environment	4	5	1	6	2	3	6	2	5	4	1	3	6
Bow River	First Nations (Siksika)	AMEC	5	3	1	7	6	2	4	2	5	4	1	3	6
		Equal Weighting	5	3	1	7	6	2	3	3	4	4	1	2	4
		Exclude Cost	3	2	1	7	5	4	5	2	4	5	1	3	6
		Exclude Environment	4	3	1	7	6	2	5	2	5	4	1	3	6
Bow River	Priddis	AMEC	4	5	1	6	2	7	2	3	2	1	6	4	5
		Equal Weighting	4	6	1	5	2	7	2	5	2	1	6	2	4
		Exclude Cost	2	3	1	4	5	7	5	2	1	3	6	4	5
		Exclude Environment	2	3	1	6	4	7	4	5	2	1	6	3	4
Elbow River	Bragg Creek	AMEC	4	5	2	6	1	6	3	5	6	2	3	1	4
		Equal Weighting	4	5	1	6	1	6	3	5	5	2	3	1	4
		Exclude Cost	3	4	2	6	1	6	5	6	4	3	2	1	5
		Exclude Environment	3	5	2	6	1	6	4	5	6	2	3	1	4

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Option Ranking by Area & Weighting Scheme

Rank Legend

Structural Options:

Most Preferred						Least Preferred
1	2	3	4	5	6	7

Non-Structural Options:

Most Preferred					Least Preferred
1	2	3	4	5	6

			Structural Options							Non-Structural Options					
Basin	**Area**	**Weighting Scheme**	**Wet Dam**	**Dry Dam**	**Levee / Dyke**	**By-Pass Channel**	**Erosion Protection**	**Improve Conveyance**	**Sediment/Debris Control**	**Managed Retreat**	**Warning / Forecasting / Management**	**Land Zoning (Restricted Development)**	**Buy-Outs**	**Flood Proofing**	**Building Code Changes**
Elbow River	Upstream of Glenmore Dam	AMEC	4	2	1	5	3	5	5	4	3	1	6	2	5
		Equal Weighting	4	2	1	5	3	5	5	4	3	1	5	2	5
		Exclude Cost	3	1	2	5	4	5	5	3	2	1	5	4	6
		Exclude Environment	3	2	1	5	3	5	5	4	3	1	6	2	5
Elbow River	Downstream of Glenmore Dam	AMEC	4	7	2	1	3	6	5	3	2	5	1	6	4
		Equal Weighting	4	7	1	1	3	6	4	3	1	5	1	6	3
		Exclude Cost	3	4	2	1	5	7	6	3	2	6	1	4	5
		Exclude Environment	4	5	2	1	3	5	7	3	2	5	1	6	4
Oldman River Basin	Pincher Creek	AMEC	5	6	2	7	4	3	1	3	6	1	5	2	4
		Equal Weighting	5	6	1	7	3	3	1	3	3	1	3	1	3
		Exclude Cost	3	4	2	7	6	4	1	5	2	3	4	1	6
		Exclude Environment	5	6	2	7	3	4	1	3	6	1	5	2	4
Oldman River Basin	Crowsnest Pass	AMEC	4	4	3	4	4	1	2	5	5	2	4	1	3
		Equal Weighting	4	4	3	4	4	1	2	5	5	2	4	1	3
		Exclude Cost	4	4	3	4	4	1	1	5	5	2	4	1	3
		Exclude Environment	4	4	3	4	4	1	2	5	5	2	4	1	3
Oldman River Basin	Cardston	AMEC	5	5	4	7	2	1	3	3	6	1	2	4	5
		Equal Weighting	5	6	4	7	2	1	3	4	5	1	1	3	5
		Exclude Cost	2	2	4	7	5	1	5	3	4	1	2	5	6
		Exclude Environment	5	5	4	7	2	1	3	3	6	1	2	4	5
Oldman River Basin	Lethbridge	AMEC	4	5	2	6	1	6	3	1	4	2	6	5	3
		Equal Weighting	4	5	2	6	1	6	3	2	3	1	6	4	4
		Exclude Cost	1	4	3	6	2	6	5	1	4	2	6	3	5
		Exclude Environment	3	5	2	6	1	6	4	1	4	2	6	5	3
Oldman River Basin	Fort MacLeod	AMEC	4	5	3	6	1	6	2	1	4	3	2	5	6
		Equal Weighting	4	5	3	6	1	6	2	1	3	4	2	4	6
		Exclude Cost	4	5	3	6	1	6	2	1	3	4	2	5	6
		Exclude Environment	4	5	3	6	1	6	2	1	4	3	2	5	6

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Score and Ranking Summary

Rank Legend

Structural Options							Non-Structural Options					
Most Preferred					Least Preferred		Most Preferred				Least Preferred	
1	2	3	4	5	6	7	1	2	3	4	5	6

Weighting Scenario: AMEC

Basin	Area		Wet Dam	Dry Dam	Levee / Dyke	By-Pass Channel	Erosion Protection	Improve Conveyance	Sediment/Debris Control	Managed Retreat	Warning / Forecasting / Management	Land Zoning (Restricted Development)	Buy-Outs	Flood Proofing	Building Code Changes
			Structural Options							**Non-Structural Options**					
Bow River	Canmore	Score:	195		241	225	223	258	239	267	223	260	268	224	238
		Rank:	6	7	2	4	5	1	3	2	6	3	1	5	4
Bow River	Exshaw	Score:			216		216	280	261	208	213	224	217	209	214
		Rank:	5	5	3	5	3	1	2	6	4	1	2	5	3
Bow River	Kananaskis Country	Score:			203	203	256	273	265	242	226	219	247		214
		Rank:	6	6	4	4	3	1	2	2	3	4	1	6	5
Bow River	First Nations (Stoney/Nakoda)	Score:													
		Rank:													
Bow River	Cochrane	Score:	149	153	257	141	210		210	190	221	214	190	235	238
		Rank:	5	4	1	6	2	7	2	5	3	4	5	2	1
Bow River	City of Calgary	Score:	168	166	251		203	191		245	224	239	255	244	222
		Rank:	4	5	1	6	2	3	6	2	5	4	1	3	6
Bow River	First Nations (Siksika)	Score:	208	219	257		197	227	210	249	219	220	265	246	214
		Rank:	5	3	1	7	6	2	4	2	5	4	1	3	6
Bow River	Priddis	Score:	208	206	260	202	210	190	210	220	221	231	196	217	214
		Rank:	4	5	1	6	2	7	2	3	2	1	6	4	5
Elbow River	Bragg Creek	Score:	196	192	219		224		201	212	206	229	226	235	223
		Rank:	4	5	2	6	1	6	3	5	6	2	3	1	4
Elbow River	First Nations (Tsuu Tina)	Score:													
		Rank:													
Elbow River	Upstream of Glenmore Dam	Score:	190	210	225		197			244	245	288	209	250	214
		Rank:	4	2	1	5	3	5	5	4	3	1	6	2	5
Elbow River	Downstream of Glenmore Dam	Score:	205	196	241	252	225	203	204	237	247	217	250	211	226
		Rank:	4	7	2	1	3	6	5	3	2	5	1	6	4
Oldman River Basin	Pincher Creek	Score:	196	187	233		210	214	235	216	211	229	212	227	214
		Rank:	5	6	2	7	4	3	1	3	6	1	5	2	4

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

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Rank Legend

Structural Options: Most Preferred						Least Preferred	Non-Structural Options: Most Preferred					Least Preferred
1	2	3	4	5	6	7	1	2	3	4	5	6

Score and Ranking Summary

Weighting Scenario: AMEC

			Structural Options							Non-Structural Options					
Basin	Area		Wet Dam	Dry Dam	Levee / Dyke	By-Pass Channel	Erosion Protection	Improve Conveyance	Sediment/Debris Control	Managed Retreat	Warning / Forecasting / Management	Land Zoning (Restricted Development)	Buy-Outs	Flood Proofing	Building Code Changes
Oldman River Basin	Crowsnest Pass	Score:			216			265	257			255	202	266	214
		Rank:	4	4	3	4	4	1	2	5	5	2	4	1	3
Oldman River Basin	Cardston	Score:	194	194	207		222	247	215	238	221	251	245	233	226
		Rank:	5	5	4	7	2	1	3	3	6	1	2	4	5
Oldman River Basin	First Nations (Pikani)	Score:													
		Rank:													
Oldman River Basin	First Nations (Blood)	Score:													
		Rank:													
Oldman River Basin	Lethbridge	Score:	199	187	211		217		205	242	212	238	158	210	214
		Rank:	4	5	2	6	1	6	3	1	4	2	6	5	3
Oldman River Basin	Fort MacLeod	Score:	181	176	216		250		230	265	224	226	241	221	214
		Rank:	4	5	3	6	1	6	2	1	4	3	2	5	6
Oldman River Basin	River Bottoms - A	Score:													
		Rank:													
Oldman River Basin	River Bottoms - B	Score:													
		Rank:													

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	Bragg Creek

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

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Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		1		4		1		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4				4	
		Test Result:	Pass		Pass		Pass		Fail		Pass		Fail		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		4	36		4	36			0		3	27			0		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	4	32		4	32		4	32			0		3	24			0		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		2	10		1	5			0		2	10			0		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24		3	24		2	16			0		2	16			0		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24	Related to flood volume, not peak flow rate	3	24	Related to flood volume, not peak flow rate	4	32			0		3	24			0		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8	Related to flood volume, not peak flow rate	2	8	Related to flood volume, not peak flow rate	4	16			0		2	8			0		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16		1	4		1	4			0		1	4			0		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		1	6		2	12			0		2	12			0		3	18	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7		1	7		3	21			0		3	21			0		3	21	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7		1	7		2	14			0		2	14			0		2	14	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20		2	20		1	10			0		4	40			0		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		2	6		3	9			0		4	12			0		4	12	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8		2	8		3	12			0		3	12			0		3	12	
			Desired Outcomes Score:	196			192			219			0			224			0			201		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	Bragg Creek

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27		3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24		4	32		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5		1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8		1	8		2	16	Ensure access to communities (e.g., subdivision entrances need to be made floodproof)	1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8		1	8		2	16		2	16		2	16		2	16	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4		1	4		2	8		2	8		2	8		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24		3	18		4	24		2	12		3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		2	14		4	28		4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21		3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		4	12		3	9		4	12		2	6	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12		4	16		4	16		3	12	
			Desired Outcomes Score:	212			206			229			226			235			223		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Canmore

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Structural Options

Mandatory Conditions

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Dry Dam	Levee / Dyke	By-Pass Channel	Erosion Protection	Improve Conveyance	Sediment/Debris Control
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4	1	4	4	4	4	4
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4	4	4	4	4	4	4
	Test Result:		Pass	Fail	Pass	Pass	Pass	Pass	Pass

Desired Outcomes

Category	Criteria	Weighting Scenario = AMEC	Scoring System
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit
	8. Development and construction costs.	6	1 = high cost 4 = low cost
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all

Criteria	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment
1.	3	27			0		3	27	
2.	3	24			0		3	24	
3.	1	5			0		3	15	
4.	3	24			0		4	32	
5.	4	32			0		4	32	
6.	4	16			0		4	16	
7.	4	16			0		1	4	
8.	1	6			0		3	18	
9.	1	7			0		4	28	
10.	1	7			0		2	14	
11.	2	20			0		1	10	
12.	1	3			0		3	9	
13.	2	8			0		3	12	Timing issue
Desired Outcomes Score:	195			0			241		

Criteria	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment
1.	3	27	- Cougar Creek/Mountain Creek Tributaries at the apex of the alluvial fan	4	36	- Silvertip Creek (back to original path) - On the mountain creeks; not necessarily on the Bow River
2.	2	16		4	32	
3.	2	10		1	5	
4.	4	32		3	24	
5.	4	32		1	8	
6.	4	16		1	4	
7.	1	4		1	4	
8.	2	12		3	18	
9.	3	21		2	14	
10.	2	14		2	14	Just the Bow River area
11.	2	20		4	40	
12.	3	9		4	12	
13.	3	12		3	12	
Desired Outcomes Score:	225			223		

Criteria	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
1.	4	36		4	36	
2.	4	32		4	32	
3.	3	15	Some can be negative (e.g., dredging)	3	15	
4.	4	32		3	24	
5.	2	16		1	8	
6.	2	8		1	4	
7.	1	4		1	4	
8.	2	12		4	24	
9.	3	21		2	14	
10.	3	21	Dredging is negative (2)	2	14	
11.	4	40		4	40	
12.	3	9		4	12	
13.	3	12		3	12	
Desired Outcomes Score:	258			239		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Canmore

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	2	16		4	32		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	3	15		1	5		4	20	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24		4	32		3	24	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24		1	8		2	16	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12		1	4		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	2	8		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24		3	18	Management included	4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		2	14	Management included	4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		2	14		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		4	12	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16	Management included (3)	3	12	
			Desired Outcomes Score:		**267**			**223**			**260**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	2	16		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	4	32		2	16		3	24	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		2	16		2	16	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		1	4		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	2	8		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	Look at areas other than floodway (e.g., affected by debris)	3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	4	12		4	12		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12	
			Desired Outcomes Score:		**268**			**224**			**238**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Cardston

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		1		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4	May be some transboundary input required because it originates in US	4		4				4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Fail**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36	4	36	3	27		0	3	27	4	36	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	4	32	4	32	3	24		0	3	24	4	32	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	2	10		0	1	5	1	5	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8	1	8	1	8		0	1	8	1	8	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24	4	32	3	24		0	2	16	4	32	2	16
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12	4	16	3	12		0	2	8	4	16	2	8
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4		0	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	2	12		0	4	24	3	18	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	1	7	3	21		0	4	28	3	21	3	21
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14		0	2	14	2	14	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	3	30	3	30	3	30		0	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	1	3	3	9		0	4	12	3	9	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12		0	3	12	3	12	3	12
			Desired Outcomes Score:	**194**		**194**		**207**		**0**		**222**		**247**		**215**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Cardston

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	0	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		0		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		0		4	
		Test Result:	Pass		Pass		Pass		Pass		Pass		0		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning Score	Land Zoning Weighted Score	Comment	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	0 Score	0 Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27		3	27		3	27			0		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		4	32		3	24		3	24			0		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		2	10		1	5		1	5			0		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		1	8		1	8		1	8		1	8			0		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		2	16		3	24		3	24		2	16			0		2	16	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		2	8		3	12		3	12		2	8			0		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		2	8	management of st mary reservoir	1	4		1	4		1	4			0		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	3	18		3	18		4	24		4	24		4	24			0		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28		4	28		4	28			0		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21		3	21		3	21			0		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40			0		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		3	9		4	12		4	12			0		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		4	16		3	12		4	16		4	16			0		3	12	
			Desired Outcomes Score:	238			221			251			245			233			0			226		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	City of Calgary

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		1		4		4		1	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4		4			
		Test Result:	**Pass**		**Pass**		**Pass**		**Fail**		**Pass**		**Pass**		**Fail**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36	4	36	4	36		0
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	4	32	4	32	4	32		0
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	2	10		0
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	2	16	2	16	3	24		0
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8	1	8	4	32		0
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4	1	4	3	12		0
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4		0
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	3	18		0
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	2	14	4	28		0
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	3	21		0
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20	2	20	1	10		0
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	2	6	4	12		0
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12		0
			Desired Outcomes Score:	**168**		**166**		**251**		**0**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27	3	27		0
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24	3	24		0
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	3	15	1	5		0
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8	1	8		0
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8	1	8		0
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4	1	4		0
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4	1	4		0
	8. Development and construction costs.	6	1 = high cost 4 = low cost	3	18	2	12		0
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	3	21	4	28		0
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	2	14	2	14		0
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40	4	40		0
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	4	12	3	9		0
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8		0
			Desired Outcomes Score:	**203**		**191**		**0**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

amec

Scenario ID: 1

Basin	Bow River
Area	City of Calgary

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit
	8. Development and construction costs.	6	1 = high cost 4 = low cost
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all

Criteria	Managed Retreat Score	Managed Retreat Weighted Score	Managed Retreat Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Warning / Forecasting / Management Comment	Land Zoning Score	Land Zoning Weighted Score	Land Zoning Comment
1.	4	36	All floodway plus Bowness	4	36	Includes management	3	27	
2.	3	24		3	24		3	24	
3.	3	15		2	10		3	15	
4.	2	16		3	24		1	8	
5.	2	16		1	8		2	16	
6.	2	8		1	4		2	8	
7.	1	4		1	4		1	4	
8.	3	18		3	18	Management included	4	24	
9.	4	28		2	14	Management included	4	28	
10.	3	21		3	21		3	21	
11.	4	40		4	40		4	40	
12.	1	3		3	9		4	12	
13.	4	16		3	12		3	12	
Desired Outcomes Score:	**245**			**224**			**239**		

Criteria	Buy-Outs Score	Buy-Outs Weighted Score	Buy-Outs Comment	Flood Proofing Score	Flood Proofing Weighted Score	Flood Proofing Comment	Building Code Changes Score	Building Code Changes Weighted Score	Building Code Changes Comment
1.	4	36		3	27		3	27	
2.	4	32		3	24		3	24	
3.	2	10		1	5		1	5	
4.	1	8		3	24		1	8	
5.	4	32		3	24		2	16	
6.	4	16		2	8		1	4	
7.	1	4		1	4		1	4	
8.	1	6		3	18		4	24	
9.	4	28		3	21		4	28	
10.	3	21		3	21		3	21	
11.	4	40		4	40		4	40	
12.	2	6		4	12		3	9	
13.	4	16		4	16		3	12	
Desired Outcomes Score:	**255**			**244**			**222**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Cochrane

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		1		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Fail**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27	3	27	4	36	3	27	3	27		0	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24	3	24	4	32	3	24	3	24		0	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	2	10	1	5	1	5		0	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8	1	8	2	16	1	8	1	8		0	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8	2	16	4	32	1	8	1	8		0	1	8
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4	2	8	4	16	1	4	1	4		0	1	4
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	3	12	1	4	1	4	1	4	1	4		0	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	3	18	2	12	4	24		0	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	1	7	4	28	2	14	4	28		0	4	28
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14	1	7	2	14		0	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	3	30	3	30	3	30	1	10	4	40		0	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	1	3	3	9	2	6	4	12		0	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12	3	12	3	12		0	3	12
			Desired Outcomes Score:	**149**		**153**		**257**		**141**		**210**		**0**		**210**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Cochrane

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4		2	8		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		3	12		3	12	
			Desired Outcomes Score:	190			221			214		

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		1	8		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8		3	24		3	24	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4		3	12		3	12	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		4	12		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		3	12		3	12	
			Desired Outcomes Score:	190			235			238		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Crowsnest Pass

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	1		1		4		1		1		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met					4						4		4	
		Test Result:	Fail		Fail		Pass		Fail		Fail		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome		0			0		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0		2	10	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0		2	16	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0		2	16	Crowsnest River only
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0		3	18	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0		2	14	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0		3	30	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0		3	12	
			Desired Outcomes Score:	0			0			216		

Criteria	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
1.		0			0		4	36		4	36	
2.		0			0		4	32		4	32	
3.		0			0		2	10		2	10	
4.		0			0		4	32		4	32	
5.		0			0		3	24	Tributaries (not Crowsnest River)	3	24	Tributaries (not Crowsnest River)
6.		0			0		3	12		3	12	
7.		0			0		1	4		1	4	
8.		0			0		2	12	CPR crossing bridges plus a road bridge on multiple creeks	3	18	
9.		0			0		4	28		2	14	
10.		0			0		2	14		2	14	
11.		0			0		4	40		4	40	
12.		0			0		3	9		3	9	Does not include forestry management practice
13.		0			0		3	12		3	12	
Desired Outcomes Score:	0			0			265			257		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Crowsnest Pass

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	1		1		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met					4		4		4		4	
		Test Result:	**Fail**		**Fail**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Land Zoning Score	Land Zoning Weighted Score	Buy-Outs Score	Buy-Outs Weighted Score	Flood Proofing Score	Flood Proofing Weighted Score	Building Code Changes Score	Building Code Changes Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0		0	4	36	3	27	4	36	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0		0	4	32	3	24	4	32	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0		0	1	5	1	5	1	5	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0		0	1	8	1	8	2	16	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0		0	3	24	1	8	3	24	1	8
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0		0	3	12	1	4	3	12	1	4
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0		0	1	4	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0		0	4	24	3	18	4	24	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0		0	4	28	4	28	4	28	4	28
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0		0	3	21	3	21	3	21	3	21
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0		0	4	40	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0		0	3	9	1	3	4	12	3	9
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0		0	3	12	3	12	3	12	3	12
			Desired Outcomes Score:	**0**		**0**		**255**		**202**		**266**		**214**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	Downstream of Glenmore Dam

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Weighted Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		4	36		4	36	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	4	32		4	32		4	32	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	2	10		2	10		3	15	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24		3	24		4	32	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24		3	24		4	32	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12	Glenmore Dam provides additional protection	3	12	Glenmore Dam provides additional protection	3	12	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		1	6		2	12	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7		1	7		3	21	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7		1	7		2	14	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20		2	20		1	10	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		2	6		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8		2	8		3	12	
			Desired Outcomes Score:	**205**			**196**			**241**		

Criteria	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
1.	4	36		3	27		3	27		3	27	
2.	4	32		3	24		3	24		3	24	
3.	3	15		3	15		1	5		1	5	
4.	4	32		1	8		1	8		1	8	
5.	4	32		2	16		2	16		1	8	
6.	4	16		2	8		1	4		1	4	
7.	1	4		1	4		1	4		1	4	
8.	1	6		4	24		2	12		3	18	
9.	3	21		3	21		4	28		3	21	
10.	2	14		2	14		2	14		3	21	
11.	3	30		4	40		4	40		4	40	
12.	2	6		4	12		3	9		4	12	
13.	2	8		3	12		3	12		3	12	
Desired Outcomes Score:	**252**			**225**			**203**			**204**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

amec

Scenario ID: 1

Basin	Elbow River
Area	Downstream of Glenmore Dam

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Weighted Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Weighting Scenario = AMEC	Mandatory Conditions Scoring Scheme / Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Managed Retreat Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Warning / Forecasting / Management Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Land Zoning (Restricted Development) Comment	Buy-Outs Score	Buy-Outs Weighted Score	Buy-Outs Comment	Flood Proofing Score	Flood Proofing Weighted Score	Flood Proofing Comment	Building Code Changes Score	Building Code Changes Weighted Score	Building Code Changes Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.		1 = cannot be met 4 = can be met	4			4			4			4			4			4		
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).		1 = cannot be met 4 = can be met	4			4			4			4			4			4		
			Test Result:	Pass			Pass			Pass			Pass			Pass			Pass		
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		4	36		3	27		4	36		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	4	32		4	32		3	24		4	32		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5		1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8		1	8		1	8		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24		3	24		1	8		4	32		2	16		2	16	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8		3	12		1	4		4	16		2	8		2	8	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	2	12		3	18		4	24		1	6		2	12		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		2	14		4	28		4	28		3	21		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21		3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		4	12		2	6		3	9		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12		4	16		4	16		3	12	
			Desired Outcomes Score:	237			247			217			250			211			226		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Exshaw

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	1	No place on Exshaw Creek or Jura Creek, or upstream on the Bow to put a dam	1	No place on Exshaw Creek or Jura Creek, or upstream on the Bow to put a dam	4		1		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met					4				4		4			
		Test Result:	**Fail**		**Fail**		**Pass**		**Fail**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0		0	3	27		0	3	27	4	36	4	36
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0		0	3	24		0	3	24	4	32	4	32
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0		0	2	10		0	2	10	2	10	2	10
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0		0	2	16		0	2	16	4	32	4	32
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0		0	4	32		0	1	8	4	32	2	16
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0		0	3	12		0	1	4	4	16	2	8
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0		0	1	4		0	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0		0	2	12		0	4	24	2	12	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0		0	3	21		0	3	21	4	28	3	21
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0		0	2	14		0	2	14	2	14	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0		0	2	20		0	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0		0	4	12		0	4	12	4	12	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0		0	3	12		0	3	12	3	12	3	12
			Desired Outcomes Score:	**0**		**0**		**216**		**0**		**216**		**280**		**261**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Exshaw

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	0	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4	Suggested that this should be N/A - nothing really to manage retreat of (unless flood mapping changes)	4		4		4	Suggested that this should be N/A - nothing really to buy out	4				4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4				4	
		Test Result:	Pass		Pass		Pass		Pass		Pass		0		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		3	15	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8		1	8		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		2	8		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24		3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		3	12		3	12	
			Desired Outcomes Score:	208			213			224		

Criteria	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	0 Score	0 Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
1.	3	27		3	27			0		3	27	
2.	3	24		2	16	Includes industrial areas in the flood fringe		0		3	24	
3.	1	5		1	5			0		1	5	
4.	1	8		1	8			0		1	8	
5.	1	8		1	8			0		1	8	
6.	1	4		1	4			0		1	4	
7.	1	4		1	4			0		1	4	
8.	4	24		4	24			0		4	24	
9.	4	28		4	28			0		4	28	
10.	3	21		3	21			0		3	21	
11.	4	40		4	40			0		4	40	
12.	4	12		4	12			0		3	9	
13.	3	12		3	12			0		3	12	
Desired Outcomes Score:	217			209			0			214		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Fort MacLeod

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4	For the campground	1		4		1		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4				4	
		Test Result:	Pass		Pass		Pass		Fail		Pass		Fail		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27	3	27	3	27		0
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24	3	24	3	24		0
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	2	10		0
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24	3	24	1	8		0
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	2	16	2	16	3	24		0
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8	2	8	3	12		0
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4		0
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	3	18		0
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	2	14	3	21		0
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14		0
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	3	30	3	30	3	30		0
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	1	3	4	12		0
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12		0
			Desired Outcomes Score:	181		176		216		0	

Criteria	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
1.	3	27			0	3	27
2.	3	24			0	3	24
3.	1	5			0	1	5
4.	4	32	Highway 811 abutment protection		0	2	16
5.	4	32			0	2	16
6.	4	16			0	2	8
7.	1	4			0	1	4
8.	3	18			0	4	24
9.	2	14			0	4	28
10.	2	14			0	2	14
11.	4	40			0	4	40
12.	4	12			0	4	12
13.	3	12			0	3	12
Desired Outcomes Score:	250			0		230	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Fort MacLeod

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	0	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		0		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		0		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**0**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Land Zoning Score	Land Zoning Weighted Score	Buy-Outs Score	Buy-Outs Weighted Score	Flood Proofing Score	Flood Proofing Weighted Score	0	Building Code Changes Score	Building Code Changes Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36	3	27	3	27	3	27	3	27	0	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	4	32	3	24	3	24	4	32	3	24	0	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	1	5	1	5	1	5	0	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8	1	8	1	8	1	8	1	8	0	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32	2	16	2	16	2	16	1	8	0	1	8
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16	2	8	2	8	2	8	1	4	0	1	4
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4	2	8	1	4	1	4	1	4	0	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24	3	18	4	24	4	24	4	24	0	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28	3	21	4	28	4	28	4	28	0	4	28
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21	3	21	3	21	3	21	3	21	0	3	21
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40	4	40	4	40	4	40	4	40	0	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	4	12	3	9	4	12	4	12	0	3	9
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16	4	16	3	12	4	16	4	16	0	3	12
			Desired Outcomes Score:	**265**		**224**		**226**		**241**		**221**		**0**	**214**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

amec

Scenario ID: 1

Basin	Bow River
Area	Kananaskis Country

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	1		1		4		4		4		4	Hood creek and other highway crossings	4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
		Test Result:	**Fail**		**Fail**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0		0	2	18	2	18	3	27	3	27	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0		0	2	16	2	16	3	24	4	32	4	32
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0		0	3	15	3	15	4	20	4	20	4	20
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0		0	1	8	1	8	3	24	4	32	4	32
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0		0	4	32	4	32	3	24	3	24	3	24
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0		0	4	16	4	16	4	16	4	16	4	16
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0		0	1	4	1	4	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0		0	2	12	2	12	3	18	2	12	3	18
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0		0	3	21	3	21	3	21	4	28	2	14
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0		0	1	7	1	7	2	14	2	14	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0		0	3	30	3	30	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0		0	4	12	4	12	4	12	4	12	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0		0	3	12	3	12	3	12	3	12	3	12
			Desired Outcomes Score:	**0**		**0**		**203**		**203**		**256**		**273**		**265**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Kananaskis Country

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		1		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Fail**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning Score	Land Zoning Weighted Score	Comment	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27		3	27			0		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24		3	24			0		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		2	10		2	10		2	10			0		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8		1	8			0		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		2	16		1	8		4	32			0		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		2	8		1	4		4	16			0		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4			0		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	2	12		3	18		4	24		2	12			0		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28		4	28			0		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	4	28		3	21		3	21		4	28			0		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40			0		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	2	6		3	9		3	9		2	6			0		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		3	12		3	12		3	12			0		3	12	
			Desired Outcomes Score:	**242**			**226**			**219**			**247**			**0**			**214**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Lethbridge

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		1		4		1		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4				4	
		Test Result:	Pass		Pass		Pass		Fail		Pass		Fail		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27	3	27	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24	3	24	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	3	15	3	15	2	10
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	4	32	4	32	2	16
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	2	16	2	16	3	24
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8	2	8	2	8
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	2	12
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	1	7	3	21
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	3	30	3	30	3	30
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	1	3	3	9
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12
			Desired Outcomes Score:	199		187		211	

Criteria	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
1.		0	3	27		0	3	27
2.		0	3	24		0	3	24
3.		0	2	10		0	1	5
4.		0	1	8		0	2	16
5.		0	3	24		0	1	8
6.		0	3	12		0	2	8
7.		0	1	4		0	1	4
8.		0	2	12		0	4	24
9.		0	3	21		0	2	14
10.		0	2	14		0	2	14
11.		0	4	40		0	4	40
12.		0	3	9		0	3	9
13.		0	3	12		0	3	12
Desired Outcomes Score:	0		217		0		205	

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Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014
Scenario ID: 1

Basin	Oldman River Basin
Area	Lethbridge

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Weighting Scenario = AMEC	Scoring System / Mandatory Conditions Scoring Scheme	Managed Retreat Score	Managed Retreat Weighted Score	Managed Retreat Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Warning / Forecasting / Management Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Land Zoning (Restricted Development) Comment	Buy-Outs Score	Buy-Outs Weighted Score	Buy-Outs Comment	Flood Proofing Score	Flood Proofing Weighted Score	Flood Proofing Comment	0 Score	0 Weighted Score	0 Comment	Building Code Changes Score	Building Code Changes Weighted Score	Building Code Changes Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.		1 = cannot be met 4 = can be met																	0				
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).		1 = cannot be met 4 = can be met																	0				
			Test Result:	**Pass**			**Pass**			**Pass**			**Pass**			**Pass**			**0**			**Pass**		
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		3	27		3	27		3	27		3	27			0		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24		3	24		3	24			0		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5		1	5		1	5			0		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24		1	8		1	8		1	8		2	16			0		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		1	8		3	24		1	8		1	8			0		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		1	4		3	12		1	4		1	4			0		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		3	12		1	4		1	4		1	4			0		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		3	18		4	24		2	12		2	12			0		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28		4	28		3	21			0		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21		3	21		3	21			0		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		1	10		4	40			0		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		4	12		3	9		1	3		4	12			0		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	3	12		3	12	Includes reservoir management	3	12		1	4		4	16			0		3	12	
			Desired Outcomes Score:	**242**			**212**			**238**			**158**			**210**			**0**			**214**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	First Nations (Pikani)

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met														
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met														
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0			0	
			Desired Outcomes Score:	0			0			0			0			0			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

amec

Scenario ID: 1

Basin	Oldman River Basin
Area	First Nations (Pikani)

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met												
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met												
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning Score	Land Zoning Weighted Score	Comment	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0	
			Desired Outcomes Score:	0			0			0			0			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Pincher Creek

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Dry Dam	Levee / Dyke	By-Pass Channel	Erosion Protection	Improve Conveyance	Sediment/Debris Control
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4	4	4	1	4	4	4
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4	4	4	4	4	4	4
		Test Result:	**Pass**	**Pass**	**Pass**	**Fail**	**Pass**	**Pass**	**Pass**

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36	4	36	4	36		0	3	27	3	27	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	4	32	4	32	4	32		0	3	24	3	24	4	32
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	1	5		0	1	5	1	5	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8	1	8	1	8		0	1	8	1	8	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32	4	32	4	32		0	1	8	2	16	3	24
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16	4	16	3	12		0	1	4	2	8	3	12
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4		0	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	3	18		0	4	24	2	12	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	1	7	4	28		0	4	28	4	28	3	21
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14		0	2	14	3	21	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20	2	20	2	20		0	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	2	6	4	12		0	4	12	3	9	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12		0	3	12	3	12	3	12
			Desired Outcomes Score:	**196**		**187**		**233**		**0**		**210**		**214**		**235**	

Comment columns for each option are blank.

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Oldman River Basin
Area	Pincher Creek

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Weighted Score	Comment	Warning / Forecasting / Management Score	Weighted Score	Comment	Land Zoning (Restricted Development) Score	Weighted Score	Comment	Buy-Outs Score	Weighted Score	Comment	Flood Proofing Score	Weighted Score	Comment	Building Code Changes Score	Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		4	36		3	27		3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24		3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5		1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		1	8		1	8		1	8		1	8		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	1	8		1	8		2	16		1	8		2	16		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8		2	8		2	8		1	4		2	8		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24		3	18		4	24		3	18		3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		2	14		4	28		4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21		3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		4	12		3	9		4	12		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12		4	16		4	16		3	12	
			Desired Outcomes Score:	**216**			**211**			**229**			**212**			**227**			**214**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Priddis

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Comment	Dry Dam	Comment	Levee / Dyke	Comment	By-Pass Channel	Comment	Erosion Protection	Comment	Improve Conveyance	Comment	Sediment/Debris Control	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Dry Dam Score	Dry Dam Weighted Score	Levee / Dyke Score	Levee / Dyke Weighted Score	By-Pass Channel Score	By-Pass Channel Weighted Score	Erosion Protection Score	Erosion Protection Weighted Score	Improve Conveyance Score	Improve Conveyance Weighted Score	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36	4	36	4	36	3	27	3	27	3	27	3	27
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	4	32	4	32	4	32	3	24	3	24	3	24	3	24
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5	1	5	1	5	1	5	1	5	1	5	1	5
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	3	24	3	24	3	24	2	16	1	8	1	8	1	8
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32	4	32	4	32	2	16	1	8	1	8	1	8
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12	3	12	4	16	2	8	1	4	1	4	1	4
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16	1	4	1	4	1	4	1	4	1	4	1	4
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6	1	6	3	18	2	12	4	24	3	18	4	24
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7	1	7	4	28	4	28	4	28	3	21	4	28
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7	1	7	2	14	2	14	2	14	2	14	2	14
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20	3	30	3	30	3	30	4	40	4	40	4	40
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	1	3	3	9	2	6	4	12	3	9	4	12
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8	2	8	3	12	3	12	3	12	2	8	3	12
			Desired Outcomes Score:	**208**		**206**		**260**		**202**		**210**		**190**		**210**	

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	Priddis

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		3	27		4	36		3	27		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	4	32		3	24		4	32		3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5		1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	1	8		2	16		1	8		1	8		1	8		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	2	16		2	16		1	8		1	8		1	8		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8		2	8		1	4		1	4		1	4		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	2	12		3	18		4	24		2	12		4	24		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28		4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	4	28		3	21		3	21		3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		3	9		3	9		1	3		4	12		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0		3	12		3	12		3	12		3	12		3	12	
			Desired Outcomes Score:	**220**			**221**			**231**			**196**			**217**			**214**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	First Nations (Siksika)

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Mandatory Conditions

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4	Dam to be built between Calgary and reserve	4	Dam to be built between Calgary and reserve	4		1		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4		4		4	
		Test Result:	**Pass**		**Pass**		**Pass**		**Fail**		**Pass**		**Pass**		**Pass**	

Desired Outcomes

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		4	36		4	36	Would need to be localized
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		4	32		4	32	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		2	10		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	4	32		4	32		4	32	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		4	32		4	32	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12		3	12		4	16	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		1	6		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7		2	14		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7		1	7		2	14	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	2	20		2	20		1	10	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		2	6		4	12	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8		2	8		3	12	
			Desired Outcomes Score:	**208**			**219**			**257**		

Criteria	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
1.		0		3	27		3	27		3	27	
2.		0		3	24		3	24		3	24	
3.		0		1	5		1	5		1	5	
4.		0		1	8		4	32		1	8	
5.		0		1	8		2	16		1	8	
6.		0		1	4		1	4		1	4	
7.		0		1	4		1	4		1	4	
8.		0		3	18		2	12		4	24	
9.		0		3	21		4	28		4	28	
10.		0		2	14		2	14		2	14	
11.		0		4	40		4	40		4	40	
12.		0		4	12		3	9		4	12	
13.		0		3	12		3	12		3	12	
Desired Outcomes Score:	**0**			**197**			**227**			**210**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	First Nations (Siksika)

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Mandatory Conditions

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		4	Relates to relocation of residences	4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4	Assume that this could be administered by the Band Council.	4		4	Assume that this could be administered by the Band Council.	4	Assume that this could be administered by the Band Council.	4	Assume that this could be administered by the Band Council.	4	Assume that this could be administered by the Band Council.
		Test Result:	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Desired Outcomes

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Comment	Land Zoning (Restricted Development) Score	Land Zoning (Restricted Development) Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		4	36		4	36	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	2	16		3	24		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24		1	8		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	2	8		1	4		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	4	24	Assumes houses destroyed in 2013 are rebuilt in current locations.	3	18		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		2	14	Includes management	4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3	Assumes houses destroyed in 2013 are rebuilt in current locations.	3	9		2	6	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		3	12		3	12	
			Desired Outcomes Score:	**249**			**219**			**220**		

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Buy-Outs Score	Buy-Outs Weighted Score	Comment	Flood Proofing Score	Flood Proofing Weighted Score	Comment	Building Code Changes Score	Building Code Changes Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	4	36		3	27		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome	3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	2	16		2	16	Includes self-access to things like power & water	1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		3	24		1	8	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		2	8		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	3	18		4	24		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	3	9	Assumes people currently without housing would be relocated now, rather than after rebuilding.	3	9		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12	
			Desired Outcomes Score:	**265**			**246**			**214**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	First Nations (Stoney/Nakoda)

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Weighting Scenario = AMEC	Mandatory Conditions Scoring Scheme / Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.		1 = cannot be met 4 = can be met																					
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).		1 = cannot be met 4 = can be met																					
			Test Result:	Pass			Pass			Pass			Pass			Pass			Pass			Pass		
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0			0	
			Desired Outcomes Score:	0			0			0			0			0			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Bow River
Area	First Nations (Stoney/Nakoda)

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met												
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met												
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Weighted Score	Comment	Warning / Forecasting / Management Score	Weighted Score	Comment	Land Zoning Score	Weighted Score	Comment	Buy-Outs Score	Weighted Score	Comment	Flood Proofing Score	Weighted Score	Comment	Building Code Changes Score	Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0	
			Desired Outcomes Score:	0			0			0			0			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	First Nations (Tsuu Tina)

Legend

4		Strongly Positive
3		Positive
2		Negative
1		Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam		Dry Dam		Levee / Dyke		By-Pass Channel		Erosion Protection		Improve Conveyance		Sediment/Debris Control	
				Comment		Comment		Comment		Comment		Comment		Comment		Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met														
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met														
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam			Dry Dam			Levee / Dyke			By-Pass Channel			Erosion Protection			Improve Conveyance			Sediment/Debris Control		
				Score	Weighted Score	Comment	Score	Weighted Score	Comment	Score	Weighted Score	Comment	Score	Weighted Score	Comment	Score	Weighted Score	Comment	Score	Weighted Score	Comment	Score	Weighted Score	Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure)	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0			0	
			Desired Outcomes Score:	0			0			0			0			0			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	First Nations (Tsuu Tina)

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Weighting Scenario = AMEC	Mandatory Conditions Scoring Scheme / Scoring System	Managed Retreat: Score	Managed Retreat: Weighted Score	Managed Retreat: Comment	Warning / Forecasting / Management: Score	Warning / Forecasting / Management: Weighted Score	Warning / Forecasting / Management: Comment	Land Zoning (Restricted Development): Score	Land Zoning (Restricted Development): Weighted Score	Land Zoning (Restricted Development): Comment	Buy-Outs: Score	Buy-Outs: Weighted Score	Buy-Outs: Comment	Flood Proofing: Score	Flood Proofing: Weighted Score	Flood Proofing: Comment	Building Code Changes: Score	Building Code Changes: Weighted Score	Building Code Changes: Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.		1 = cannot be met 4 = can be met																		
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).		1 = cannot be met 4 = can be met																		
			Test Result:	**Pass**			**Pass**			**Pass**			**Pass**			**Pass**			**Pass**		
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit		0			0			0			0			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost		0			0			0			0			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost		0			0			0			0			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome		0			0			0			0			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk		0			0			0			0			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years		0			0			0			0			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all		0			0			0			0			0			0	
			Desired Outcomes Score:	**0**			**0**			**0**			**0**			**0**			**0**		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

Scenario ID: 1

Basin	Elbow River
Area	Upstream of Glenmore Dam

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Wet Dam	Wet Dam Comment	Dry Dam	Dry Dam Comment	Levee / Dyke	Levee / Dyke Comment	By-Pass Channel	By-Pass Channel Comment	Erosion Protection	Erosion Protection Comment	Improve Conveyance	Improve Conveyance Comment	Sediment/Debris Control	Sediment/Debris Control Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4		4		4		1		4		1		1	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4				4					
		Test Result:	Pass		Pass		Pass		Fail		Pass		Fail		Fail	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Wet Dam Score	Wet Dam Weighted Score	Wet Dam Comment	Dry Dam Score	Dry Dam Weighted Score	Dry Dam Comment	Levee / Dyke Score	Levee / Dyke Weighted Score	Levee / Dyke Comment	By-Pass Channel Score	By-Pass Channel Weighted Score	By-Pass Channel Comment	Erosion Protection Score	Erosion Protection Weighted Score	Erosion Protection Comment	Improve Conveyance Score	Improve Conveyance Weighted Score	Improve Conveyance Comment	Sediment/Debris Control Score	Sediment/Debris Control Weighted Score	Sediment/Debris Control Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		4	36		3	27			0		3	27			0			0	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		4	32		3	24	Includes protection of Discovery Ridge in the flood fringe		0		3	24			0			0	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	2	10		2	10		2	10			0		1	5			0			0	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	2	16		2	16		1	8			0		1	8			0			0	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	3	24		4	32		4	32			0		1	8			0			0	
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	3	12		4	16		4	16			0		1	4			0			0	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	4	16		1	4		1	4			0		1	4			0			0	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	1	6		1	6		3	18			0		3	18			0			0	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	1	7		1	7		3	21			0		3	21			0			0	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	1	7		1	7		2	14			0		2	14			0			0	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	3	30	Less risk than upstream	3	30		3	30			0		4	40			0			0	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		2	6		3	9			0		4	12			0			0	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	2	8		2	8		3	12			0		3	12			0			0	
			Desired Outcomes Score:	190			210			225			0			197			0			0		

Flood Mitigation Feasibility Study

Assessment of Flood Mitigation Options
Prepared by AMEC Environment & Infrastructure
Project No. CW2174
April 1, 2014

amec

Scenario ID: 1

Basin	Elbow River
Area	Upstream of Glenmore Dam

Legend

4	Strongly Positive
3	Positive
2	Negative
1	Strongly Negative

Definition

Weighting	1 = Low Importance to 10 = High Importance
Score	Weighting Scenario x Scoring System Result = Weighted Score

Non-Structural Options

Category	Criteria	Mandatory Conditions Scoring Scheme	Managed Retreat	Comment	Warning / Forecasting / Management	Comment	Land Zoning (Restricted Development)	Comment	Buy-Outs	Comment	Flood Proofing	Comment	Building Code Changes	Comment
Mandatory Conditions	1. Ensure flood control infrastructure can be designed and built in a suitable location. Ensure non-structural options can be implemented.	1 = cannot be met 4 = can be met	4	No infrastructure in the floodway; Lott Creek potentially affected (under review on the floodplain map)	4		4		4		4		4	
	2. Must meet existing transboundary legal commitments (i.e., downstream volumes to other users).	1 = cannot be met 4 = can be met	4		4		4		4		4		4	
		Test Result:	Pass		Pass		Pass		Pass		Pass		Pass	

Category	Criteria	Weighting Scenario = AMEC	Scoring System	Managed Retreat Score	Managed Retreat Weighted Score	Managed Retreat Comment	Warning / Forecasting / Management Score	Warning / Forecasting / Management Weighted Score	Warning / Forecasting / Management Comment	Land Zoning Score	Land Zoning Weighted Score	Land Zoning Comment	Buy-Outs Score	Buy-Outs Weighted Score	Buy-Outs Comment	Flood Proofing Score	Flood Proofing Weighted Score	Flood Proofing Comment	Building Code Changes Score	Building Code Changes Weighted Score	Building Code Changes Comment
Desired Outcomes	1. Improve existing shelter, sustenance and security for individuals within the basin (compared to current situation and not increase flood impacts to other users/basins both upstream and downstream.	9	1 = negative outcome 4 =positive outcome	3	27		4	36		4	36		3	27		4	36		3	27	
	2. Increase property protection for residents, business, and First Nations (note: business includes agriculture and irrigation, as well as provincial and municipal infrastructure).	8	1 = negative outcome 4 =positive outcome	3	24		3	24		4	32		3	24		3	24		3	24	
	3. Protection of designated natural areas (traditional use, recreation, historical resources).	5	1 = low benefit 4 = high benefit	1	5		1	5		3	15		1	5		1	5		1	5	
	4. Ensure access to life-line services (fire, police, hospital, water & wastewater etc.) for all residents within the basin.	8	1 = low benefit 4 = high benefit	2	16		3	24		3	24		1	8		1	8		1	8	
	5. Provide adequate protection for at least the 1% annual exceedance probability event.	8	1 = low benefit 4 = high benefit	4	32		2	16		3	24		1	8		3	24		1	8	Assuming that there are already stringent building codes in place for Lott Creek & Discovery Ridge
	6. Provide adequate protection for the largest historical flood of record.	4	1 = low benefit 4 = high benefit	4	16		2	8		3	12		1	4		2	8		1	4	
	7. Be designed and operated to meet multi-purpose objectives (e.g., manage water resources for both floods and droughts).	4	1 = low benefit 4 = high benefit	1	4		1	4		1	4		1	4		1	4		1	4	
	8. Development and construction costs.	6	1 = high cost 4 = low cost	2	12		3	18		4	24		2	12		4	24		4	24	
	9. Operating and maintenance costs.	7	1 = high cost 4 = low cost	4	28		3	21		4	28		4	28		4	28		4	28	
	10. Ensure species (fish, wildlife, vegetation, etc.) are not adversely impacted.	7	1 = negative outcome 4 =positive outcome	3	21		3	21		4	28		3	21		3	21		3	21	
	11. Must not increase potential for flood-related loss of life (compared to existing situation).	10	1 = high risk 4 =low risk	4	40		4	40		4	40		4	40		4	40		4	40	
	12. Protection is implemented in the near term.	3	1 = 10+ years 2 = 5-10 years 3 = 2-5 years 4 = <2 years	1	3		4	12		3	9		4	12		4	12		3	9	
	13. Meets existing federal and provincial policies and regulations.	4	1 = meets few/none 2 = meets some 3= meets most 4 =meets all	4	16		4	16		3	12		4	16		4	16		3	12	
			Desired Outcomes Score:	244			245			288			209			250			214		

Appendix C

Hydrologic Assessment Memoranda

Memo

To:	Syed Abbas	**File No:**	CW2174
Company:	Flood Mitigation Task Force	**Date:**	27 February 2014
From:	Gary Beckstead	**cc:**	Geoff Graham
Phone:	(403) 387-1628		
Email:	gary.beckstead@amec.com		
Subject:	Hydrological Assessment of BG1 Dam		

SUMMARY

A hydrological assessment of the BG1 dam proposed by the Flood Advisory Panel was undertaken to determine likely reductions in water levels along the Bow River in Calgary.

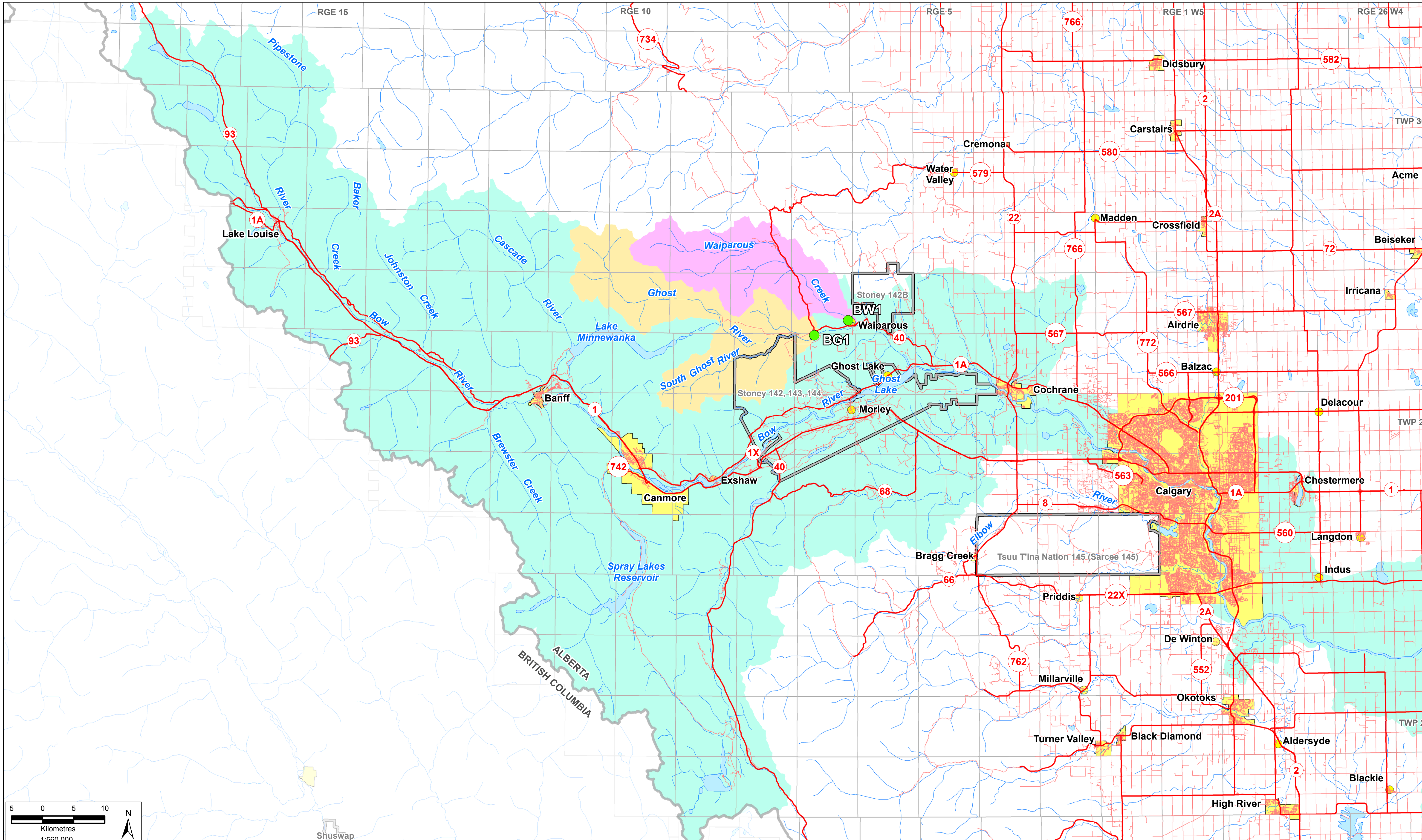
The drainage area of the Ghost River upstream of the proposed BG1 dam is approximately 485 km^2 or approximately 4.2% of the drainage area of the Bow River upstream of the Elbow River confluence. **Figure 1** illustrates the drainage basin upstream of the proposed BG1 Dam in relation to the catchment of the Bow River basin upstream of Calgary; it also shows the location of BW1, which is another site proposed by the Flood Advisory Panel.

The assessment was based on a routing model, which determined the outflows from Ghost Dam based on inflows from the Bow River near Seebe, the Ghost River above Waiparous Creek and from Waiparous Creek near the mouth and characteristics of Ghost Dam and Ghost Lake upstream of the dam. Flows from Jumpingpound Creek were added to the Ghost Dam outflows to provide a representation of the flows in the Bow River at Calgary. To evaluate the effects of the proposed BG1 Dam on the Ghost River, two scenarios were modeled:

1. No outflow from the Ghost River above Waiparous Creek – representative of a dam retaining 100% of the Ghost river flow, which would result in a maximum effect that is likely not attainable; and
2. A 60% reduction in the flows in the Ghost River above Waiparous Creek – representative of a detention dam as proposed by the Flood Advisory Panel at Quirk Creek on the Elbow River.

The key findings from the evaluation were:

- Peak discharges would be reduced by a maximum of 10% (129 m^3/s) with no outflow from BG1, and by 6% (77 m^3/s) for the detention dam scenario (60% outflow).
- Water levels along the Bow River in Calgary would potentially be reduced by a maximum of 0.18 to 0.27 m if 100% of the Ghost River flow is retained. Water level reductions for a detention dam at the BG1 site would more likely be less, in the range of 0.1 to 0.16 m.



Legend

- Township and Range
- Native Reserve
- Urban Location
- Bow River Drainage Basin
- Ghost River Basin Upstream of BG1
- Waiparous Creek Basin Upstream of BW1
- River or Lake
- River or Creek
- Highway
- Road
- Dam Site

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Alberta Flood Recovery Task Force
Flood Mitigation Study

The Bow Basin Upstream of Calgary

DATE: February 2014
ANALYST: NH
QA/QC: TR KK GG
PDF: Fig1 Bow US of Calgary 14-02-25

Figure 1

amec

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1.0 INTRODUCTION

In response to your request of 20 February 2014, AMEC Environment and Infrastructure, a division of AMEC Americas Ltd. (AMEC), has prepared the following hydrological evaluation of the BG1 dam proposed by the Flood Advisory Panel.

1.1 Background

The proposed BG1 dam site is located on the Ghost River upstream of the confluence with Waiparous Creek. Downstream of the mouth of Waiparous Creek, the lower Ghost River flows into Ghost Lake, formed by the Ghost Dam on the Bow River.

The drainage area of the Ghost River upstream of the proposed BG1 dam is approximately 485 km^2 or approximately 4.2% of the drainage area of the Bow River upstream of the Elbow River confluence. **Figure 1** in the Summary section of this report illustrates the drainage basin upstream of the proposed BG1 dam in relation to the catchment of the Bow River basin upstream of Calgary.

From a general perspective, the ability of the proposed BG1 dam to moderate flows at Calgary is in close proportion to it contributing drainage area. Hydrological data obtained at the Water Survey of Canada (WSC) hydrometric gauge 05BG010 located at the proposed dam site, indicate that the June flow volume is, on average, about 10% of that measured on the Bow River at Calgary (i.e., at the WSC gauge 05BH004, located upstream of the Elbow River confluence).

While the contributing area and flow volume are small in proportion to the respective values for the Bow River at Calgary, these do not necessarily indicate the true effectiveness of a flood detention dam on the Ghost River in terms of lowering flood levels at Calgary. Therefore, a more in-depth hydrological analysis was undertaken to further assess the flood mitigation benefits of the proposed BG1 dam.

1.2 Methodology

1.2.1 Approach

The following methodology was employed to evaluate the effectiveness of flood detention by the proposed BG1 Dam on the Ghost River:

- Daily flow data for hydrometric gauges in the area were obtained from the WSC web site (WSC 2014). These stations were:
  - Bow River near Seebe (05BE004)
  - Ghost River above Waiparous Creek (05BG010)
  - Waiparous Creek near the mouth (05BG006)
  - Ghost Lake near Cochrane (05BE005)
  - Ghost Tailrace (05BE999)
  - Jumpingpound Creek near the mouth (05BH009)
  - Bow River at Calgary (05BH004)

- Hydrographs were evaluated and normalized hydrographs were produced for each major inflow to Ghost Lake, for Jumpingpound Creek and for the Bow River at Calgary. In general, the highest flow years were used to characterize the shape of the normalized hydrograph.
- Based on available frequency analyses and the dimensionless hydrographs, stream discharge hydrographs were developed for the major streams to be modeled.
- Information on the storage characteristics of Ghost Lake (stage-storage-area table) and the outflow characteristics of Ghost Dam were obtained from TransAlta Corporation (TAC; Roger Drury, 2014 pers. comm.). Additional information on Ghost Dam (WER, 1981) was used to understand the nature of the service and emergency spillways. Outflow rating curves for Ghost Dam were developed from this information.
- A flood routing model was prepared using HEC-HMS to assess the regulating effect of Ghost Dam on downstream discharges.
- Historical discharges were evaluated in the routing model to confirm the routing of flows through Ghost Dam.
- Hydrographs for the 1% exceedance event on the contributing streams were run through the model to determine an estimate of the unmitigated hydrograph for the Bow River at Calgary. Then the inflow from the Ghost River was deleted to approximate the effect of a flood retention dam at site BG1 (i.e., a dam retaining 100% of the inflow) and to evaluate the difference in flood peak discharge at Calgary versus the unmitigated scenario.
- The evaluation of routed discharges with and without the proposed BG1 dam was extended by determining the effect of lower discharges on the water levels that might occur at the WSC gauge 05BH004, Bow River at Calgary.
- The differences in discharge were used to determine the difference in flow depth, using the rating curve for the WSC gauge.

1.2.2 Assumptions and Limitations

The hydrometric data employed for this assessment was based on the period of record for each of the stations. In general, the period of record employed was not consistent throughout. Data were not extended using regression or other methods to achieve a consistent period of record.

The depth-storage-area data provided by TAC was used as-is. The data were not verified.

Outflows from Ghost Dam result from flow through the turbines and flows over the service and emergency spillways. The spillways have several bays all controlled with stoplogs. A varying number of spillway bays are employed to route incoming flood discharges through the dam; (e.g., one bay was partially open in the June 2005 flood and three bays were open for the 2013 event). For AMEC's modeling, the maximum spillway discharge for a given water level was used (i.e., all bays operating). This maximum rating curve was found to perform well for the 1% event, as lower outflows resulted in over-filling of the reservoir. As the intent of the exercise is to determine the difference in water levels at Calgary for flood mitigation with (and without) the proposed BG1 dam in place, the lack of a known operating procedure for spillway adjustment for a given event is not seen as a appreciable shortcoming.

Inflow discharge hydrographs were available on a mean daily basis. For the purpose of modeling, these data were interpolated to an hourly time step. Although hourly gauged discharge would have been preferred, such data were not readily available for this analysis. The HEC-HMS routing model was run at a 15 minute computational time step.

All basins were assumed to be under 1% exceedance flood discharge conditions simultaneously. Though possibly conservative, this assumption was thought to be reasonable for the upper Bow River basin, based on experience and analysis of prior floods. Flood discharge peak values for the various basins were obtained from the following sources:

- Bow River near Seebe (AENV, 1983).
- Ghost River above Waiparous Creek (Golder, 2013).
- Waiparous Creek near the Mouth (Golder 2013).
- Jumpingpound Creek near the Mouth (AENV, 1990).
- Bow River at Calgary (Golder, 2010).

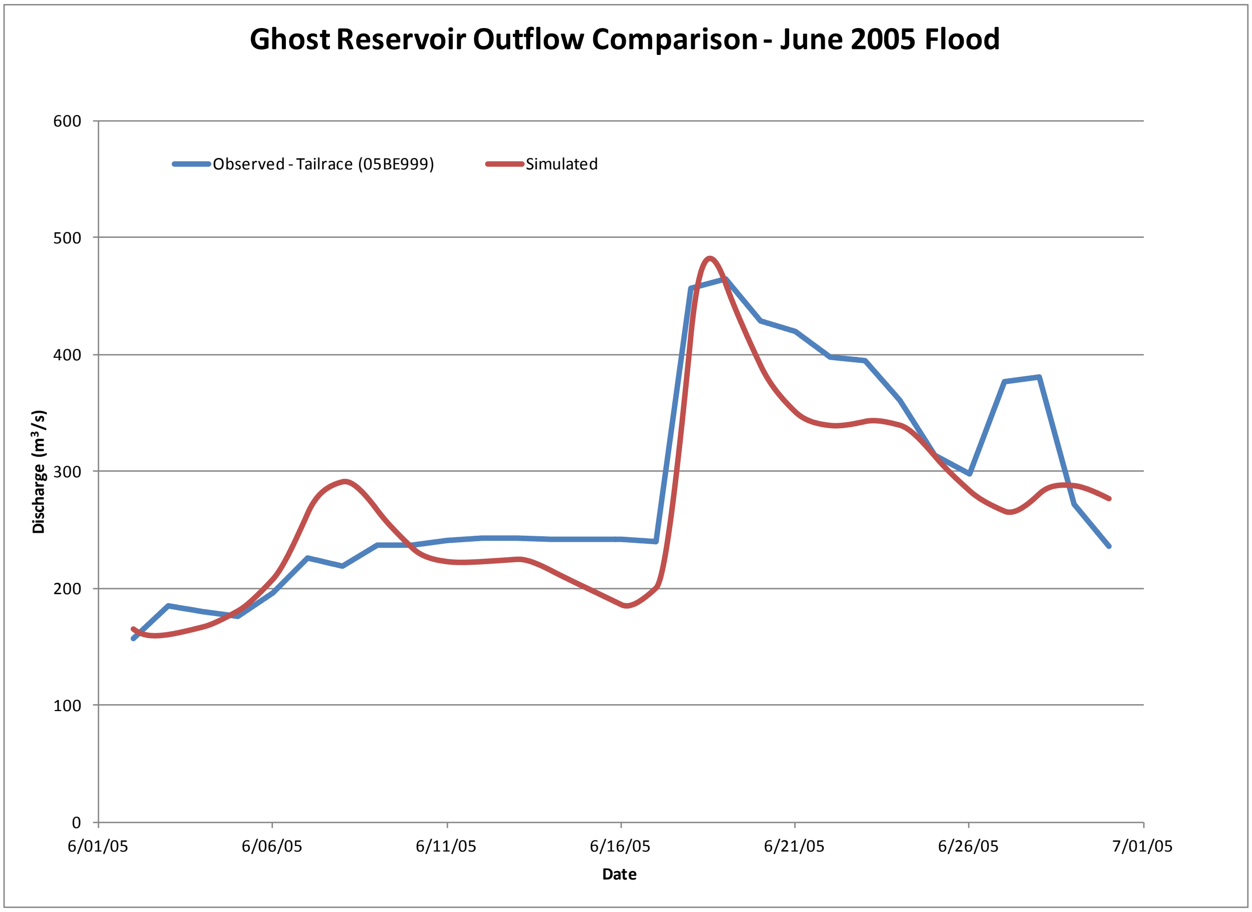
No channel routing effects (i.e., time lag or peak attenuation) between Ghost Lake and Calgary were accounted for in the model, including any potential influence of Bearspaw Reservoir on the hydrograph at Calgary. Bearspaw Dam is commonly operated as a run-of-river facility, and flood peak attenuation would generally be small for large floods.

2.0 RESULTS

2.1 Model Calibration

As discussed in **Section 1.2.2**, the floods in June 2005 were used to test the initial model set-up. **Figure 2** illustrates the measured and simulated outflows from Ghost Dam during June 2005. The agreement was found to be acceptable for the purposes of this assessment.

Figure 2 Comparison of Measured and Simulated Outflows from Ghost Dam in June 2005

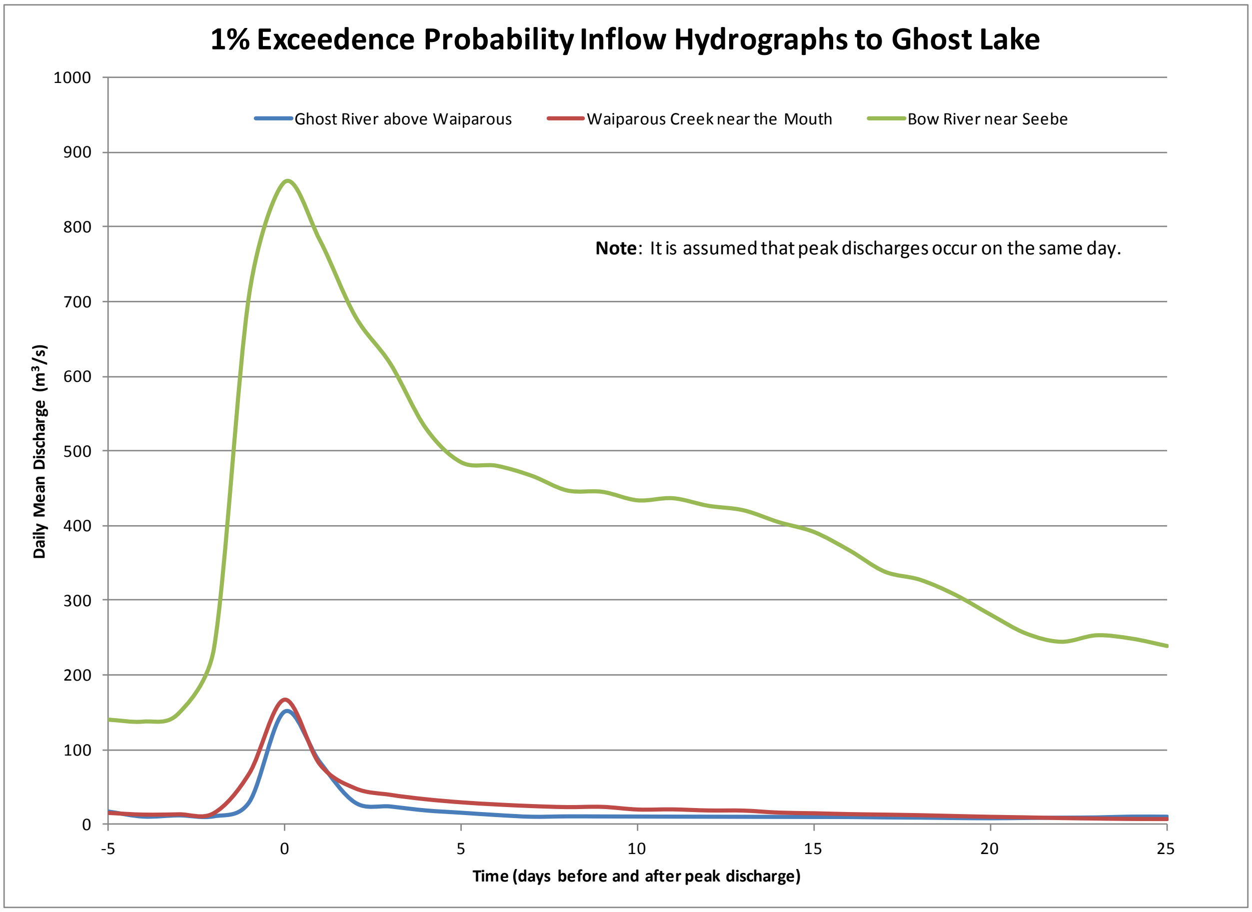


2.2 Discharges for 1% Exceedence Flood

2.2.1 Discharges with Contributions from the Ghost River

Figure 3 illustrates the 1% exceedance probability hydrographs for the streams entering Ghost Lake. Based on a review of the available information, it was determined that the peak discharge for all streams, except the Bow River at Calgary, would generally occur on the same day, while the Bow River at Calgary would peak one day later than the rest.

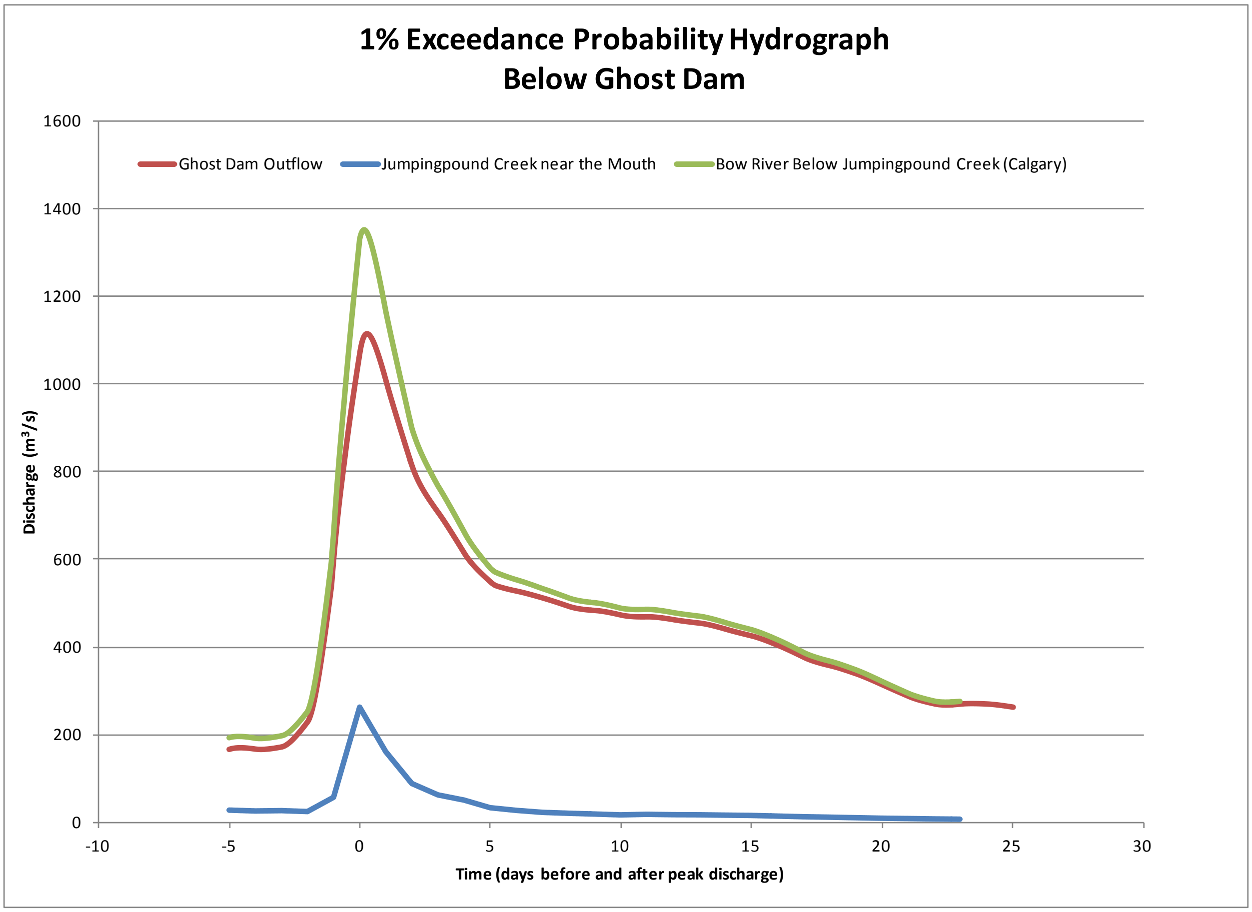
Figure 3 Hydrographs for Streams Entering Ghost Lake



Routing of the Bow River, Ghost River and Waiparous Creek inflows through Ghost Lake results in some reduction in the peak discharge. For example, and considering the limitations of the modeling used for this assessment, the sum of the peak inflows is approximately 1,180 m^3/s, while the maximum outflow is computed to be 1,115 m^3/s, a reduction of 5%.

Figure 4 illustrates the outflow from Ghost Dam, the flow from Jumpingpound Creek that flows into the Bow River upstream of Cochrane, and the sum of these two discharges (1,353 m^3/s).

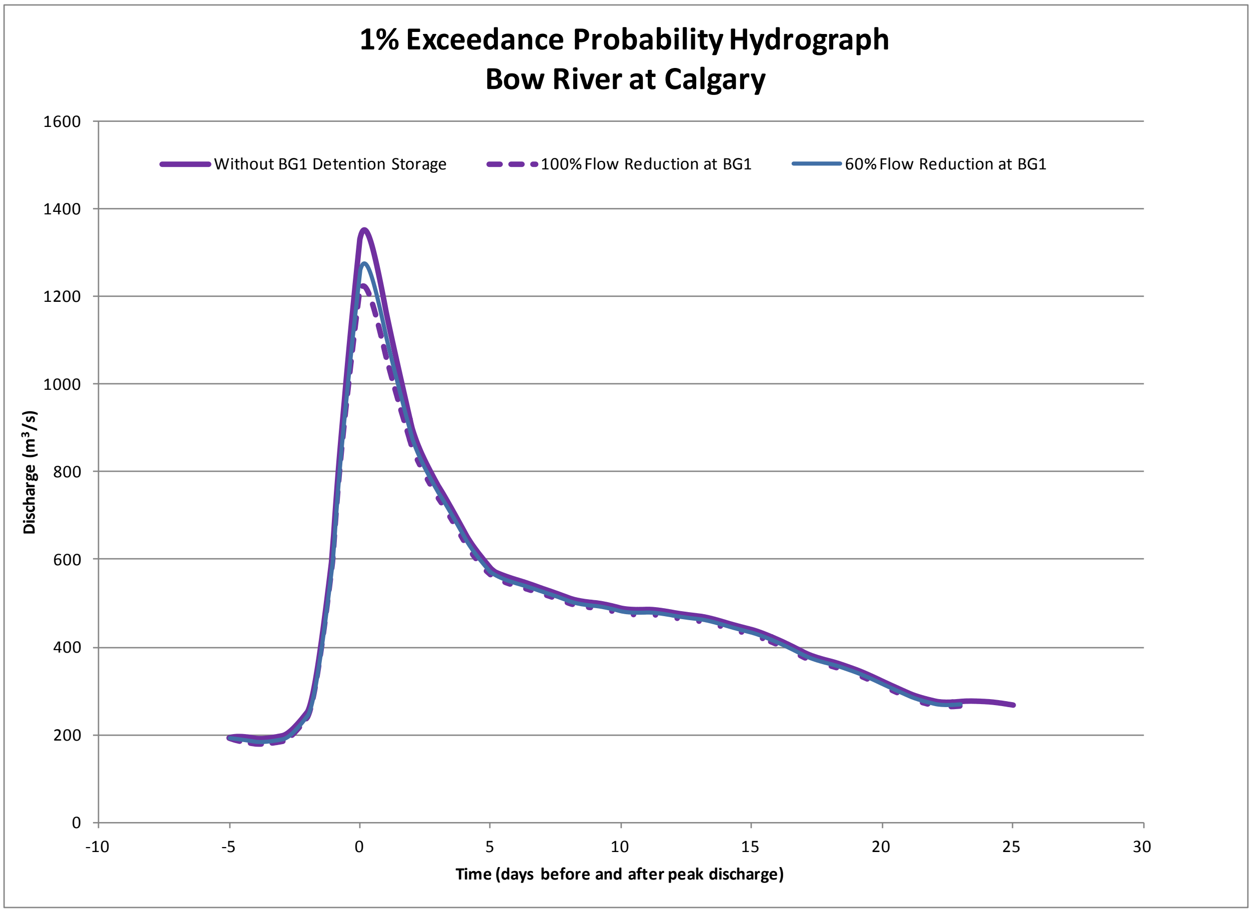
Figure 4 Hydrographs Below Ghost Dam



2.2.2 Effects on Discharges with BG1 Detention Dam

The proposed detention dam BG1 will hold back flows from the Ghost River. If the assumption is made that flows are entirely retained (outflow is zero), then the flow contribution from the Ghost River in the model can be simply deleted. For this case, the routing of the flow through Ghost Dam results in a peak daily mean outflow discharge of 980 m^3/s. Adding the Jumpingpound flow results in a modeled peak daily discharge of 1,224 m^3/s at Calgary. This is 129 m^3/s less than was modeled with the inflow from the Ghost River included (a reduction of 10%). **Figure 4** illustrates the outflow from Ghost Dam with and without the contribution from the Ghost River at BG1.

Figure 4 Comparison of 1% Exceedance Probability Flood Hydrographs for the Bow River at Calgary With and Without Proposed BG1 Detention Storage



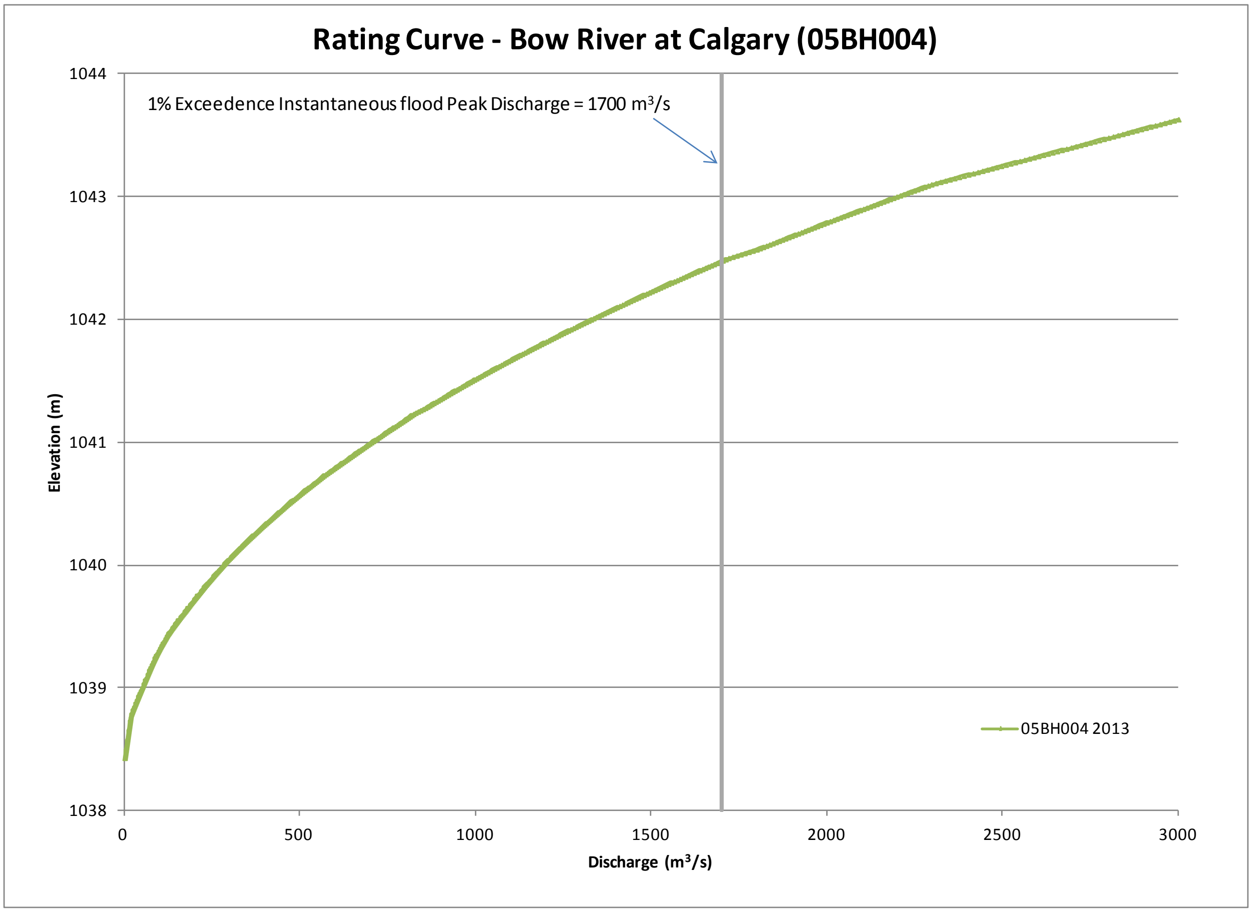
The effect modeled above was for a retention facility, which would effectively retain all of the flow from the Ghost River basin upstream of Waiparous Creek. For the detention type of facility envisaged by the Flood Advisory Panel, some flow would be released during the event. Based on modeling conducted by AMEC using the Flood Advisory Panel's representation of a similar facility (detention dam EQ1 on the Elbow River), AMEC determined that the maximum outflow from the structure would be approximately 40% of the inflow (i.e., a 60% reduction). This percentage was applied to the Ghost River hydrograph, and the modified flow was incorporated into the model as an input to Ghost Lake. The net effect is that the maximum discharge at Calgary would be lowered by approximately 77 m^3/s (6% reduction).

2.3 Water Levels

2.3.1 Water Level Changes at WSC Gauge Site

Water levels for the various modeled discharges were estimated using the rating curve for the WSC hydrometric station, Bow River at Calgary (05BH004). **Figure 5** illustrates the curve, which is dated 10 April 2013.

Figure 5 Rating Curve – Bow River at Calgary



The difference in water levels resulting from the reduction in discharges discussed in **Section 2.2** can be determined from the rating curve. **Table 1** illustrates the changes in discharge and water level from the modeling.

Table 2.1
Comparison of Discharges and Water Levels at Calgary

Case	Maximum Daily Discharge at Calgary (m^3/s)	Water Level at WSC Station 05BH004 (m)
No dam on Ghost River	1,353	1,042.03
BG1 Dam on Ghost River – Retention dam (no outflow)	1,224	1,041.85
BG1 Dam on Ghost River – Detention dam (60% inflow reduction)	1,276	1,041.93

From **Table 1** the effect of the proposed BG1 would be to reduce water levels at Calgary by approximately 0.18 m (7 inches) if 100% of the flow is held back from the Ghost River upstream of Waiparous Creek. For the flood detention structure the 60% reduction in flow from the Ghost River would produce a reduction in water level from the no dam case of approximately 0.1 m (4 inches).

2.3.2 Water Level Changes at Other Locations

As the hydraulic conditions at the WSC gauging site might not be representative of other sites along the Bow River, two additional locations that are known to be flood prone were selected for assessment. The sites selected were at Sunnyside (downstream of the 10th Street (Hillhurst/Louise) Bridge and in Bowness along Bowness Crescent. Water levels were obtained from the results of floodplain modeling presented in Golder 2012. **Table 2** and **Table 3** present the results for Sunnyside and Bowness, respectively.

Table 2.2
Comparison of Discharges and Water Levels at Sunnyside

Case	Maximum Daily Discharge at Calgary (m^3/s)	Water Level at HEC-RAS Station 50553 (m)
No dam on Ghost River	1,353	1,046.70
BG1 Dam on Ghost River – Retention dam (no outflow)	1,224	1,046.49
BG1 Dam on Ghost River – Detention dam (60% inflow reduction)	1,276	1,046.58

Table 2.3
Comparison of Discharges and Water Levels at Bowness

Case	Maximum Daily Discharge at Calgary (m^3/s)	Water Level at HEC-RAS Station 60788 (m)
No dam on Ghost River	1,353	1,066.05
BG1 Dam on Ghost River – Retention dam (no outflow)	1,224	1,065.78
BG1 Dam on Ghost River – Detention dam (60% inflow reduction)	1,276	1,065.90

From **Table 2** and **Table .3** the effect of the proposed BG1 would be to reduce water levels at Sunnyside and at Bowness by approximately 0.21 m (8.5 inches) and 0.27 m (10.6 inches), respectively. For the flood detention structure the 60% reduction in flow from the Ghost River would produce a reduction in water level from the no dam case at Sunnyside and at Bowness by approximately 0.12 m (5 inches) and 0.15 m (6.2 inches), respectively.

3.0 CONCLUSIONS

Modeling of the potential effects of the proposed BG1 detention dam on the Ghost River above Waiparous Creek has indicated that the estimated water level reduction on the Bow River at Calgary might potentially be reduced by a maximum of 0.18m to 0.27 m. Water level reductions for a detention dam at the BG1 site would more likely be less, in the range of 0.1 m to 0.16 m.

4.0 CLOSURE

This report has been prepared for the exclusive use of the Flood Recovery Task Force. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

Gary Beckstead, M.SC. P.Eng.
Principal Engineer – Water Resources

GREB/elf

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amec

Memo

To:	**File**	**File No:**	**CW2174**
		Date:	**21 May 2014**
From:	**Agata Hall**	**cc:**	**Gary Beckstead**
	Neil van der Gugten		**Ken Kress**
Phone:			
Email:			
Subject:	**Southern Alberta Flood Recovery Task Force Flood Mitigation Measures for the Bow, Elbow and Oldman Basins Preliminary Inflow Design Floods for Flood Control Dams on the Elbow and Bow Rivers**		

1.0 PURPOSE AND LIMITATIONS

The purpose of this Memorandum is to present the results of hydrologic analyses conducted to develop preliminary inflow design flood (IDF) hydrographs for several flood control dams being considered on the Elbow and Bow Rivers, and to document the methodology and the data used. This work is limited to statistical frequency flood analyses; evaluations to estimate probable maximum flood (PMF) hydrographs were not undertaken.

The results presented herein are based on standard hydrologic methods of analysis considered appropriate for conceptual design. For subsequent preliminary and detailed design of flood mitigation measures, more detailed hydrologic analyses should be conducted.

2.0 ELBOW RIVER DAM SITES

2.1 Overview

Two potential dam sites are being considered for the Elbow River upstream of the Glenmore Reservoir - one site is on the main stem above McLean Creek (Site MC1) and the other site is off the main stem near Springbank Road (Site SR1). The two sites would provide flood control at about the same point on the Elbow River, thus one set of IDF hydrographs are considered applicable to both sites.

2.2 Available Data

The two dam sites are both located relatively near the Glenmore Reservoir, thus the hydrometric data for the Elbow River at or near Glenmore Reservoir are applicable. Three Water Survey of Canada (WSC) hydrometric stations are, or have been, operated at or near the Glenmore Reservoir, as listed in Table 1. The current operating station upstream of the reservoir is Station 05BJ010 - Elbow River at Sarcee Bridge (1979 to the present). Prior to 1979, Station 05BJ005 - Elbow River above Glenmore Dam was operational from 1933 to 1977.

AMEC Environment & Infrastructure
A Division of AMEC Americas Limited
5681 – 70 Street
Edmonton, Alberta, CANADA T6B 3P6
Tel: +1 (780) 436-2152
Fax: +1 (780) 435-8425
www.amec.com

Another current operating station is Station 05BJ001 - Elbow River below Glenmore Dam - which was established in 1908. The data from that station can be used for the period prior to 1932 before the Glenmore Dam was constructed.

Table 1 shows that the drainage areas for the three stations are within a few percent of the 1220 km^2 of the central value. Data for all three stations can therefore be combined without adjustment to represent an extended data set for Elbow River inflows to Glenmore Reservoir.

2.3 Annual Flood Peak Discharge Data Series

The combined annual peak instantaneous and daily discharge data for the Elbow River near Glenmore Reservoir are listed in Table 2. The WSC data extend to 2012. Estimated peak discharge values for 2013 were obtained from the City of Calgary. The combined data series consists of 103 years of data, covering the period 1908 through 2013 (with missing data for 1933, 1978 and 1991).

Instantaneous discharges were not monitored prior to 1979, and were also missing for a few other years. Missing values for annual peak instantaneous discharges (Q_{inst}) were estimated from peak daily discharge values (Q_{daily}) using a relationship derived from observed data; that relationship was found to be:

$$Q_{inst} = 0.0010\ Q_{daily}^2 + 1.0135\ Q_{daily}$$

The derivation of this relationship is shown in Figure 1. A time series of the instantaneous peak discharges is illustrated in Figure 2.

2.4 Characteristics of Annual Peak Hydrographs

A cursory review was undertaken of annual peak hydrographs to assess the variability in the timing and the duration of peak runoff events, and to evaluate whether they are generated by snowmelt, rainfall, or a combination of snowmelt and rainfall. The following characteristics were noted:

- The annual peak most often occurs in the period mid-May to mid-June, and has a highly variable hydrograph shape:
    - A minority of the annual peak hydrographs have simple rising and recession limbs, indicating a single primary generating mechanism of either snowmelt or rainfall.
    - Most hydrographs have one or more secondary peaks, with variable overall durations, indicating complex watershed runoff processes involving a combination of rainfall and snowmelt.
- A few annual peaks occur before mid-May - as early as the beginning of April - due to early snowmelt.
- Approximately 20 percent of annual peaks occur in the period July - September and are rainfall-only events.

The noted characteristics indicate that thorough hydrologic analyses should include investigation of the following aspects:

- Separate frequency analyses of annual snowmelt peaks and rainfall peaks
- Partial duration (peaks over threshold) frequency analyses

- Runoff hydrograph volume analyses using various durations to capture the effects of complex, overlapping and/or sequential runoff events; durations should cover a range adequate to evaluate and optimize combinations of flood storages and discharge capacities for the flood control dams being considered.

Due to inherent limitations associated with the current conceptual design phase, the above-noted aspects were not considered in this preliminary hydrologic study, however they should be part of subsequent phases.

2.5 Flood Peak Frequency Analysis

The annual peak discharges were used, as published, as the basis for frequency analyses, without consideration of the generating mechanism or time of year. Flood peak frequency analyses were conducted separately for the annual peak daily and the annual peak instantaneous discharge data sets. The lognormal, 3-parameter lognormal, Pearson Type III and log-Pearson Type III probability distributions were tested as well as each available parameter estimation technique including method of moments and maximum likelihood. It was found that for specific probability distributions, some parameter estimation techniques produced excessively high peak discharge estimates for exceedance probabilities less than 1%. Evaluation of the results indicated that the log-Pearson Type III (LP3) distribution, with the method of moments (MOM) parameter estimation technique, produced the best fit with to the data. The results of the flood frequency analyses are provided in Table 3.

Table 3 includes the median values derived from the data directly (see Table 2). The fitted 1:2 year values should ideally equal the median values, but as is often the case when fitting a theoretical probability distribution, they deviate slightly from the median values. The median value is the more correct definition of the 1:2 year value[1], however it may be more consistent to use the fitted 1:2 year value when other return period values are being considered in design computations.

2.6 Flood Volume Frequency Analysis

The typical shape of major flood hydrographs was evaluated by examining plots of recorded daily discharges for several selected larger flood events, normalized on the peak day value, as shown in Figure 3. The selected hydrographs were chosen to represent events with a single main peak and a minimum of secondary peaks. The plotted hydrographs indicated that the typical main peak involves a 7-day duration and a 2-day rise to peak, with the peak occurring on Day 2. In addition, a base flow amount is typically present at the start of the hydrograph rise.

A unit hydrograph approach to IDF development was initially considered, but was found inapplicable due to the fact that return period values for hydrograph volumes were found to be discordant with return period values for hydrograph peak discharges (i.e. ratios of V_N:V_2 did not agree with ratios of Q_N:Q_2). Separate frequency analyses were therefore conducted on flood runoff volumes. The methodology involved the following steps:

[1] Thus in Table 3 the instantaneous value is slightly higher than the daily value for the medians, as expected, while that is not the case for the fitted 1:2 year values.

- First, data series of annual maximum flood volumes were developed for consecutive durations of 1 day through 7 days, for the combined daily discharge data provided by the three WSC stations. No attempt was made to restrict the search window to a specific runoff event. Thus, although the annual 1-day duration peak volume would automatically occur on the same day as the annual peak daily discharge, annual 2-day or longer duration volumes could correspond to a different runoff event than the one that produced the annual peak daily discharge. The data series so produced should therefore be considered as synthetic.

- Second, a frequency analysis was conducted on the data set for each duration. The log-Pearson Type III (LP3) distribution, with the method of moments (MOM) parameter estimation technique, was used for consistency with the frequency analysis of flood peaks. The results are listed in Table 4.

2.7 IDF Hydrographs

Return periods of 20, 100 and 500 years were selected for hydrograph volume development, based on guidance from the dam design team. Synthetic hydrographs were then constructed for each return period as follows:

- Day 2 (the day of the peak) receives the 1-day return period value,
- Day 3 (the first day of the recession limb) receives the net of the 2-day value minus the 1-day value,
- Day 1 (the rising limb) receives the net of the 3-day value minus the 2-day value,
- Day 4 receive the net of the 4-day value minus the 3-day value,
- Days 5, 6 and 7 each receive in descending order the net volume per day of the remaining days.
- The base flow amount prior to Day 1 is shown on Day 0.

The total 7-day volume for the hydrograph so obtained was compared with the volume obtained from the frequency analysis for the 7-day duration to verify the results. The Day 0 base flow amount is not included in the 7-day volume.

The resulting 20-year, 100-year and 500-year return period daily discharge hydrographs are presented in Figures 4, 5 and 6 respectively, and are summarized in Table 5 below.

2.8 Flood Volumes - Flood Peaks Relationships

The relationship between flood runoff volume and the annual instantaneous peak discharge as well as the annual daily peak discharge was determined by plotting the return period values as shown in Figures 7 and 8 respectively. The relationships are given below:

IDF 7-Day Volume (dam^3) = 2086 $(Q_{inst})^{0.605}$

IDF 7-Day Volume (dam^3) = 1344 $(Q_{daily})^{0.728}$

2.9 Incorporation of Historical Flood Data

2.9.1 Flood Peak Analyses - Previous Studies

Several large historically observed floods occurred in 1879, 1897, and 1902 on the Bow and Elbow Rivers prior to the beginning of systematic hydrometric monitoring. Estimates of peak instantaneous discharges for those floods, based on high water marks and/or anecdotal descriptions, have been made for the Bow River at Calgary, as reported in AENV 1983. Those peak discharges were estimated at 2270 m^3/s (80,000 cfs) for both the 1879 and 1897 floods, and 1560 m^3/s (55,000 cfs) for the 1902 flood.

As part of the noted 1983 study, Alberta Environment conducted frequency analyses for annual peak discharges on the Bow River above the Elbow River, for both the hydrometric record period of 1908 to 1980, and the extended period of 1879 to 1980 which included the three noted flood peaks. The Pearson Type III distribution was used for those analyses. The analyses found that the estimated instantaneous peaks derived from the frequency analysis for the extended period were higher than the corresponding estimates for the hydrometric record period only. The relationships between the two estimates are given in Table 6. The 1983 study also examined the relationship between flood frequencies of the Elbow River near Glenmore Dam and those of the Bow River above the Elbow, and found that the two sets of flood frequencies exhibited the same properties, such that the Table 6 values were directly applicable to the Elbow River. The ratios in Table 6 for the 1:200 and 1:500 year frequencies were obtained from a subsequent study (W-E-R *et al.* 1986).

2.9.2 Flood Peak Analyses - Current Study

For the current study, the 1983 approach was applied to the Bow River at Calgary (WSC Station 05BH004) using the period of hydrometric record 1911 to 2013, and the extended period 1879 to 2013. The extended period data set (1879 to 2013) was created by adding the three pre-1911 flood peak data and then filling in the missing years with the median value of the 1911 to 2013 data set. The log-Pearson Type III (LP3) distribution and the method of moments (MOM) parameter estimation technique was used for both periods. The results are given in Table 7.

The Table 7 ratios are smaller than the Table 6 ratios obtained in the previous studies. That is to be expected, as the Table 7 ratios incorporate the effects of both a longer period of record and the large 2013 flood peak, both of which reduce the influence of the three historic flood peaks in the extended period. Based on the finding by previous studies of flood frequency similarity between the Bow and Elbow Rivers, it is considered that the Table 7 ratios are directly applicable to the Elbow River near Glenmore Reservoir. The Table 7 ratios were thus applied to the instantaneous flood peak frequency results obtained for the period of record 1908 - 2013 as shown in Table 3, to estimate values for the extended period 1879 to 2013; the results are listed in Table 8.

Table 8 also lists, for the extended period 1879 to 2013, the peak daily discharges corresponding to the peak instantaneous discharges. Those daily values were computed using the two relationships found for 7-day flood runoff volume and the annual instantaneous peak discharge and the annual daily peak discharge as presented above in Section 2.8. This method was used to maintain consistency between flood peaks and volumes in the IDF hydrographs.

2.9.3 Adjustment of Flood Volumes

As indicated above, return period 7-day flood volumes corresponding to the flood peaks obtained by up-scaling using the extended period data set (1879 to 2013) were obtained by applying the instantaneous peak vs 7-day flood volume relationship presented in Section 2.7. The 7-Day flood volumes for both the 1908 to 2013 and the 1987 to 2013 periods, and their ratios, are summarized in Table 9.

2.10 Historically Adjusted IDF Hydrographs

The 1:20 year, 1:100 year and 1:500 year IDF hydrographs as derived from the recorded data for the period 1908 to 2013 were adjusted to account for the three large historical floods, by increasing the flood volumes and daily discharges in accordance with the adjustment ratios and values found as reported in the preceding sections. The adjustments to daily discharges were made as follows:

- The total 7-day runoff volume was adjusted to equal the adjusted value as reported in Table 9.
- The hydrograph peak day value, i.e. the Day 2 value, was increased to the adjusted peak daily value as per the last column of Table 8. It was found that the incremental increase for that day represented 40 % (for the 1:20 year event) to 54 % (for the 1:500 year event) of the total 7-day volume increase.
- The remainder of the 7-day volume increase was proportionately distributed between Day 1 and Day 3, in order to provide a conservative hydrograph shape for design, which was focussed on providing flood storage volume above a specific threshold.
- Days 4 through 7 were retained unchanged.

The resulting daily discharge values for each IDF are summarized in Table 10.

In addition to the above, quasi-instantaneous hydrographs were estimated from the adjusted daily discharge hydrographs, as follows:

- Assign the adjusted peak instantaneous value (Table 8 second last column) to the beginning of the peak day (Day 2).
- Select other instantaneous values at 6-hour point intervals for the rising limb and the recession limb so as to preserve the runoff volume corresponding to the daily discharge volume for each day.

The resulting 6-hour (quarter-day) point discharge values for each IDF are summarized in Table 11.

The adjusted IDF hydrographs are illustrated in Figures 9, 10 and 11 for the 1:20 year, 1:100 year and 1:500 year return periods, respectively. In each case the daily discharge IDF is shown as a bar chart, while the quasi-instantaneous IDF is shown as quarter-day point values with connecting lines.

3.0 BOW RIVER DAM SITES

3.1 Overview

The only location currently under consideration for flood control dams on the Bow River is a dam site near Morley.

3.2 Available Data

There are four WSC hydrometric stations relevant to developing flood hydrology for the Bow River near Morley; those stations and their periods of record are listed in Table 12. One WSC station - Bow River near Morley (05BE001) - was located at the site of interest, but was only operated in 1910 and 1911. However, an active station - Bow River near Seebe (05BE004) - is located just upstream of Morley. The Seebe station has a drainage area within 4 % of that of the Morley Station and the data for Seebe can therefore be used without adjustment. The Seebe station began operation in 1923, but has a large data gap extending from 1963 to 1978. Various correlations with regional stations were attempted to fill in the missing 16 years of data, but the results were not considered acceptable.

The Station 05BE004 data set was extended back to 1912 using two upstream stations - Bow River near Kananaskis (05BE003) and Kananaskis River near Seebe (05BF001). Those two stations combined (drainage areas of 4160 km^2 and 933 km^2 respectively) closely approximate the discharge at Station 05BE004 (drainage area 5170 km^2).

3.3 Annual Flood Peak Discharge Data Series

The combined annual peak instantaneous and daily discharge data for the Bow River near Morley are listed in Table 13. The WSC data extend to 2011. Estimated peak discharge values for 2013 were obtained from TransAlta Corp. The combined data series consists of 85 years of data, covering the period 1912 through 2013, with missing data for the years 1963 to 1978 and 2012.

Missing values for annual peak instantaneous discharges (Q_{inst}) were estimated from peak daily discharge values (Q_{daily}) using a relationship derived from the observed data (but excluding 2013); that relationship was found to be a linear relationship as follows:

$$Q_{inst} = 1.147\ Q_{daily}$$

The derivation of this relationship is shown in Figure 12. A time series of the instantaneous peak discharges is illustrated in Figure 13.

3.4 Characteristics of Annual Peak Hydrographs

Characteristics of the annual peak hydrograph for the Bow River appear to resemble Elbow River hydrographs in terms of variability and complexity. Due to inherent limitations associated with the current conceptual design phase, special studies related to hydrograph characteristics were not included in this preliminary hydrologic study, however they should be part of subsequent phases. For consistency in this study, the same hydrologic methods were used for the Bow River as were used for the Elbow.

3.5 Flood Peak Frequency Analysis

Flood frequency analyses were performed only on the annual peak daily discharges. As for the Elbow River analyses, the log-Pearson Type III (LP3) distribution with the method of moments (MOM) parameter estimation technique was determined to best fit the data. Frequency values for annual peak instantaneous discharges were not computed by frequency analysis of the instantaneous discharge data series, but were estimated by applying the linear relationship between the instantaneous and daily peaks found above. Table 14 lists the return period values for both the annual daily and the annual instantaneous peaks.

3.6 Flood Volume Frequency Analysis

The typical shape of major flood hydrographs was evaluated by examining plots of recorded daily discharges for several selected larger flood events, normalized on the peak day value, as shown in Figure 14. The selected hydrographs were chosen to represent events with a single main peak and a minimum of secondary peaks. The plotted hydrographs indicated that the typical main peak involves a 10-day duration and a 5-day rise to peak, with the peak occurring on Day 5. In addition, a base flow amount is typically present at the start of the hydrograph rise.

Using the same method as described above for the Elbow River (Section 2.6), frequency analyses of 1-day to 10-day annual maximum flood volumes yielded the results as summarized in Table 15.

3.7 IDF Hydrographs

Return periods of 20, 100, 500 and 1000 years were selected for hydrograph volume development, based on guidance from the dam design team. Synthetic hydrographs were then constructed for each return period as follows:

- Day 5 (the day of the peak) receives the 1-day return period value,
- Day 6 (the first day of the recession limb) receives the net of the 2-day value minus the 1-day value,
- Day 4 (the day before the peak) receives the net of the 3-day value minus the 2-day value,
- Day 7 receive the net of the 4-day value minus the 3-day value,
- Days 8, 2, 9, 10 and 1 then each receive in descending order the net volume per day of the remaining days.
- The base flow amount prior to Day 1 is shown on Day 0.

The total 10-day volume for the hydrograph so obtained was compared with the volume obtained from the frequency analysis for the 10-day duration to verify the results. The Day 0 base flow amount is not included in the 10-day volume. The resulting 20-year, 100-year, 500-year and 1000-year return period daily discharge hydrographs are presented in Figures 15, 16, 17 and 18 respectively; their daily values are summarized in Table 16 below.

3.8 Flood Volumes - Flood Peaks Relationships

The relationship between flood runoff volume and the annual instantaneous peak discharge as well as the annual daily peak discharge was determined by plotting the return period values as shown in Figures 19 and 20 respectively. The relationships are given below:

$$\text{IDF 10-Day Volume (dam}^3\text{)} = 2894\ (Q_{inst})^{0.754}$$

$$\text{IDF 10-Day Volume (dam}^3\text{)} = 3210\ (Q_{daily})^{0.754}$$

Note that the above equations are not independent and reflect the fact that the instantaneous peak discharge return period values were estimated from the corresponding daily values by the constant factor 1.147 (Section 3.3).

3.9 Incorporation of Historical Flood Data

3.9.1 Flood Peak Analysis

The three large historical flood peaks of 1879, 1897 and 1902 were used to scale up the flood peak frequency results for the Bow River near Morley derived from the hydrometric data set using the same approach as described in Section 2.9.2 above, i.e., derive a set of scaling ratio values based on frequency analyses of the Bow River at Calgary using first the 1911 to 2013 data set and then the extended 1879 to 2013 data set. However, in this case the 1911 to 2013 data set was revised by removing the data for the period 1963 to 1978, in order to correspond to the Bow River near Morley data set which has data missing for that period. The resulting frequency results and scaling ratios are summarized in Table 17. The noted scaling ratios are then applied to the previously obtained Bow River near Morley values from Table 14 to produce adjusted values as summarized in Table 18.

3.9.2 Adjustment of Flood Volumes

Return period 10-day flood volumes corresponding to the flood peaks obtained by up-scaling using the extended period data set (1879 to 2013) were obtained by applying the 10-day flood volume vs. instantaneous peak discharge relationship presented in Section 3.8. The 10-day flood volumes for both the 1912 to 2013 and the 1987 to 2013 data sets, and their ratios, are summarized in Table 19.

3.10 Historically Adjusted IDF Hydrographs

The 1:20 year, 1:100 year, 1:500 and 1:1000 year IDF hydrographs as derived from the recorded data for the period 1912 to 2013 were adjusted to account for the three large historical floods, by increasing the flood volumes and daily discharges in accordance with the adjustment ratios and values found as reported in the preceding sections. The adjustments to daily discharges were made as follows:

- The total 10-day runoff volume was adjusted to equal the adjusted value as reported in Table 19.
- The hydrograph peak day value, i.e. the Day 5 value, was increased to the adjusted peak daily value as per the second last column of Table 18. It was found that the incremental increase for that day represented 18 % (for the 1:20 year event) to 20 % (for the 1:1000 year event) of the total 10-day volume increase.
- The remainder of the 10-day volume increase was proportionately distributed between the three days before and the three days after Day 5.
- Days 1, 9 and 10 were retained unchanged.

The resulting daily discharge values for each IDF are summarized in Table 20. The adjusted IDF hydrographs are illustrated in Figures 21, 22, 23, and 24 for the 1:20 year, 1:100 year, 1:500 year and 1:1000 year return periods, respectively. In addition, a quasi-instantaneous hydrograph is shown for the 1:100 year IDF using the same approach as described above for the Elbow River in Section 2.10. Inspection of the daily and quasi-instantaneous 1:100 year IDF hydrographs shows little difference between the two, therefore quasi-instantaneous versions for the other IDFs were not prepared at this stage.

4.0 REFERENCES

Alberta Environment (AENV) 1983. City of Calgary Floodplain Study.

Northwest Hydraulic Consultants Ltd. (NHC), 1992. Little Bow River Project, Little Bow River Dam, Volume II – Ancillary Report 2, Flood Frequency Analyses, Highwood and Little Bow Rivers. Prepared for Alberta Public Works, Supply & Services.

W-E-R Engineering Ltd, IBI Group, Ecos Engineering Services, Ltd., 1986. Elbow River Floodplain Management Study. Prepared for Alberta Environment.

Table 1: Elbow River near Glenmore Reservoir Hydrometric Stations

Station Number	Station Name	Record Period	Drainage Area (km^2)
05BJ001	Elbow River below Glenmore Dam	1908 to present	1240
05BJ005	Elbow River above Glenmore Dam	1933 to 1977	1220
05BJ010	Elbow River at Sarcee Bridge	1979 to present	1190

Table 2: Elbow River near Glenmore Reservoir Annual Peak Discharge Data Stations 05BJ001, 05BJ005, 05BJ010 (1908-2013)

Station Number	Year	Peak Instantaneous Discharge[2] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BJ001	1908	*186*		159	June 2
05BJ001	1909	*104*		94	June 3
05BJ001	1910	*19.2*		18.6	Sept 19
05BJ001	1911	*98.7*		89.5	Aug 8
05BJ001	1912	*139*		122	June 16
05BJ001	1913	*40.8*		38.8	Aug 10
05BJ001	1914	*30.1*		28.9	June 18
05BJ001	1915	*299*		239	June 26
05BJ001	1916	*169*		146	June 29
05BJ001	1917	*171*		147	June 3
05BJ001	1918	*37.1*		35.4	June 10
05BJ001	1919	*78.7*		72.5	Aug 6
05BJ001	1920	*73.2*		67.7	July 13
05BJ001	1921	*39.3*		37.4	May 25
05BJ001	1922	*27.6*		26.5	May 17
05BJ001	1923	*445*		331	June 1
05BJ001	1924	*63.8*		59.5	Aug 4
05BJ001	1925	*71.8*		66.5	June 12
05BJ001	1926	*97.1*		88.1	Sept 11
05BJ001	1927	*91.4*		83.3	June 10
05BJ001	1928	*111*		100	June 19
05BJ001	1929	*533*		382	June 3
05BJ001	1930	*31.9*		30.6	May 31
05BJ001	1931	*23.7*		22.9	April 8
05BJ001	1932	726[3]		311	June 3
	1933	-		-	
05BJ005	1934	*25.3*		24.4	June 10

[2] Italicized instantaneous discharge values were computed using the following relationship derived from observed data: $Q_{inst} = 0.0010*Q_{daily}^2 + 1.0135*Q_{daily}$.
[3] The 1932 instantaneous discharge is provided in W-E-R *et al.,* 1986.

Station Number	Year	Peak Instantaneous Discharge[2] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BJ005	1935	*30.4*		29.2	June 18
05BJ005	1936	*33.8*		32.3	June 2
05BJ005	1937	*56.7*		53.2	June 14
05BJ005	1938	*64.8*		60.3	July 3
05BJ005	1939	*100*		90.6	June 17
05BJ005	1940	*38.0*		36.2	Sept 6
05BJ005	1941	*41.2*		39.1	June 2
05BJ005	1942	*145*		127	May 11
05BJ005	1943	*32.5*		31.1	April 4
05BJ005	1944	*24.8*		23.9	June 13
05BJ005	1945	*81.4*		74.8	June 1
05BJ005	1946	*54.0*		50.7	June 7
05BJ005	1947	*73.8*		68.2	May 11
05BJ005	1948	*145*		127	May 23
05BJ005	1949	*20.4*		19.7	May 22
05BJ005	1950	*36.8*		35.1	June 16
05BJ005	1951	*158*		137	Aug 31
05BJ005	1952	*86.3*		79	June 23
05BJ005	1953	*151*		132	June 4
05BJ005	1954	*51.1*		48.1	Aug 25
05BJ005	1955	*48.6*		45.9	May 20
05BJ005	1956	*39.3*		37.4	July 4
05BJ005	1957	*31.6*		30.3	June 9
05BJ005	1958	*58.7*		54.9	July 14
05BJ005	1959	*52.4*		49.3	June 27
05BJ005	1960	*31.3*		30	June 4
05BJ005	1961	*54.3*		51	May 27
05BJ005	1962	*28.9*		27.8	June 17
05BJ005	1963	*141*		124	June 30
05BJ005	1964	*67.7*		62.9	June 9
05BJ005	1965	*116*		104	June 18
05BJ005	1966	*38.3*		36.5	July 3
05BJ005	1967	*241*		199	May 31
05BJ005	1968	*54.6*		51.3	June 8
05BJ005	1969	*142*		125	June 30
05BJ005	1970	*108*		97.1	June 14
05BJ005	1971	*93.6*		85.2	June 6
05BJ005	1972	*44.2*		41.9	June 1
05BJ005	1973	*48.0*		45.3	May 27
05BJ005	1974	*66.7*		62	June 18
05BJ005	1975	*52.1*		49	June 21
05BJ005	1976	*39.8*		37.9	Aug 6
05BJ005	1977	*16.8*		16.3	Aug 15
	1978	-		-	
05BJ010	1979	41.3	May 27	36	May 27
05BJ010	1980	59.7	June 4	52.9	June 4
05BJ010	1981	121	May 26	101	May 26
05BJ010	1982	38.2	June 15	32.3	June 15

Station Number	Year	Peak Instantaneous Discharge[2] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BJ010	1983	42.8	April 25	30.4	April 25
05BJ010	1984	21.9	June 9	20.7	June 9
05BJ010	1985	71.7	Sept 13	63.2	Sept 13
05BJ010	1986	54.1	May 29	49.7	May 29
05BJ010	1987	29.6	July 19	27.4	July 19
05BJ010	1988	35.1	June 8	29.4	June 8
05BJ010	1989	23	June 10	22.4	June 10
05BJ010	1990	158	May 26	128	May 26
05BJ010	1991	-		-	
05BJ010	1992	122	June 15	110	June 15
05BJ010	1993	*93.1*		84.8	June 17
05BJ010	1994	*72.4*		67	June 7
05BJ010	1995	*261*		213	June 7
05BJ010	1996	*46.9*		44.3	June 9
05BJ010	1997	*64.2*		59.8	June 1
05BJ010	1998	*114*		102	May 28
05BJ010	1999	63.4	July 15	54.9	July 15
05BJ010	2000	19	June 11	18.3	June 11
05BJ010	2001	*45.8*		43.3	June 5
05BJ010	2002	89	June 17	80.4	June 17
05BJ010	2003	60.1	April 26	35.2	May 26[4]
05BJ010	2004	*38.2*		36.4	Aug 26
05BJ010	2005	338	June 18	268	June 18
05BJ010	2006	140	June 16	122	June 16
05BJ010	2007	76.1	June 7	68.9	June 18
05BJ010	2008	220	May 25	183	May 25
05BJ010	2009	43.6	July 14	40.2	July 14
05BJ010	2010	51.9	June 18	49.1	June 18
05BJ010	2011	215	May 27	180	May 27
05BJ010	2012[5]	146	June 6	113	June 6
	2013[6]	1240	June 20	682	June 21
basic statistics of the data					
maximum		1240		682	
mean		107		85.7	
median		63.4		54.9	
min		16.8		16.3	

[4] For the derivation of the instantaneous peak vs daily peak relationship, the actual April 26 daily discharge of 33.9 m^3/s was used.
[5] The 2012 discharge is preliminary and was provided by WSC.
[6] The 2013 discharge is preliminary and was provided by the City of Calgary.

Table 3: Elbow River near Glenmore Reservoir
Annual Peak Discharge Frequency Analysis (1908 to 2013 Data)

Return Period (years)	Daily Discharge (m^3/s)	Instantaneous Discharge (m^3/s)
1000	812	1480
500	686	1230
200	537	933
100	438	737
50	350	564
20	248	372
10	182	252
5	124	155
2	58.7	57.4
median	54.9	63.4

Table 4: Elbow River near Glenmore Reservoir
Annual Peak 1-Day to 7-Day Runoff Volumes (1908 to 2013 Data)

Return Period years)	Cumulative Discharge Volume over N Consecutive Days (m^3/s - days)							7-Day Volume (dam^3)
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days	
1000	812	1310	1610	1790	1890	1970	2040	176256
500	686	1110	1370	1540	1640	1730	1800	155520
200	537	880	1090	1240	1340	1430	1510	130464
100	438	724	903	1030	1130	1220	1300	112320
50	350	584	735	851	945	1030	1100	95040
20	248	422	539	635	717	791	858	74131
10	182	316	410	490	561	626	686	59270
5	124	221	293	357	416	470	520	44928
2	58.7	110	153	194	232	269	303	26179

Table 5: Elbow River near Glenmore Reservoir IDF Hydrograph Values (1908 to 2013 Data)

Return Period (years)	Daily Discharge by Hydrograph Day (m^3/s)								7 Day Volume (dam^3)
	0	1	2	3	4	5	6	7	
500	90	260	686	424	170	100	90	70	155,520
100	60	179	438	286	127	100	90	80	112,320
20	30	117	248	174	96	82	74	67	74,131

Table 6: Bow River above Elbow River Annual Peak Instantaneous Discharge Comparison of Frequency Analyses 1908 to 1980 Data vs. 1879 to 1980 Data (from AENV 1983; WER *et al.* 1986)

Return Period (years)	Ratio of Estimated Instantaneous Peaks (1879-1980)/(1908-1980)
1000	-
500	1.57
200	1.52
100	1.47
50	1.42
20	1.33
10	1.23
5	1.12
2	0.96

Table 7: Bow River at Calgary Annual Peak Instantaneous Discharge Comparison of Frequency Analyses 1911 to 2013 Data vs. 1879 to 2013 Data

Return Period (years)	Instantaneous Discharge (m^3/s) (1911-2013)	Instantaneous Discharge (m^3/s) (1879-2013)	Ratio of Instantaneous Peaks (1879-2013)/(1911-2013)
1000	2290	3070	1.34
500	1960	2590	1.32
200	1590	2040	1.28
100	1340	1690	1.26
50	1120	1380	1.23
20	871	1030	1.18
10	702	798	1.14
5	549	596	1.09
2	357	354	0.99

Table 8: Elbow River near Glenmore Reservoir Annual Peak Discharges 1908 to 2013 Data and 1879 to 2013 Data

Return Period (years)	1908 to 2013		Ratio of Instantaneous Peaks (1879-2013)/(1908-2013)	1879 to 2013	
	Peak Daily (m^3/s)	Peak Instantaneous (m^3/s)		Peak Instantaneous (m^3/s)	Peak Daily (m^3/s)
1000	812	1480	1.34	1984	1013
500	686	1230	1.32	1625	858
200	537	933	1.28	1197	665
100	438	737	1.26	930	539
50	350	564	1.23	695	423
20	248	372	1.18	440	289
10	182	252	1.14	286	202
5	124	155	1.09	168	130
2	58.7	57.4	0.99	57	53

Table 9: Elbow River near Glenmore Reservoir Annual Flood 7-Day Volume 1908 to 2013 Data and 1879 to 2013 Data

Return Period (years)	7-Day Volume (1908 - 2013) (dam^3)	7-day Volume (1879 - 2013) (dam^3)	Ratio of Volumes
1000	176256	206659	1.172
500	155520	183139	1.178
200	130464	152203	1.167
100	112320	130640	1.163
50	95040	109523	1.152
20	74131	83049	1.120
10	59270	63987	1.080
5	44928	46369	1.032
2	26179	24104	0.921

Table 10: Elbow River near Glenmore Reservoir IDF Hydrograph Daily Values (1879 to 2013 Data)

Return Period (years)	Daily Discharge by Hydrograph Day (m^3/s)								7 Day Volume (dam^3)
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
500	90	316	858	516	170	100	90	70	183,139
100	60	222	539	354	127	100	90	80	130,640

20	30	142	289	211	96	82	74	67	83,049

Table 11: Elbow River near Glenmore Reservoir
IDF Hydrograph 6-Hour Values (1879 to 2013 Data)

Time (days)	Discharge (m^3/s)		
	1:500 Year	1:100 Year	1:20 Year
0.00	90	60	30
0.25	90	60	30
0.50	90	60	30
0.75	90	60	30
1.00	90	60	30
1.25	90	60	50
1.50	115	100	100
1.75	200	233	185
2.00	1625	930	440
2.25	900	580	295
2.50	750	475	265
2.75	655	430	250
3.00	630	410	245
3.25	590	400	235
3.50	530	385	220
3.75	470	325	195
4.00	320	200	140
4.25	200	135	100
4.50	150	115	90
4.75	110	105	85
5.00	105	103	84
5.25	103	101	83
5.50	100	100	82
5.75	98	99	81
6.00	95	97	78
6.25	92	94	75
6.50	90	90	73
6.75	88	87	72
7.00	86	81	70
7.25	80	80	68
7.50	75	80	67
7.75	70	80	66
8.00	65	80	65

Table 12: Bow River near Morley Hydrometric Stations

Station Number	Station Name	Record Period	Drainage Area (km^2)
05BE001	Bow River near Morley	1910 to1911	5380
05BF001	Kananaskis River near Seebe	1911 to1962	933
05BE003	Bow River near Kananaskis	1912 to 1922	4160
05BE004	Bow River near Seebe	1923 to 1963 1978 to 2011	5170

Table 13: Bow River near Morley Annual Peak Discharge Data Stations 05BE003+05BF001, 05BE004 (1912 to 2013)

Station Number	Year	Peak Instantaneous Discharge[7] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BE003+05BF001	1912	*363*		317	July 14
05BE003+05BF001	1913	*425*		371	June 13
05BE003+05BF001	1914	*411*		358	June 18
05BE003+05BF001	1915	*572*		499	June 28
05BE003+05BF001	1916	*876*		764	June 21
05BE003+05BF001	1917	*406*		354	June 18
05BE003+05BF001	1918	*516*		450	June 14
05BE003+05BF001	1919	*360*		314	June 23
05BE003+05BF001	1920	*506*		442	July 13
05BE003+05BF001	1921	*420*		366	June 9
05BE003+05BF001	1922	*430*		375	June 5
05BE004	1923	697	June 15	663	June 15
05BE004	1924	337	July 5	334	July 5
05BE004	1925	362	June 23	343	June 23
05BE004	1926	274	July 10	212	July 8
05BE004	1927	583	June 27	411	June 11
05BE004	1928	515	June 29	493	June 29
05BE004	1929	699	June 3	555	June 3
05BE004	1930	453	June 9	374	June 9
05BE004	1931	275	June 19	265	June 19
05BE004	1932	903	June 2	762	June 3

[7] Italicized instantaneous discharge values were computed using the following relationship derived from observed data: Q_{inst} 1.147*Q_{daily}.

Station Number	Year	Peak Instantaneous Discharge[7] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BE004	1933	705	June 17	583	June 18
05BE004	1934	430	May 31	416	May 31
05BE004	1935	309	June 1	289	June 17
05BE004	1936	343	May 30	334	June 2
05BE004	1937	306	June 19	232	June 18
05BE004	1938	453	June 22	419	June 23
05BE004	1939	328	July 3	306	July 2
05BE004	1940	306	May 27	280	May 26
05BE004	1941	279	June 19	173	June 15
05BE004	1942	459	June 9	289	June 9
05BE004	1943	368	July 27	320	July 10
05BE004	1944	340	July 7	215	June 13
05BE004	1945	419	May 31	274	June 22
05BE004	1946	402	May 28	323	May 29
05BE004	1947	413	June 3	306	June 12
05BE004	1948	498	May 25	419	May 24
05BE004	1949	248	May 16	193	June 8
05BE004	1950	348	June 22	343	June 22
05BE004	1951	385	July 7	331	July 7
05BE004	1952	283	July 6	249	July 6
05BE004	1953	368	June 13	354	June 14
05BE004	1954	334	June 16	323	July 9
05BE004	1955	368	June 24	281	June 24
05BE004	1956	411	June 4	297	June 6
05BE004	1957	220	June 5	203	May 21
05BE004	1958	340	June 11	215	June 11
05BE004	1959	317	June 23	249	June 24
05BE004	1960	258	July 1	217	July 2
05BE004	1961	411	June 6	368	June 6
05BE004	1962	276	June 27	250	June 27
05BE004	1979	*190*		166	May 28
05BE004	1980	*304*		265	June 19
05BE004	1981	379	May 28	343	May 27
05BE004	1982	312	June 17	257	June 23
05BE004	1983	245	May 31	212	June 1
05BE004	1984	*292*		255	July 1
05BE004	1985	*235*		205	May 26
05BE004	1986	*469*		409	June 2
05BE004	1987	*252*		220	May 14
05BE004	1988	331	June 9	318	June 9
05BE004	1989	*306*		267	June 16
05BE004	1990	*439*		383	June 2

Station Number	Year	Peak Instantaneous Discharge[7] (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date
05BE004	1991	*403*		351	July 5
05BE004	1992	*221*		193	June 15
05BE004	1993	*235*		205	June 3
05BE004	1994	*214*		187	June 8
05BE004	1995	*487*		425	June 7
05BE004	1996	*358*		312	June 10
05BE004	1997	*313*		273	June 7
05BE004	1998	*274*		239	May 29
05BE004	1999	*284*		248	July 16
05BE004	2000	*200*		174	July 3
05BE004	2001	*226*		197	May 29
05BE004	2002	*411*		358	June 29
05BE004	2003	*257*		224	June 2
05BE004	2004	*247*		215	June 13
05BE004	2005	*370*		323	June 19
05BE004	2006	*279*		243	June 17
05BE004	2007	*483*		421	June 8
05BE004	2008	*289*		252	July 2
05BE004	2009	*218*		190	June 18
05BE004	2010	*218*		190	June 25
05BE004	2011	*337*		294	June 24
	2013[8]	818		720	June 21
basic statistics of the data					
maximum		903		764	
mean		379		325	
median		348		306	
min		190		166	

[8] The 2013 discharge data were provided by TransAlta Corporation and are preliminary.

Table 14: Bow River near Morley
Annual Peak Discharge Frequency Analysis (1912 to 2013 Data)

Return Period (years)	Daily Discharge (m^3/s)	Instantaneous Discharge (m^3/s)
1000	1050	1204
500	950	1090
200	831	953
100	745	855
50	664	762
20	560	642
10	484	555
5	408	468
2	300	344
median	306	348

Table 15: Bow River near Morley
Annual Peak 1-Day to 10-Day Runoff Volumes (1912 to 2013 Data)

Return Period years)	Cumulative Discharge Volume over N Consecutive Days (m^3/s - days)										10-Day Volume (dam^3)
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days	8 Days	9 Days	10 Days	
1000	1050	2030	2870	3660	4340	4940	5460	5970	6470	6980	603072
500	950	1840	2620	3350	3990	4570	5070	5570	6040	6540	565056
200	831	1620	2310	2960	3550	4090	4570	5030	5480	5940	513216
100	745	1450	2080	2680	3230	3730	4190	4630	5060	5490	474336
50	664	1290	1870	2410	2910	3380	3820	4230	4640	5040	435456
20	560	1090	1590	2050	2500	2920	3310	3690	4060	4430	382752
10	484	946	1380	1790	2190	2570	2930	3270	3610	3940	340416
5	408	799	1170	1520	1870	2200	2520	2830	3130	3420	295488
2	300	588	866	1130	1390	1640	1890	2130	2370	2600	224640

Table 16: Bow River near Morley
IDF Hydrograph Daily Values (1912 to 2013 Data)

Return Period (years)	Daily Discharge by Hydrograph Day (m^3/s)											10-Day Volume (dam^3)
	0	1	2	3	4	5	6	7	8	9	10	
1000	300	500	520	680	840	1050	980	790	600	510	510	603,072
500	275	470	500	640	780	950	890	730	580	500	500	565,056
100	225	430	460	550	630	745	705	600	500	440	430	474,336
20	175	370	390	450	500	560	530	460	420	380	370	382,752

Table 17: Bow River at Calgary Annual Peak Instantaneous Discharge
Comparison of Frequency Analyses 1911 to 1962/1978 to 2013 Data vs 1879 to 2013 Data

Return Period (years)	Instantaneous Discharge (m^3/s) (1911 to 1962 and 1978 to 2013)	Instantaneous Discharge (m^3/s) (1879 to 2013)	Ratio of Instantaneous Peaks (1879-2013)/(1911-1962 and 1978 to 2013)
1000	2380	3070	1.29
500	2060	2590	1.26
200	1670	2040	1.22
100	1420	1690	1.19
50	1190	1380	1.16
20	919	1030	1.12
10	738	798	1.08
5	573	596	1.04
2	363	354	0.98

Table 18: Bow River near Morley Annual Peak Discharges
1912 to 2013 Data and 1879 to 2013 Data

Return Period (years)	1912 to 2013		Ratio of Peaks	1879 to 2013	
	Peak Daily (m^3/s)	Peak Instantaneous (m^3/s)		Peak Daily (m^3/s)	Peak Instantaneous (m^3/s)
1000	1050	1204	1.29	1355	1554
500	950	1090	1.26	1197	1373
200	831	953	1.22	1014	1163
100	745	855	1.19	887	1017
50	664	762	1.16	770	883
20	560	642	1.12	627	719
10	484	555	1.08	523	600
5	408	468	1.04	424	487

2	300	344	0.98	294	337

Table 19: Bow River near Morley Annual Flood 10-Day Volume 1912 to 2013 Data and 1879 to 2013 Data

Return Period (years)	10-Day Volume (1912 to 2013) (dam^3)	10-Day Volume (1879 - 2013) (dam^3)	Ratio of Volumes
1000	603072	739762	1.23
500	565056	673895	1.19
200	513216	594532	1.16
100	474336	537311	1.13
50	435456	483224	1.11
20	382752	413848	1.08
10	340416	360695	1.06
5	295488	308184	1.04
2	224640	233668	1.04

Table 20: Bow River near Morley IDF Hydrograph Daily Values (1879 to 2013 Data)

Return Period (years)	Daily Discharge by Hydrograph Day (m^3/s)											10-Day Volume (dam^3)
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
1000	300	500	671	877	1083	1355	1264	1019	774	510	510	739,762
500	275	470	623	797	972	1197	1109	909	723	500	500	673,895
100	225	430	538	644	737	887	825	702	585	440	430	537,311
20	175	370	432	498	553	627	586	509	465	380	370	413,848

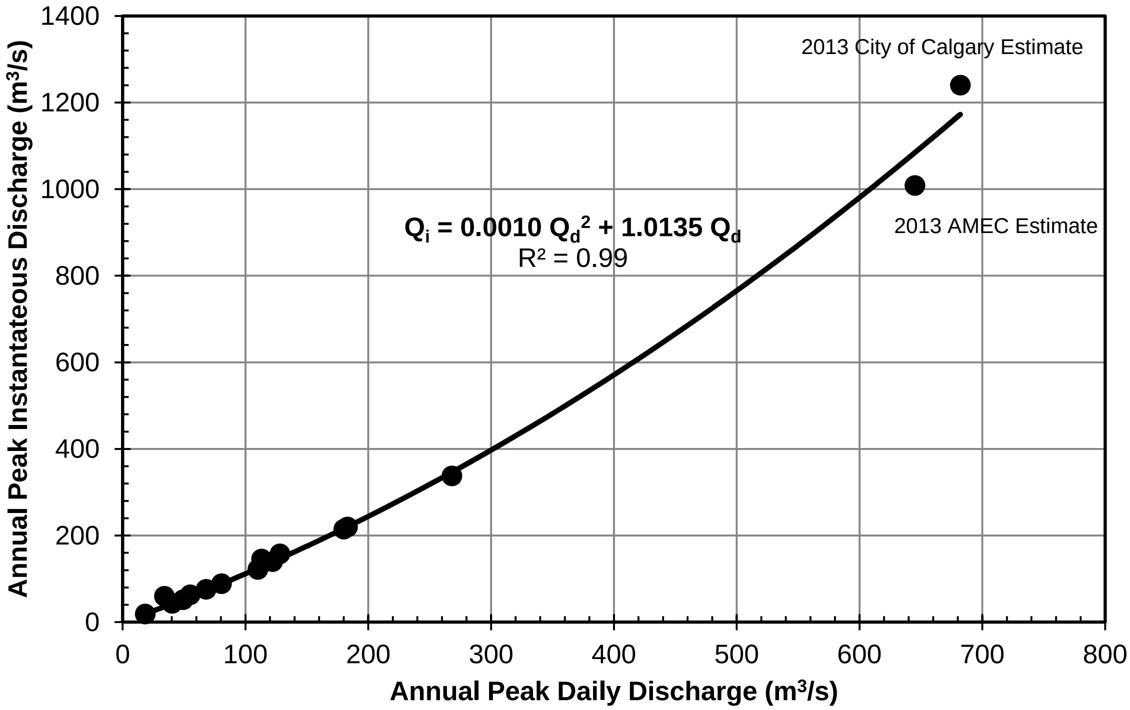


Figure 1: Elbow River near Glenmore Reservoir Annual Peak Instantaneous vs. Annual Peak Daily Discharges (1908-2013 Data)

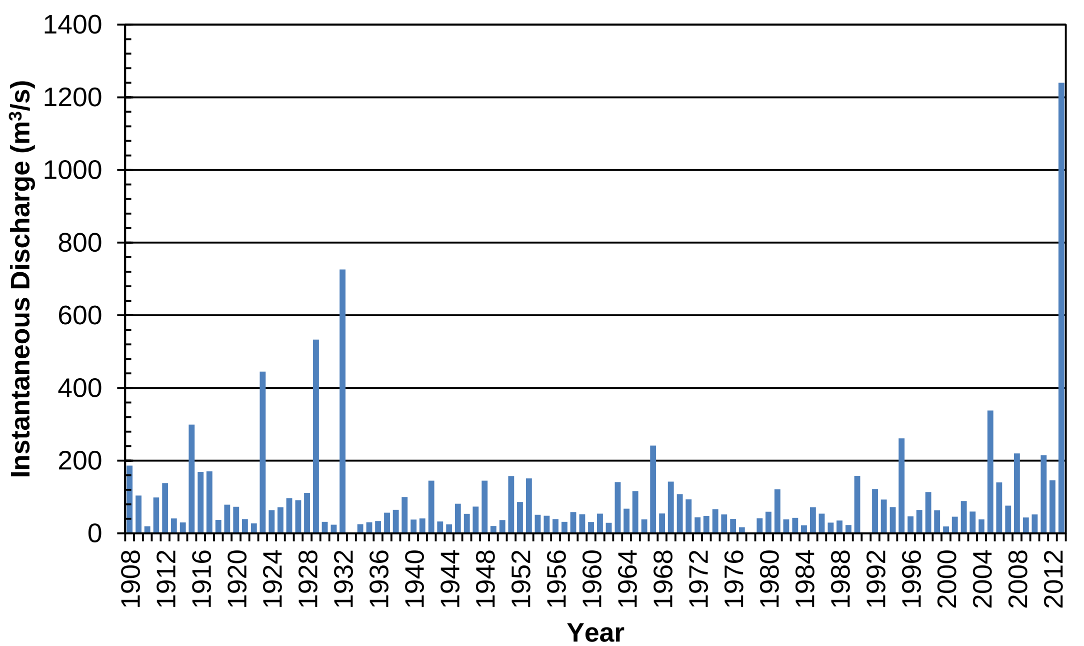


Figure 2: Elbow River near Glenmore Reservoir Annual Peak Instantaneous Discharges (1908 to 2013).

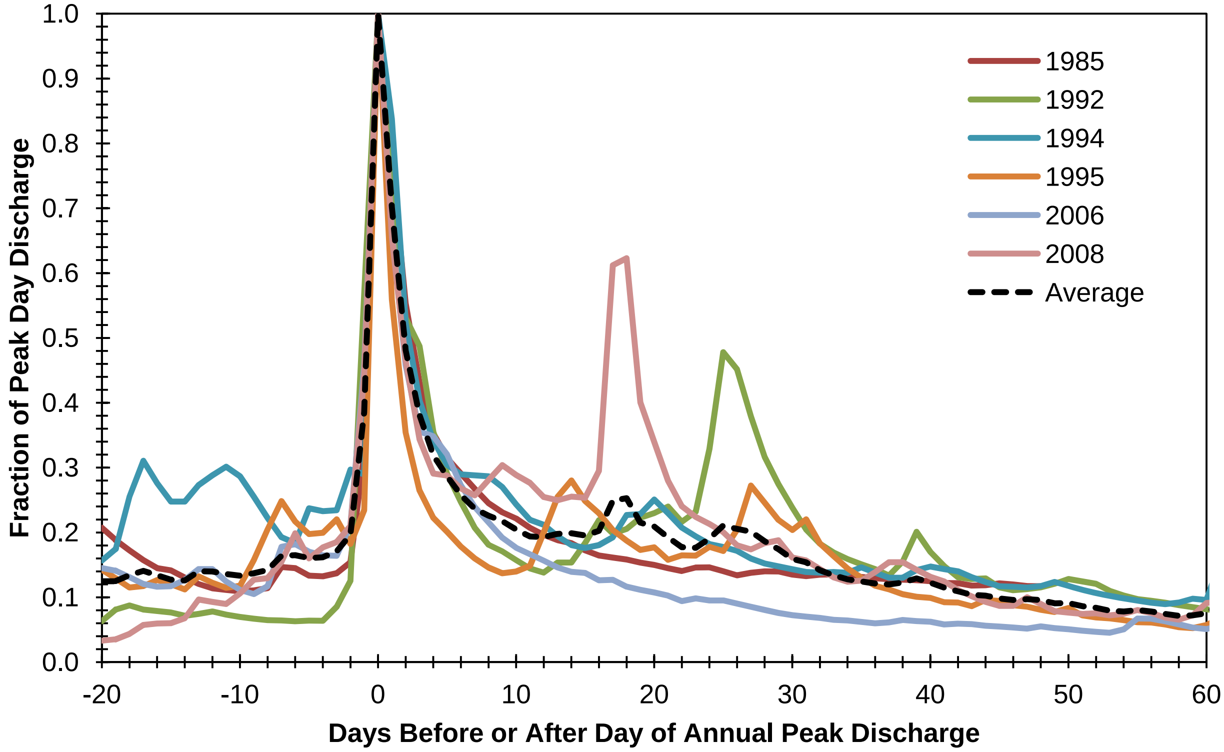


Figure 3: Elbow River near Glenmore Reservoir Normalized Hydrographs for Selected Years

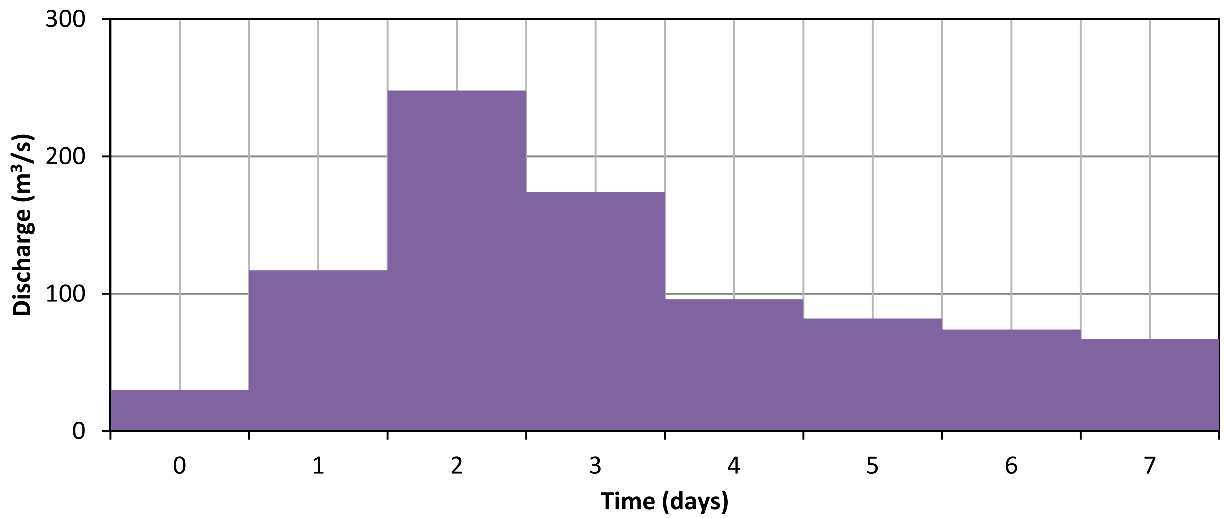


Figure 4: Elbow River near Glenmore Reservoir 1:20 Year Inflow Design Flood Daily Discharge Hydrograph (1908 to 2013 Data)

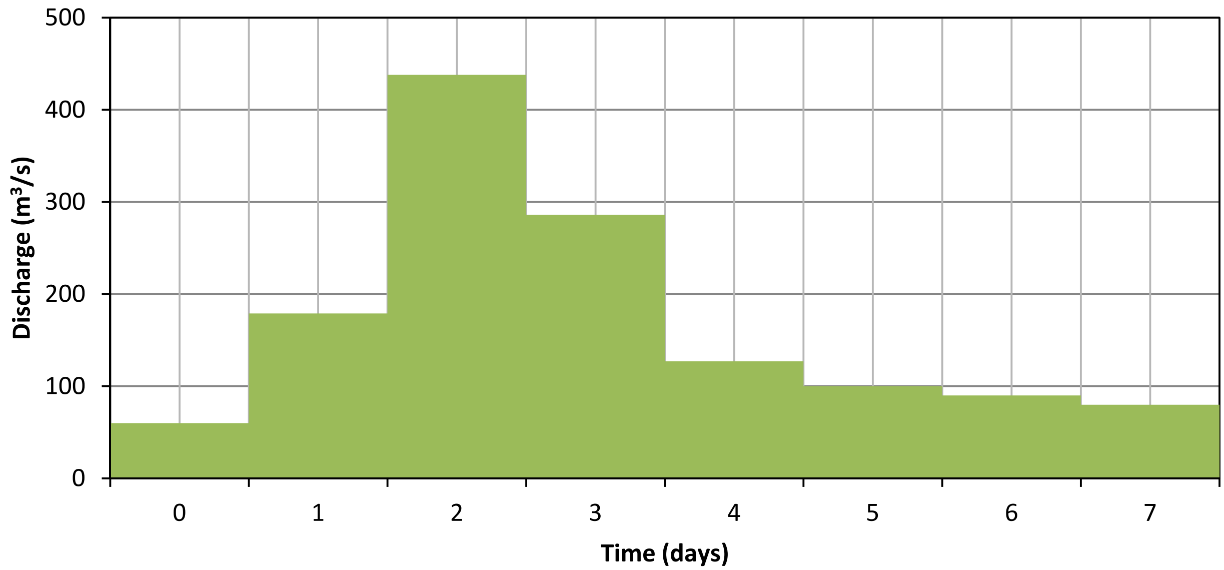


Figure 5: Elbow River near Glenmore Reservoir 1:100 Year Inflow Design Flood Daily Discharge Hydrograph (1908 to 2013 Data)

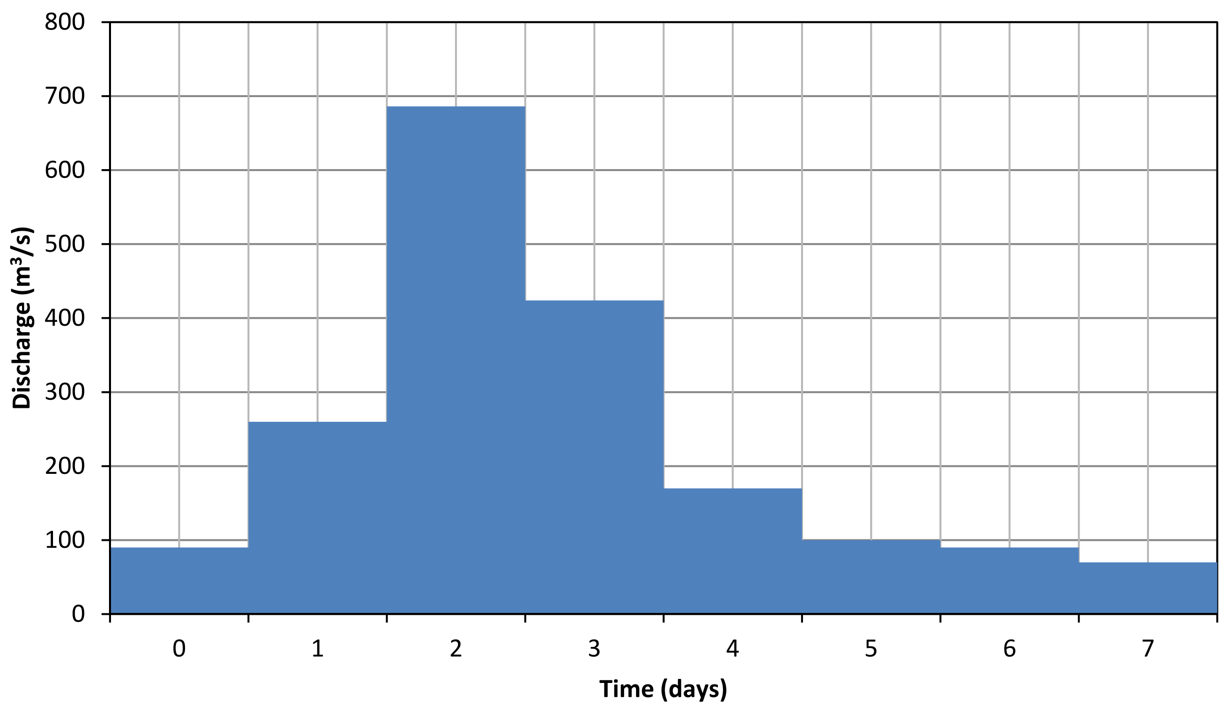


Figure 6: Elbow River near Glenmore Reservoir 1:500 Year Inflow Design Flood Daily Discharge Hydrograph (1908 to 2013 Data)

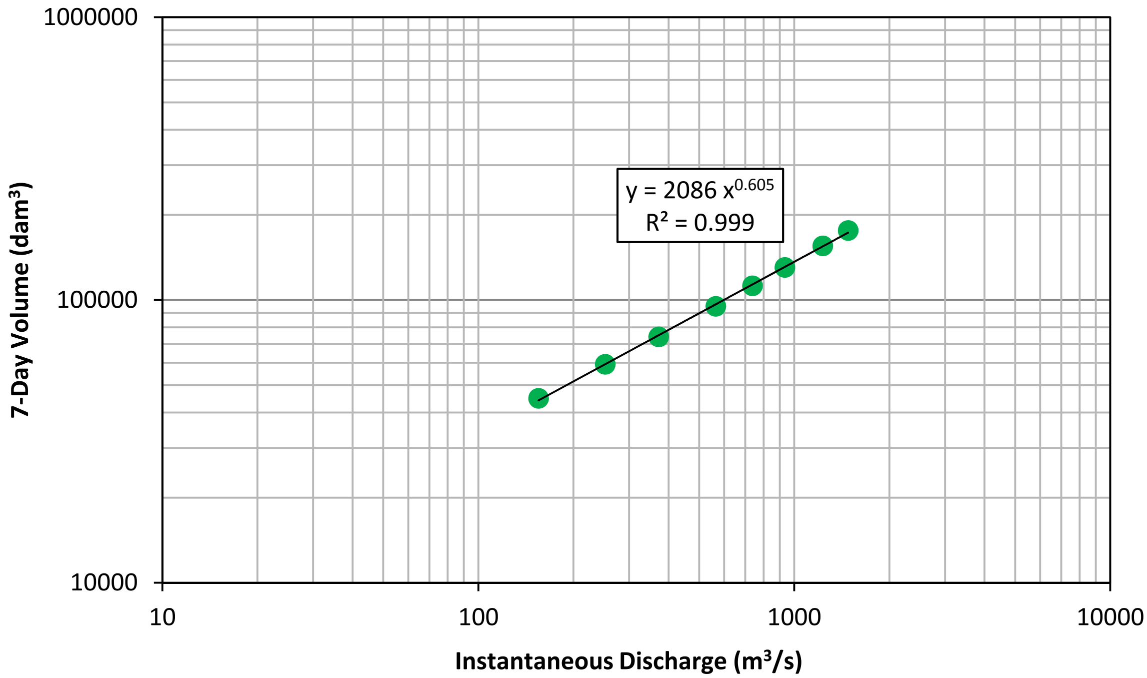


Figure 7: Elbow River near Glenmore Reservoir, Annual Peak 7-Day Volume vs Instantaneous Discharge (1908 to 2013 Data)

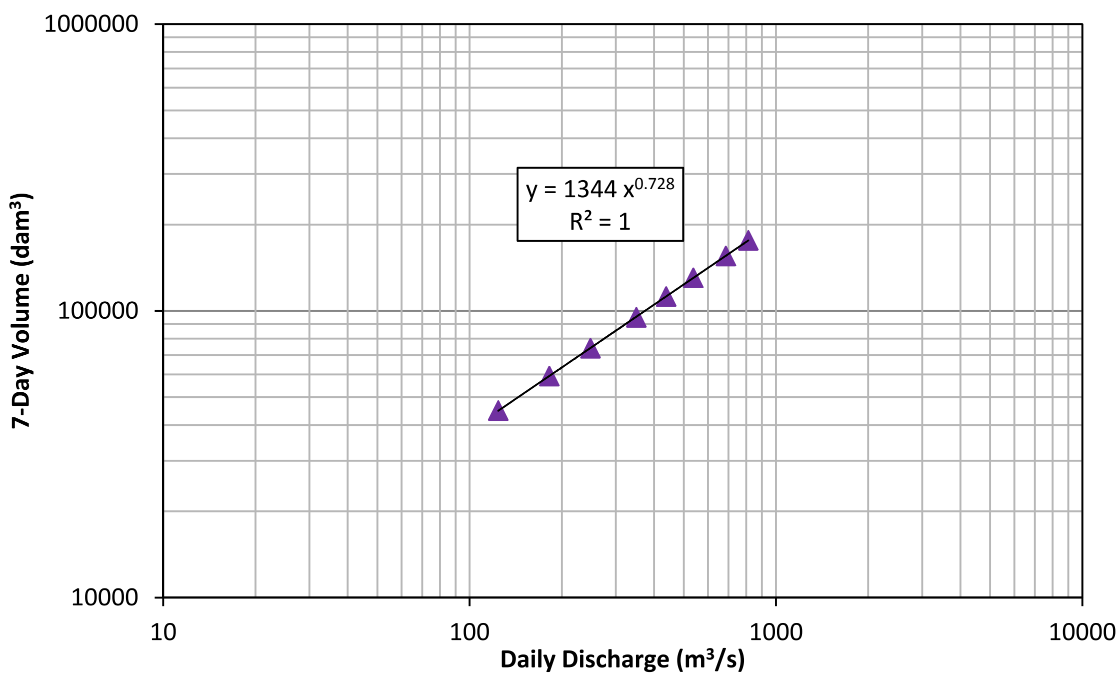


Figure 8: Elbow River near Glenmore Reservoir, Annual Peak 7-Day Volume vs Daily Discharge (1908 to 2013 Data)

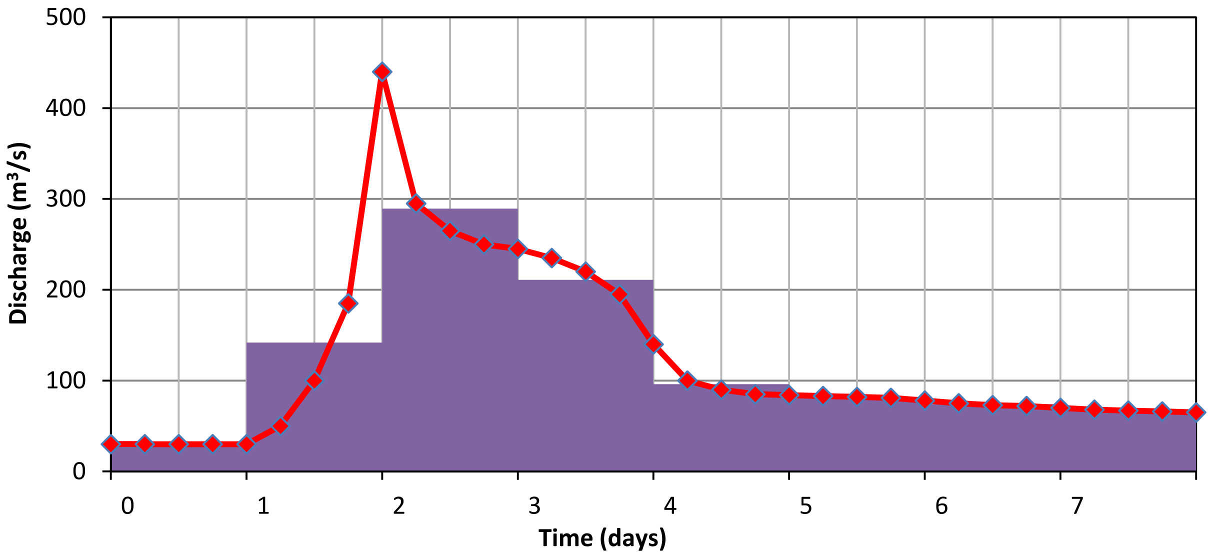


Figure 9: Elbow River near Glenmore Reservoir 1:20 Year Inflow Design Flood Daily and Quasi-Instantaneous Hydrographs (1879 to 2013 Extended Data)

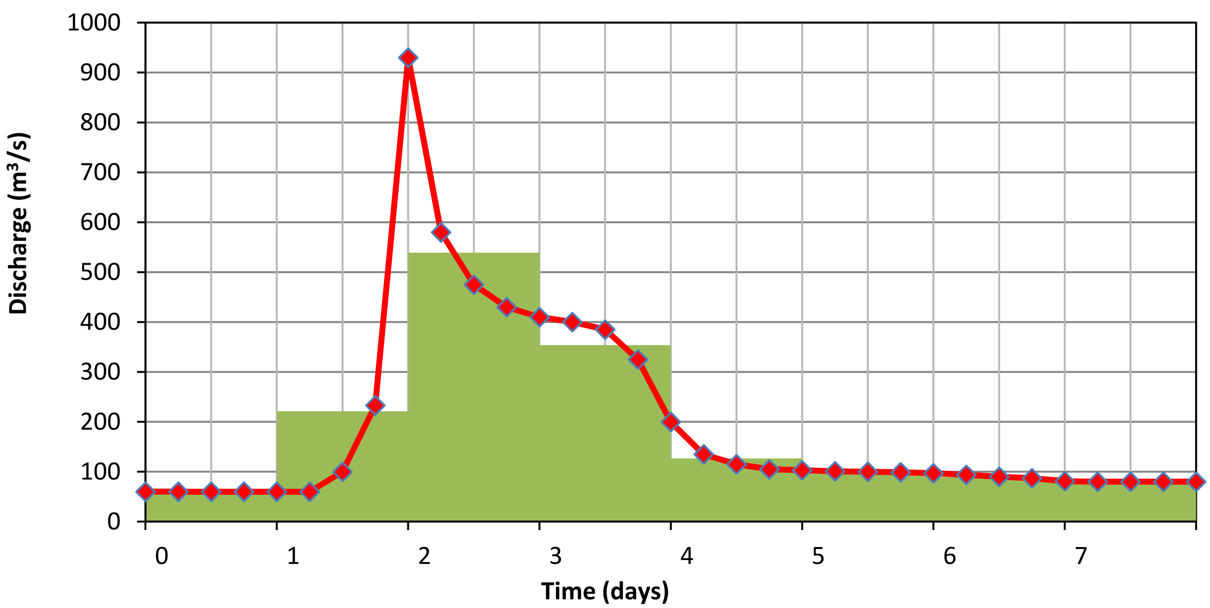


Figure 10: Elbow River near Glenmore Reservoir 1:100 Year Inflow Design Flood Daily and Quasi-Instantaneous Hydrographs (1879 to 2013 Extended Data)

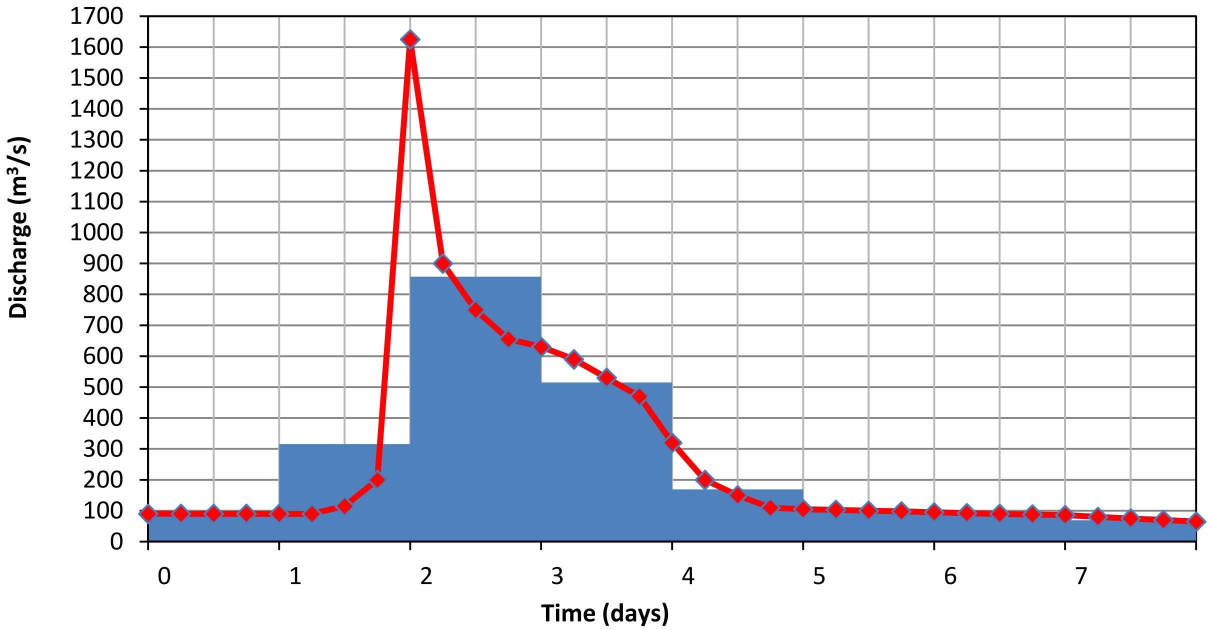


Figure 11: Elbow River near Glenmore Reservoir 1:500 Year Inflow Design Flood Daily and Quasi-Instantaneous Hydrographs (1879 to 2013 Extended Data)

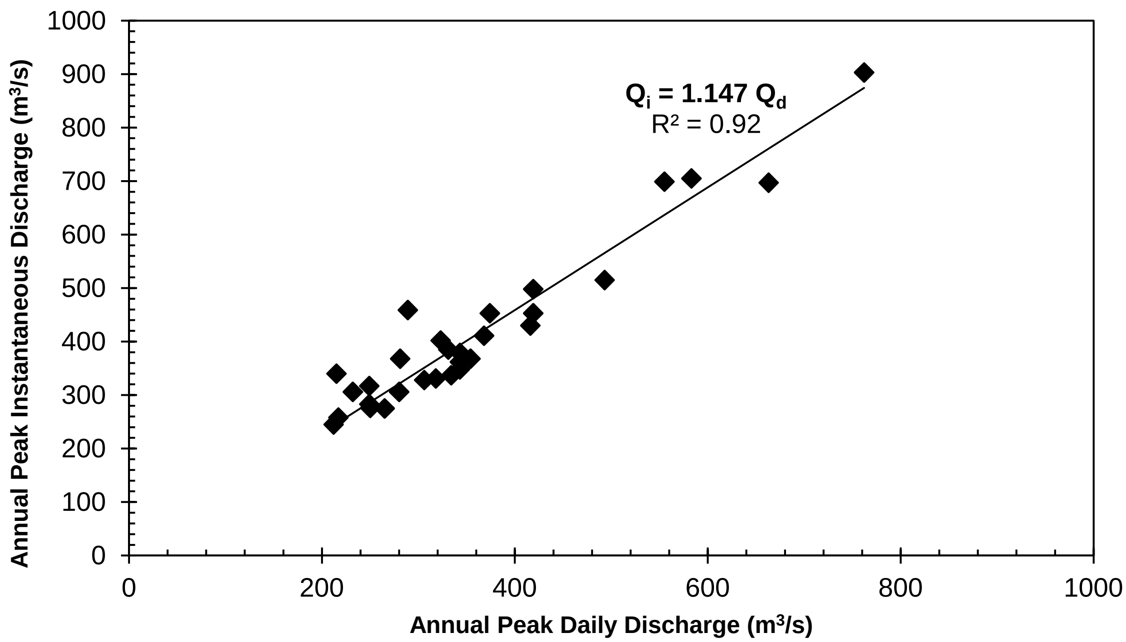


Figure 12: Bow River near Morley Annual Peak Instantaneous vs. Annual Peak Daily Discharges, (1912 to 2011)

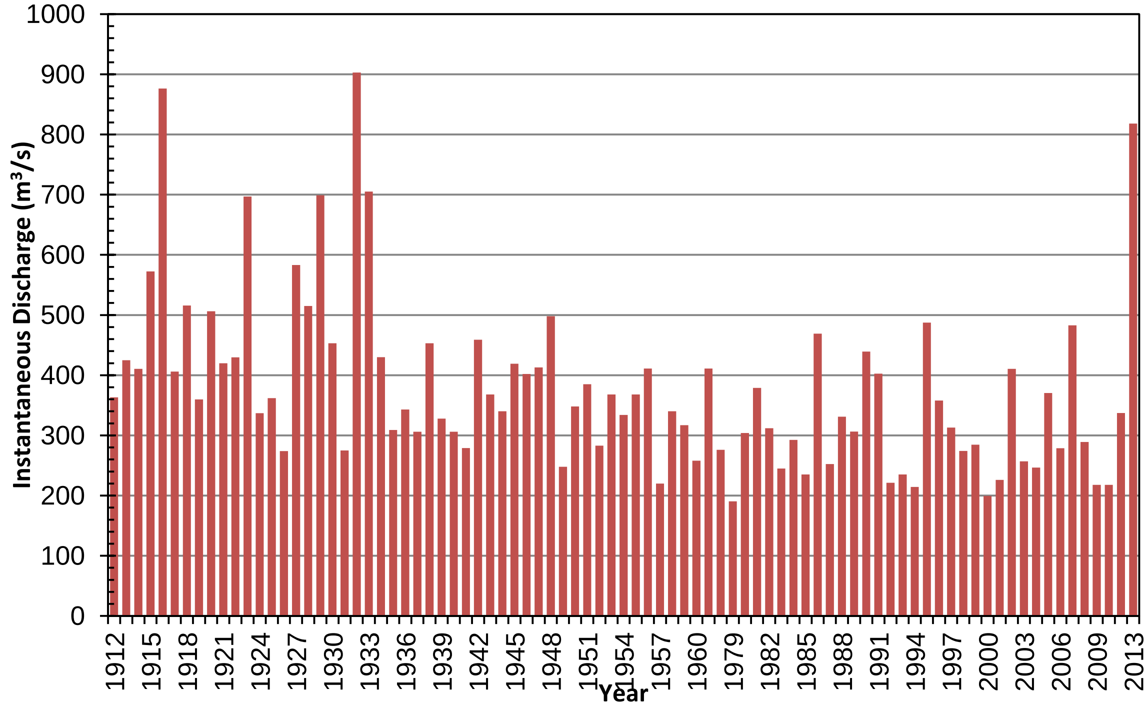


Figure 13: Bow River near Morley Annual Peak Instantaneous Discharges (1912 to 2013)

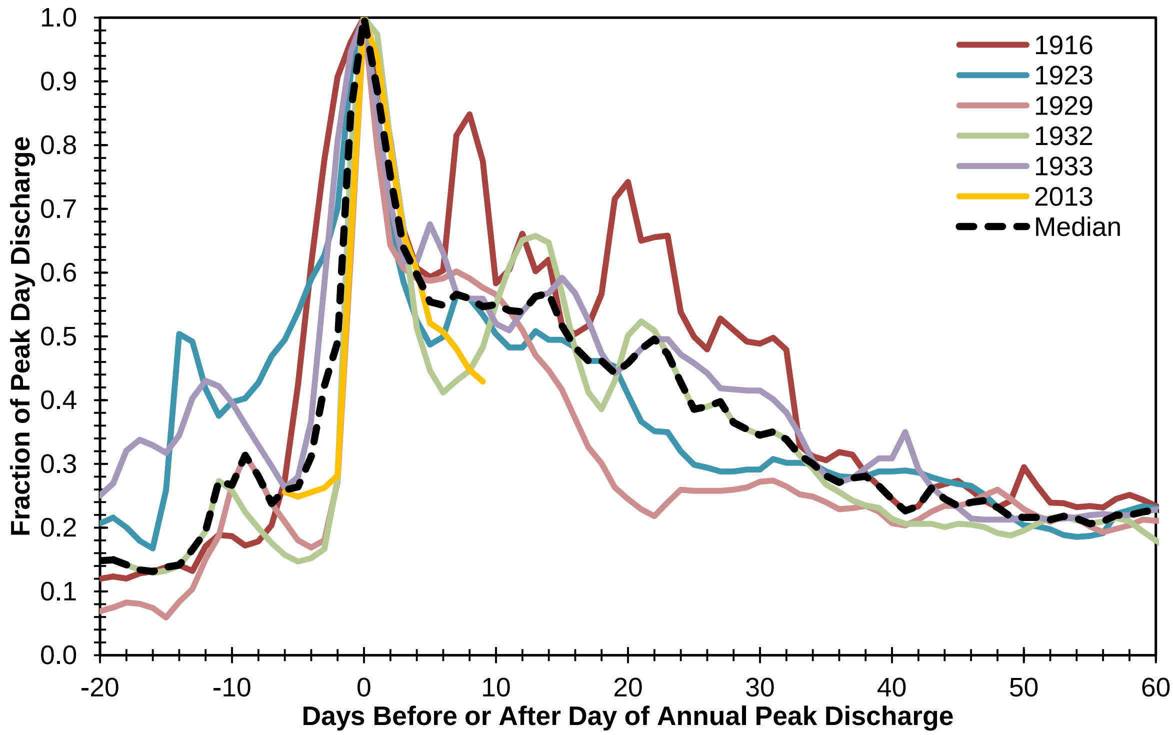


Figure 14: Bow River near Morley Normalized Hydrographs for Selected Years

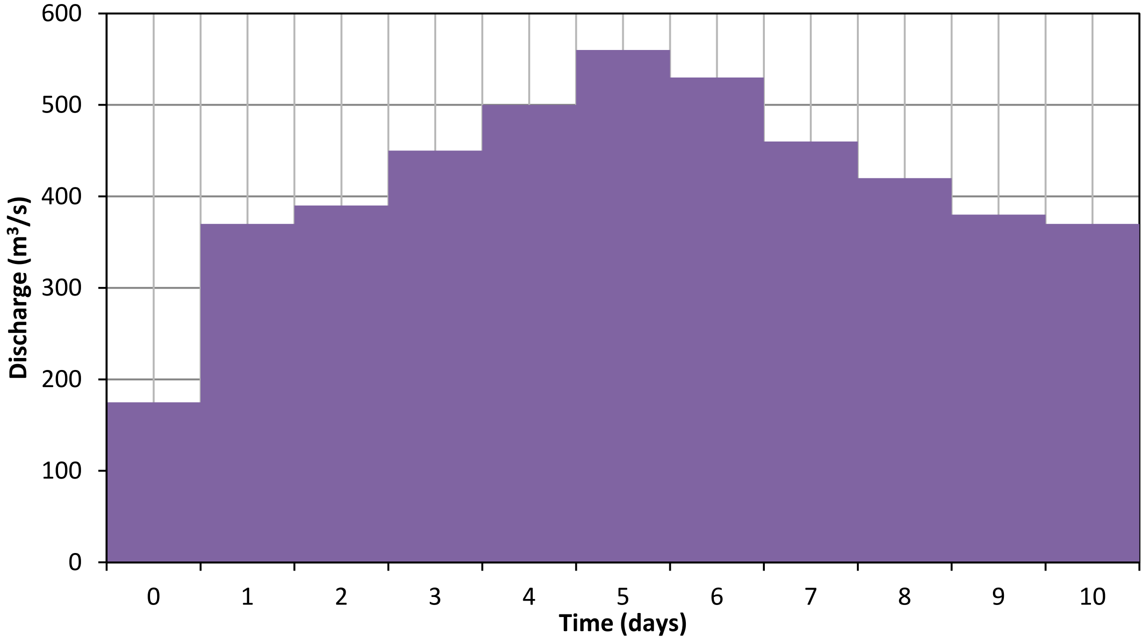


Figure 15: Bow River near Morley 1:20 Year Inflow Design Flood Daily Discharge Hydrograph (1912 to 2013 Data)

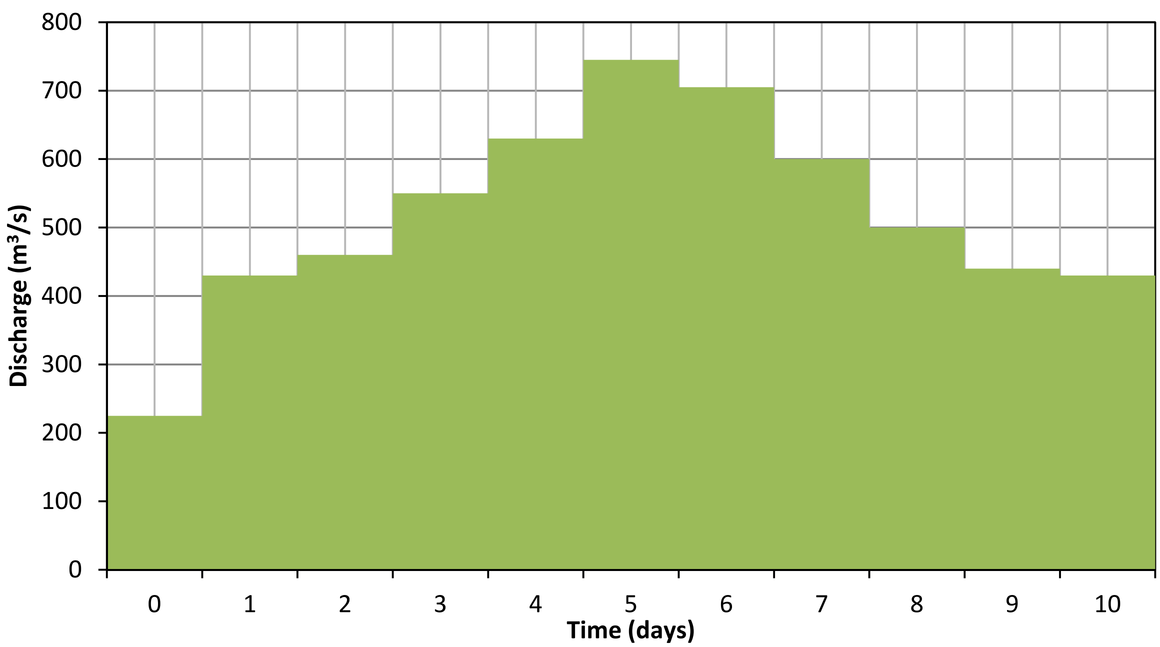


Figure 16: Bow River near Morley 1:100 Year Inflow Design Flood Daily Discharge Hydrograph (1912 to 2013 Data)

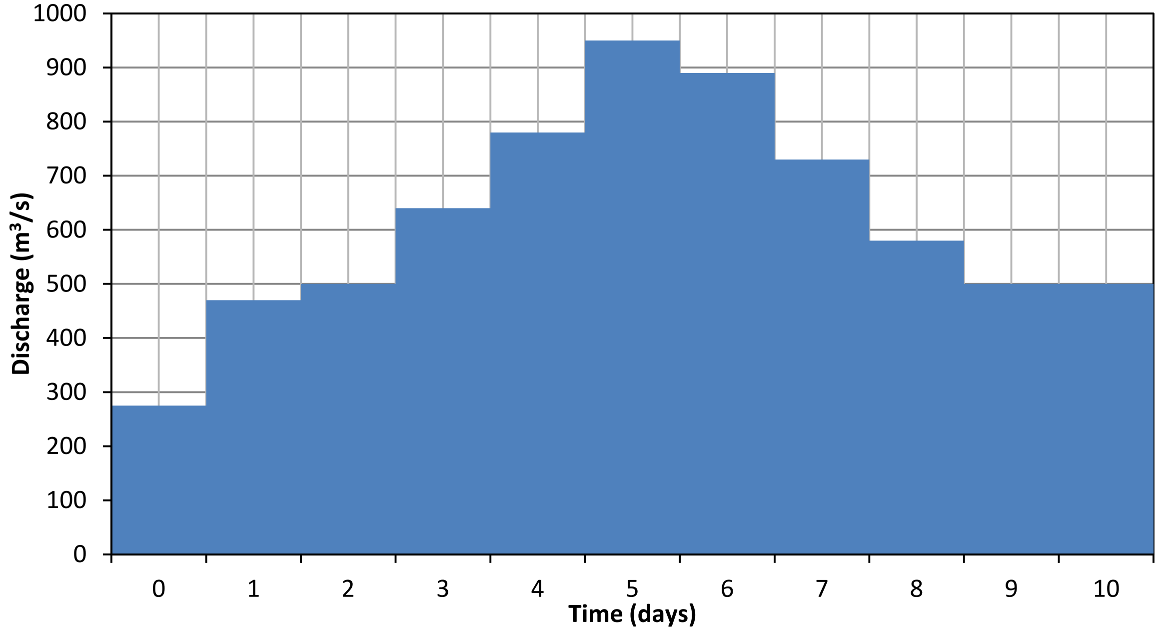


Figure 17: Bow River near Morley 1:500 Year Inflow Design Flood Daily Discharge Hydrograph (1912 to 2013 Data)

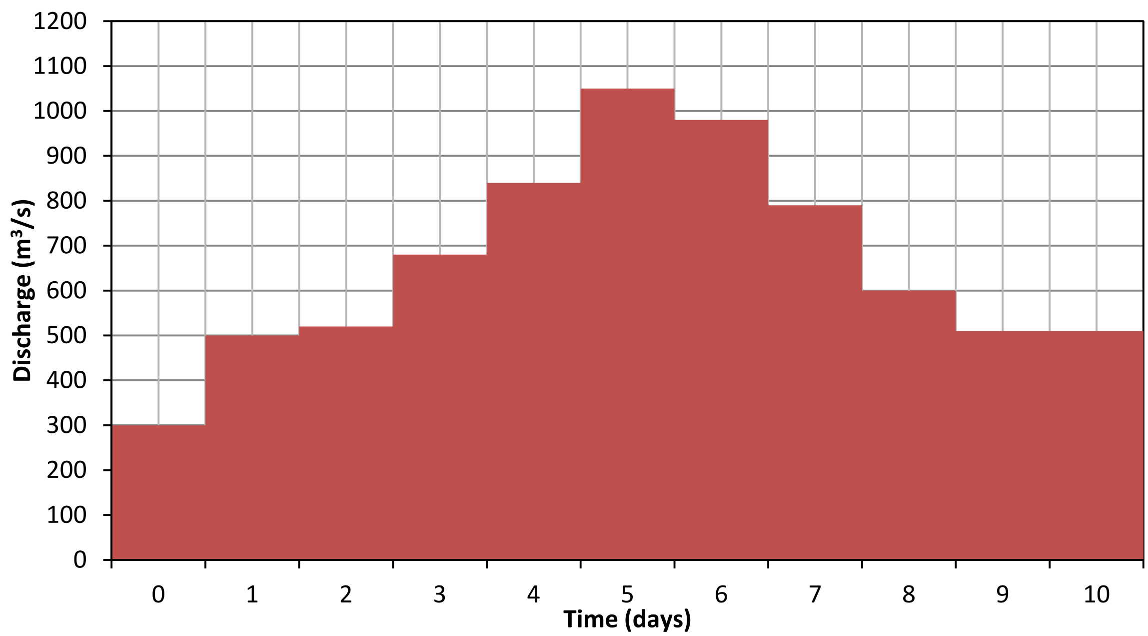


Figure 18: Bow River near Morley 1:1000 Year Inflow Design Flood Daily Discharge Hydrograph (1912 to 2013 Data)

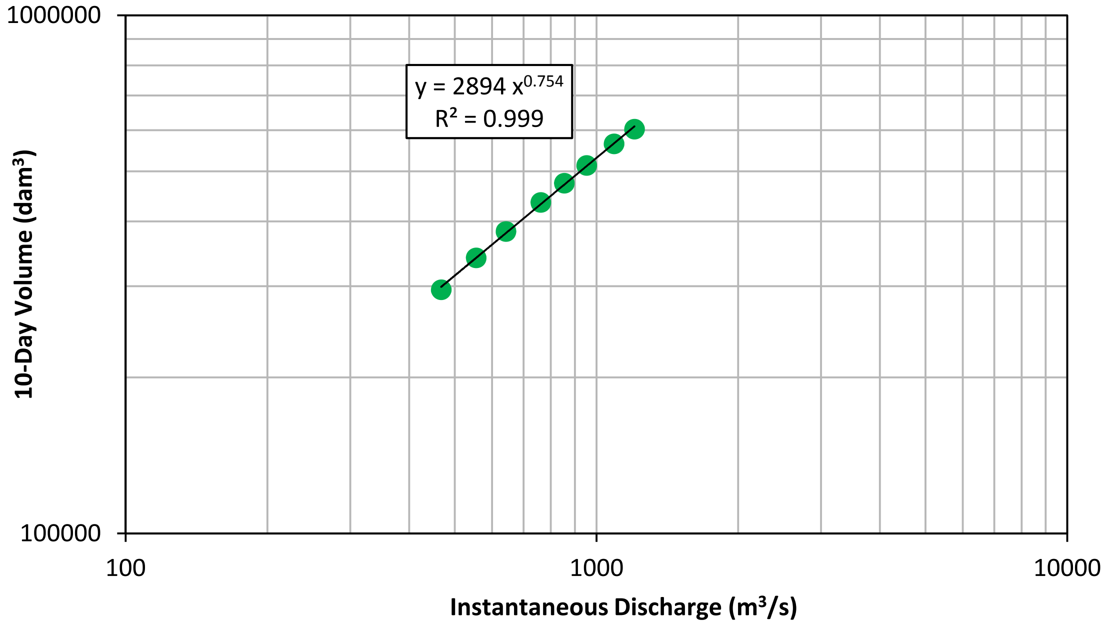


Figure 19: Bow River near Morley Annual Peak 10-Day Volume vs Instantaneous Discharge (1912 to 2013 Data)

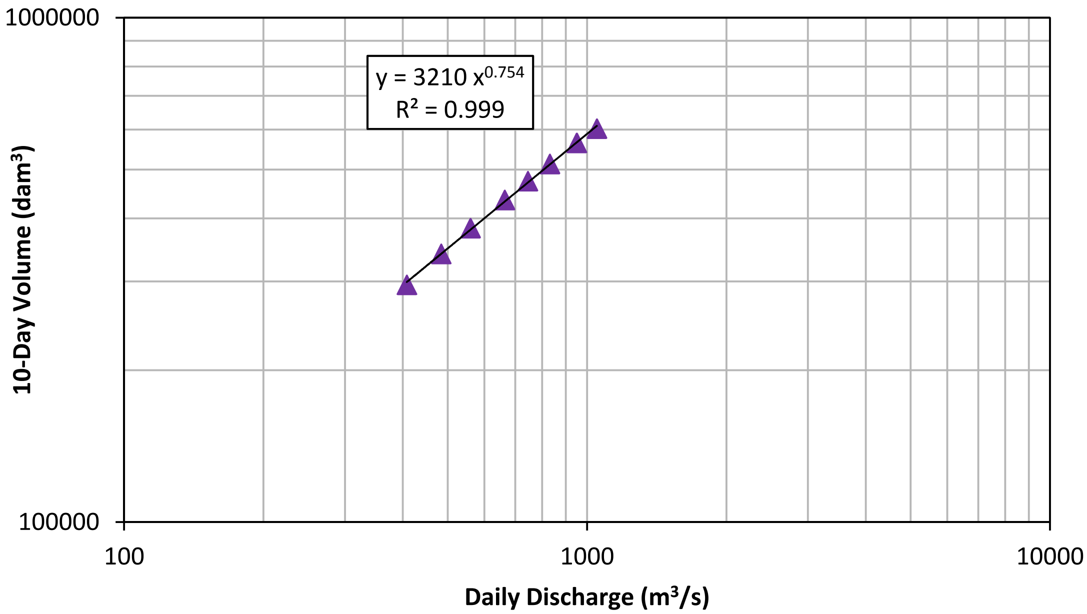


Figure 20: Bow River near Morley Annual Peak 10-Day Volume vs Daily Discharge (1912 -to 2013 Data)

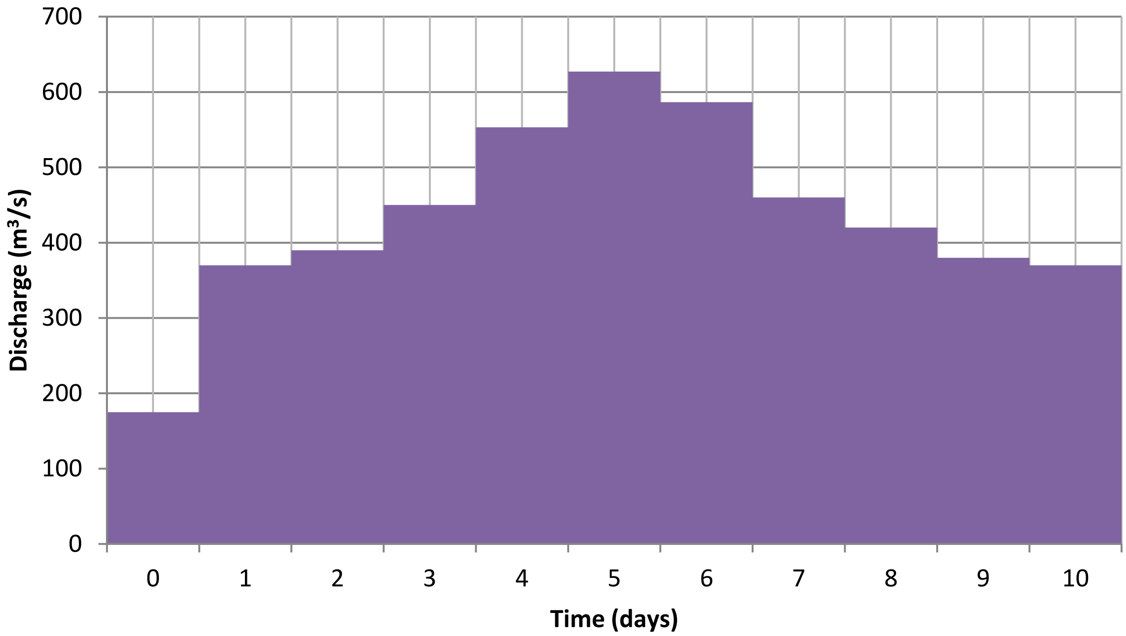


Figure 21: Bow River near Morley 1:20 Year Inflow Design Flood Daily Discharge Hydrograph (1897 to 2013 Extended Data)

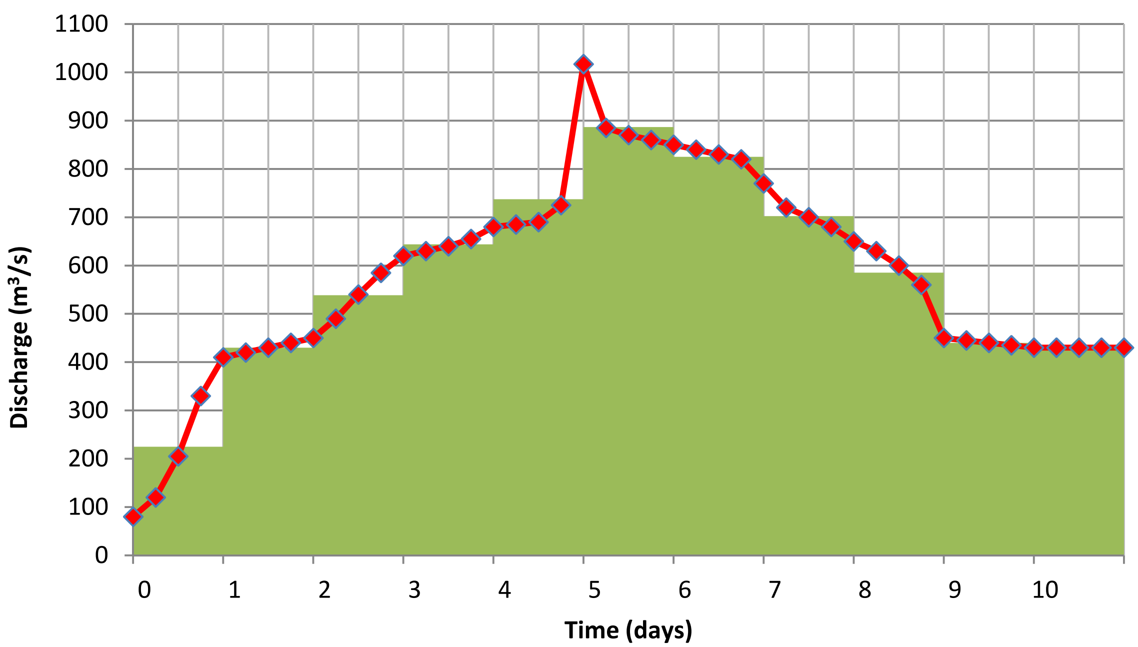


Figure 22: Bow River near Morley 1:100 Year Inflow Design Flood Daily and Quasi-Instantaneous Hydrographs (1897 to 2013 Extended Data)

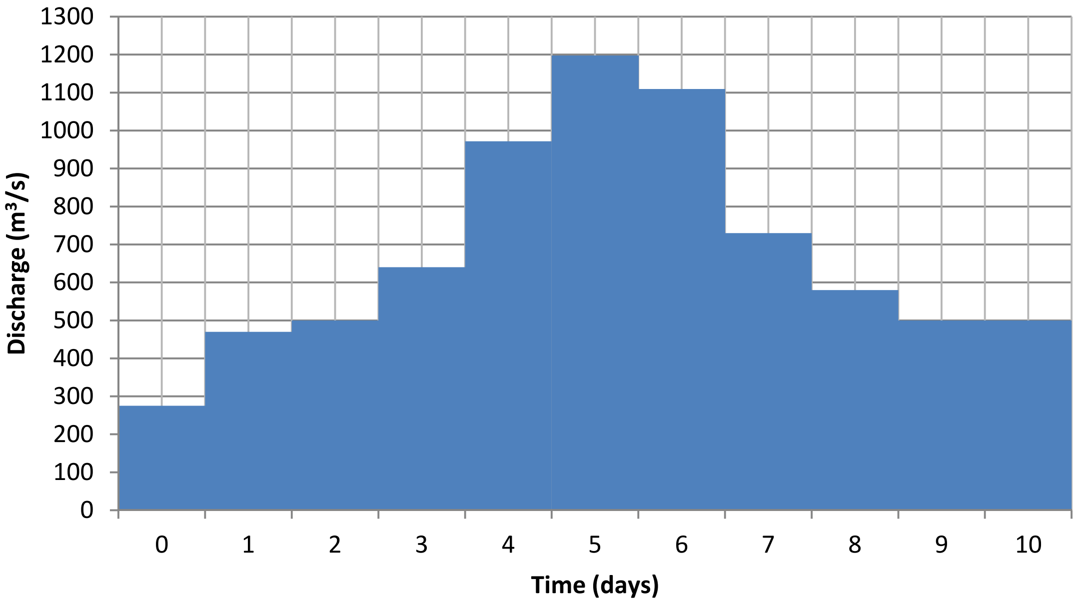


Figure 23: Bow River near Morley 1:500 Year Inflow Design Flood Daily Discharge Hydrograph (1897- to 013 Extended Data)

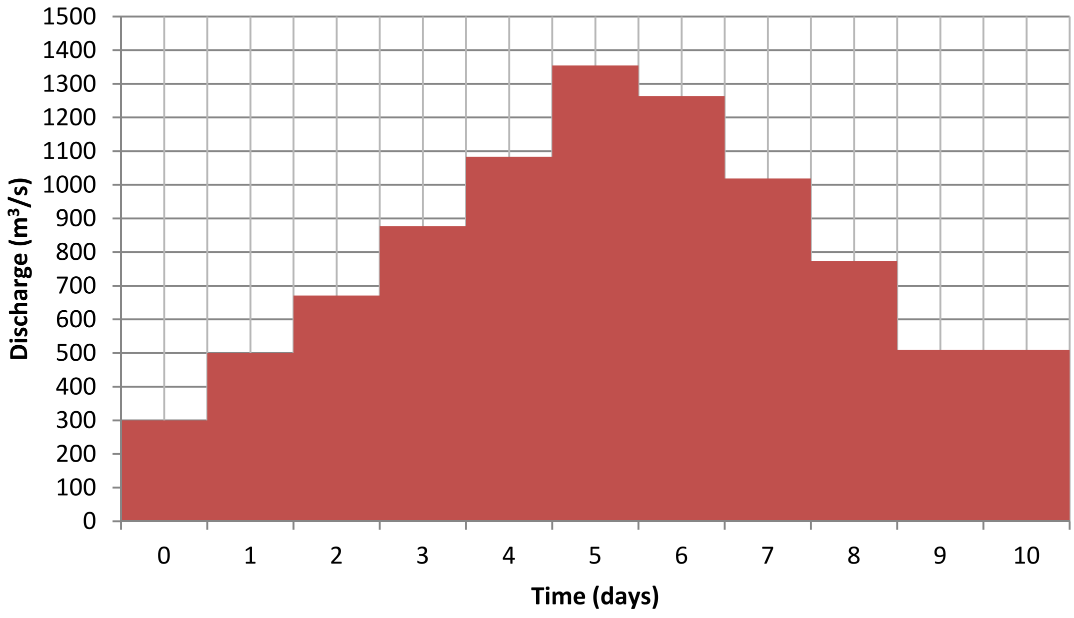


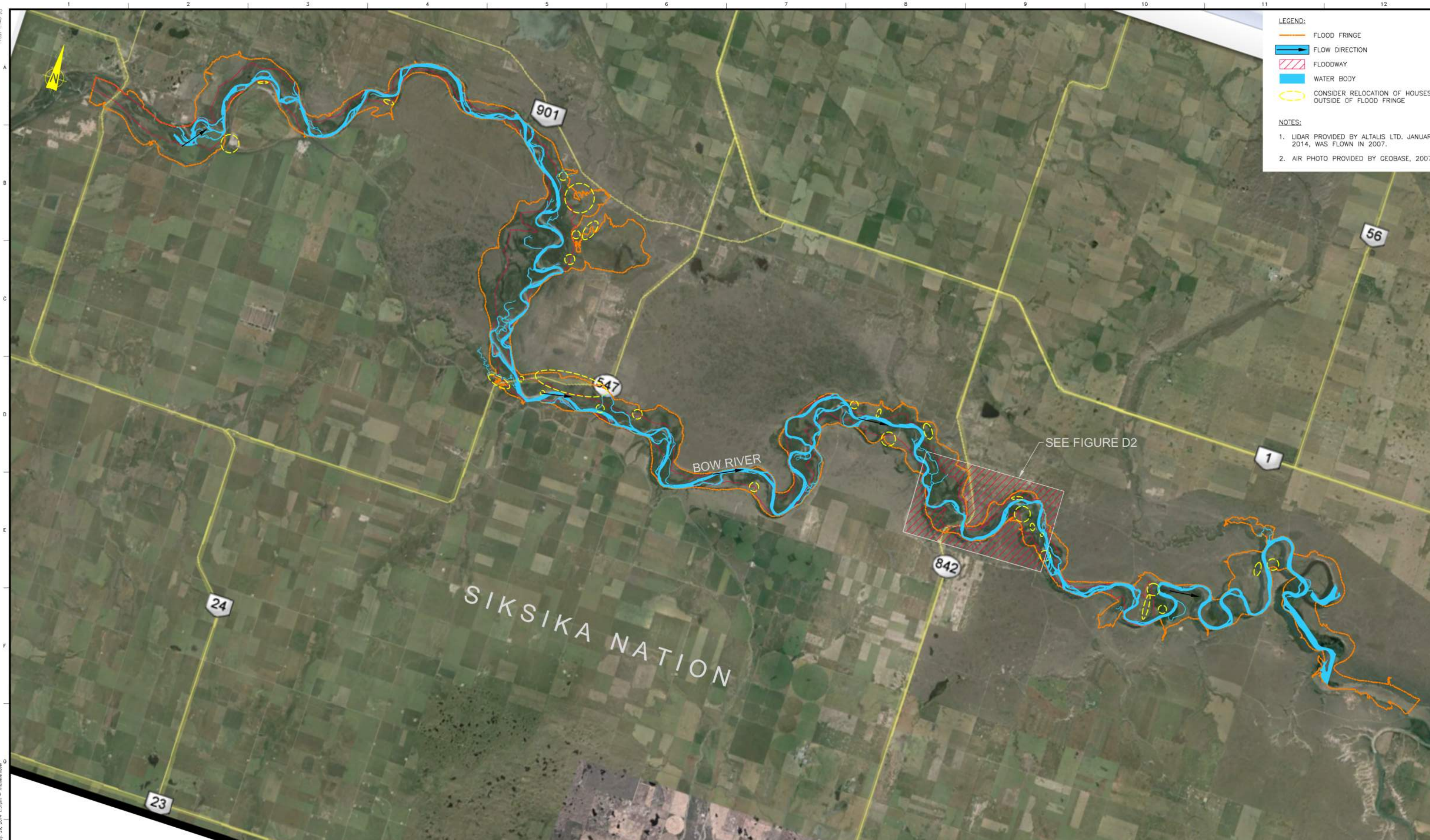
Figure 24: Bow River near Morley 1:1000 Year Inflow Design Flood Daily Discharge Hydrograph (1897 to 2013 Extended Data)

Appendix D

Conceptual Design of Flood Defences at Siksika First Nation

Conceptual Cost Estimate
Siksika Flood Defence Dykes

Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Bigger Size Riprap	Allow.	Allowance		$350,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$75,000
3	Existing and Temporary Roads	L.S.	1	Lump Sum	$25,000
	SITE PREPARATION				
4	Clearing & Grubbing	ha	8	$2,000.00	$16,600
5	Topsoil & Subsoil Stripping	m^3	37297	$5.00	$186,484
6	Care of Water	L.S.	2	Lump Sum	$25,000
	FILL PLACEMENT				
7	Low Permeable Fill	m^3	217836	$10.00	$2,178,361
	GRANULAR AND RIPRAP MATERIALS				
8	Riprap Zone 6B	tonnes	23481	$130.00	$3,052,517
9	Gravel Armour Zone 5C	tonnes	16977	$40.00	$679,061
10	Non-Woven Geotextile	m^2	28294	$3.00	$84,883
	LANDSCAPING				
14	Topsoil & Subsoil Placement	m^2	10251	$1.50	$15,377
15	Turf Reinforcement Mat	m^2	10251	$6.00	$61,508
16	Hydroseeding	m^2	10251	$3.50	$35,880
	SUBTOTAL				**$6,785,671**
	CONTINGENCIES @ 25%				**$1,696,418**
	ENGINEERING @ 12%				**$814,281**
	ESTIMATED TOTAL COST				**$9,296,000**



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0 0.5 1 1.5 km

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

NOT FOR CONSTRUCTION

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
G						
F						
E						
D						
C						
B	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.G.
A	14	03	14	ISSUED FOR CLIENT REVIEW	G.B.	G.G.

amec

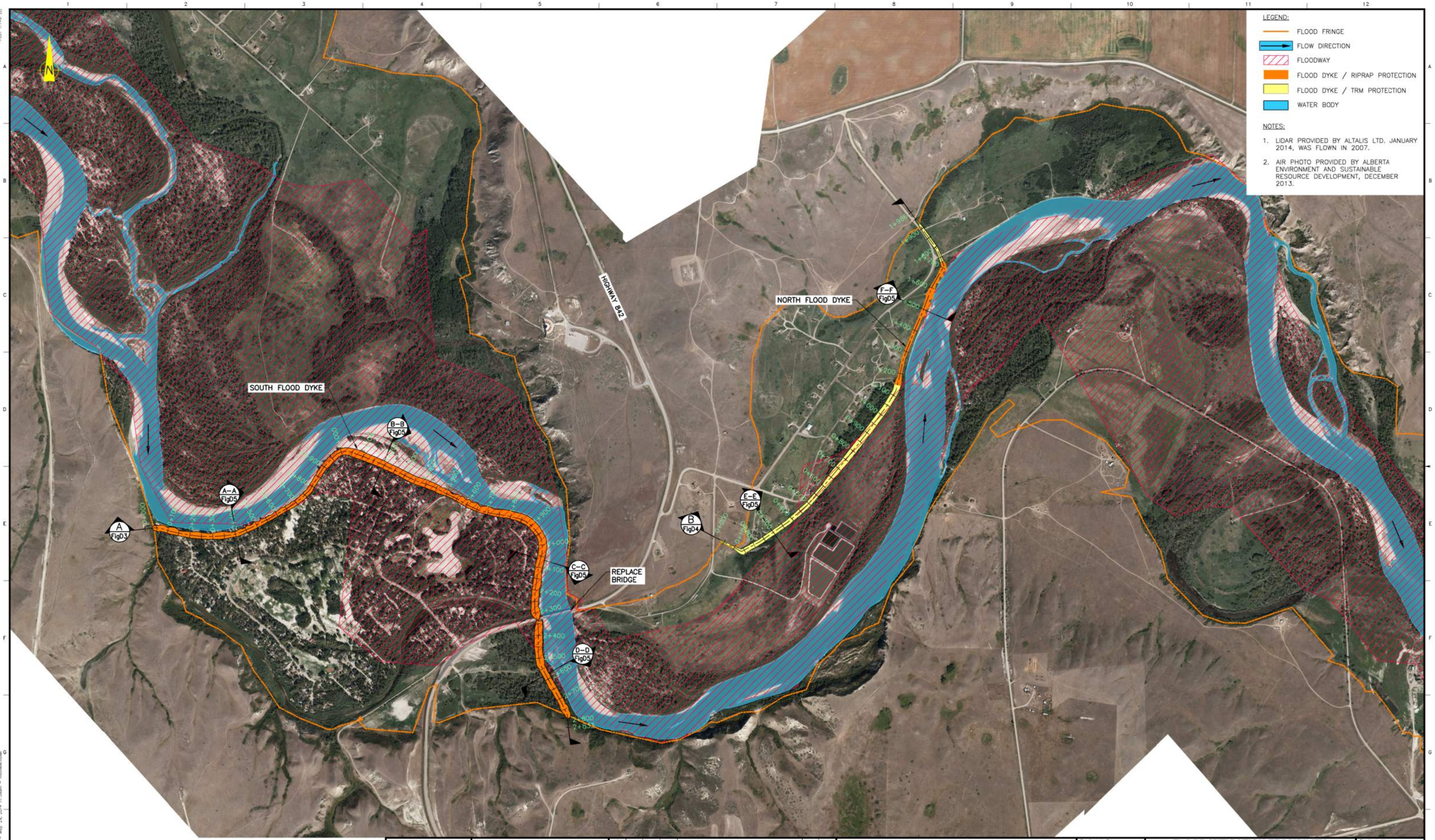
Client: **SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE**

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

Project: **FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS**

Title: **SIKSIKA FLOOD DEFENCE GENERAL PLAN**

Project No.: CW2174
CADD File: 2174-N04.dwg
Date: MARCH 2014
Drawing No.: FIGURE D1
Sheet No.: 1 of 1



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THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

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REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
G						
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B	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.B.
A	14	03	14	ISSUED FOR CLIENT REVIEW	H.M.	G.B.

amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

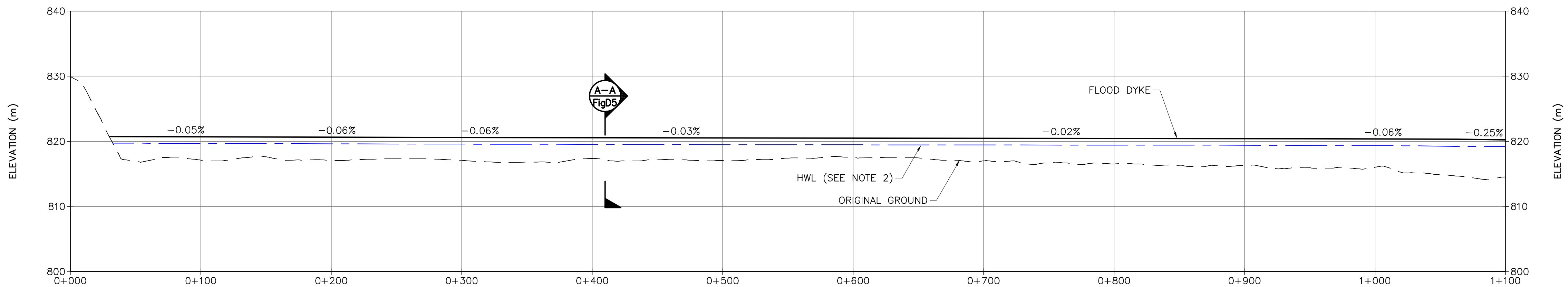
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: SIKSIKA FLOOD DEFENCE CONCEPTUAL PLAN

Project No.: CW2174
CADD File: 2174-N01.dwg
Date: MARCH 2014
Drawing No.: FIGURE D2
Sheet No.: 1 of 1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100-YEAR) FLOOD EVENT.



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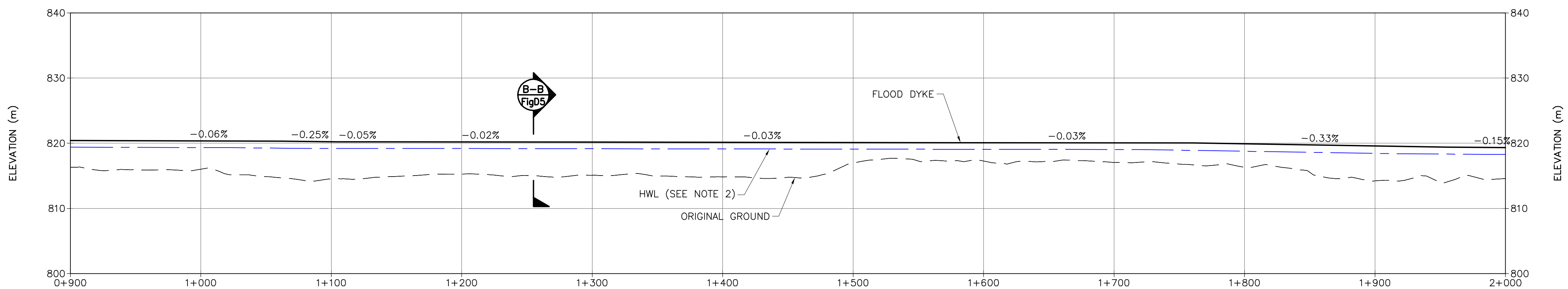
VER. 1:400



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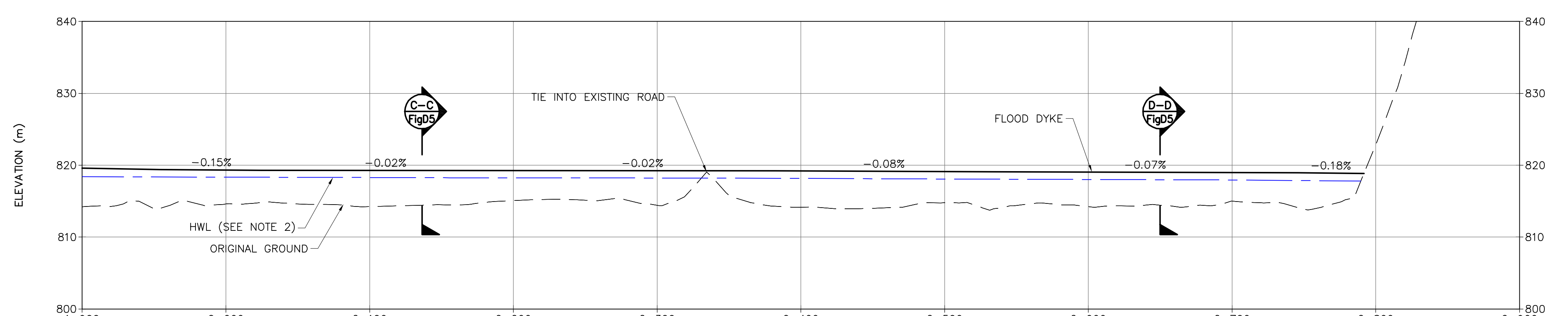

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VER. 1:400

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1:2000 0 10 20 30 40m

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Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: SIKSIKA FLOOD DEFENCE SOUTH DYKE PROFILE

Project No.: CW2174
CADD File: 2174-N01.dwg
Date: MARCH 2014
Drawing No.: FIGURE D3
Sheet No.: 1 of 1

NOTES:

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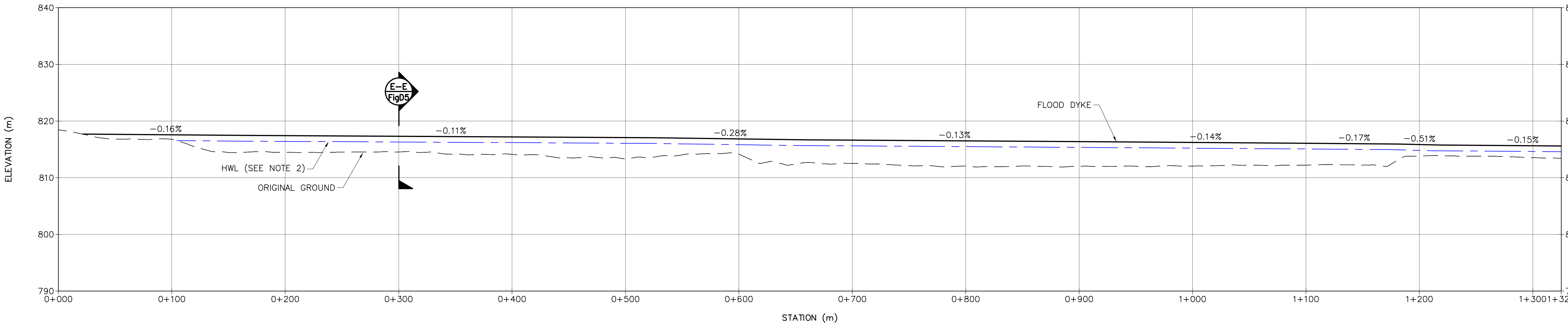
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.



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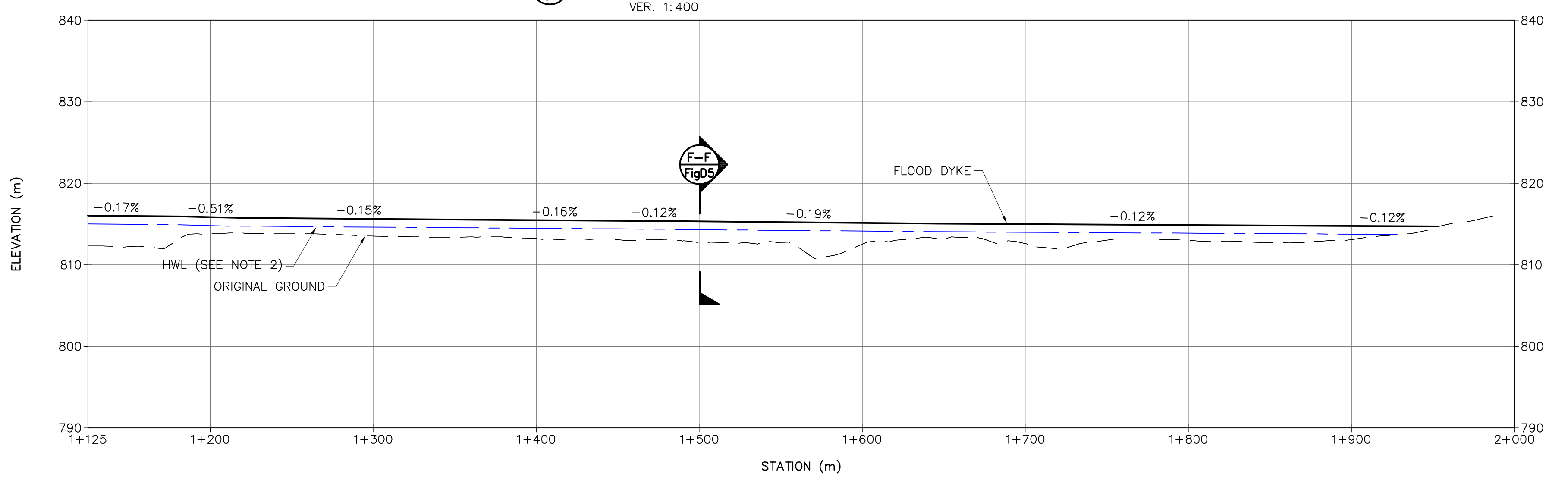

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VER. 1:400

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Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

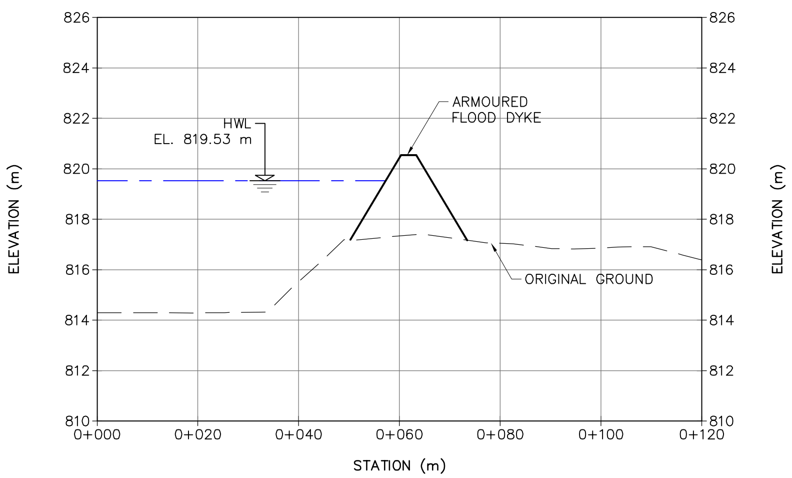
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: SIKSIKA FLOOD DEFENCE NORTH DYKE PROFILE

Project No.: CW2174
CADD File: 2174–N01.dwg
Date: MARCH 2014
Drawing No.: FIGURE D4
Sheet No.: 1 of 1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.
3. ALL SECTIONS LOOKING DOWNSTREAM.



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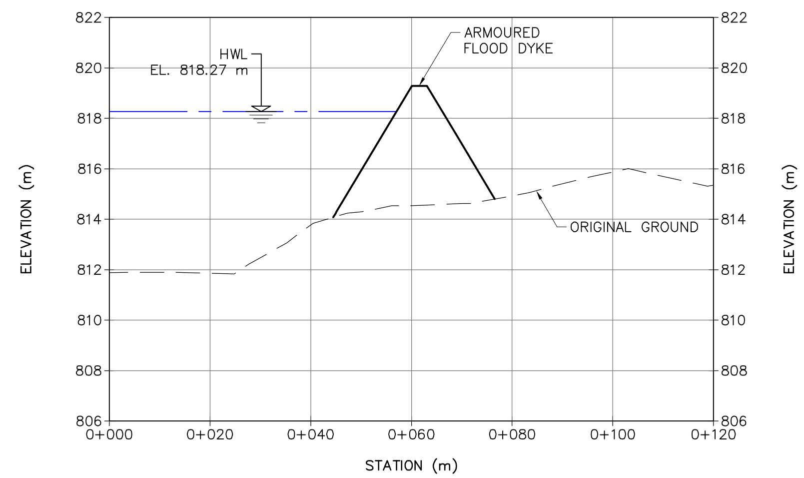

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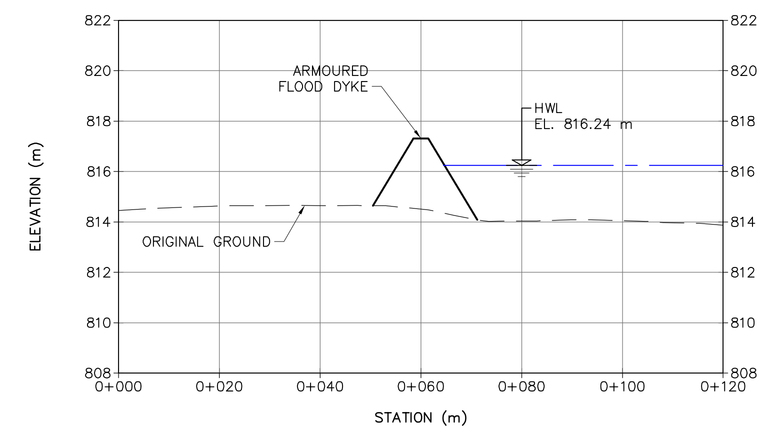

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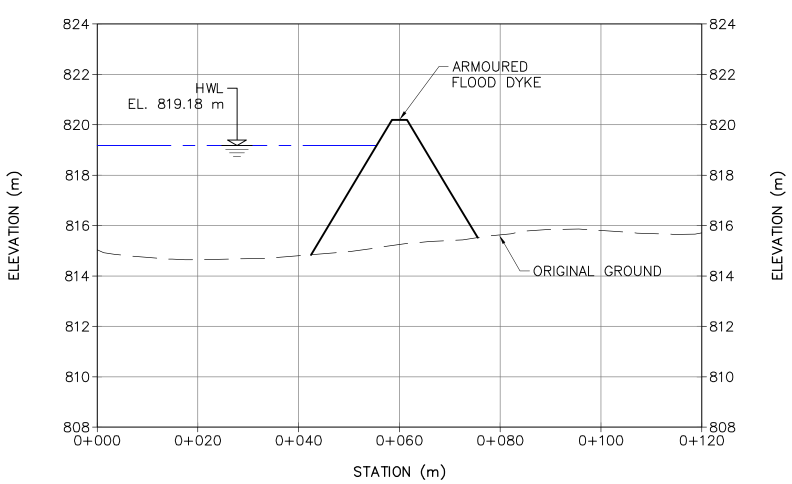

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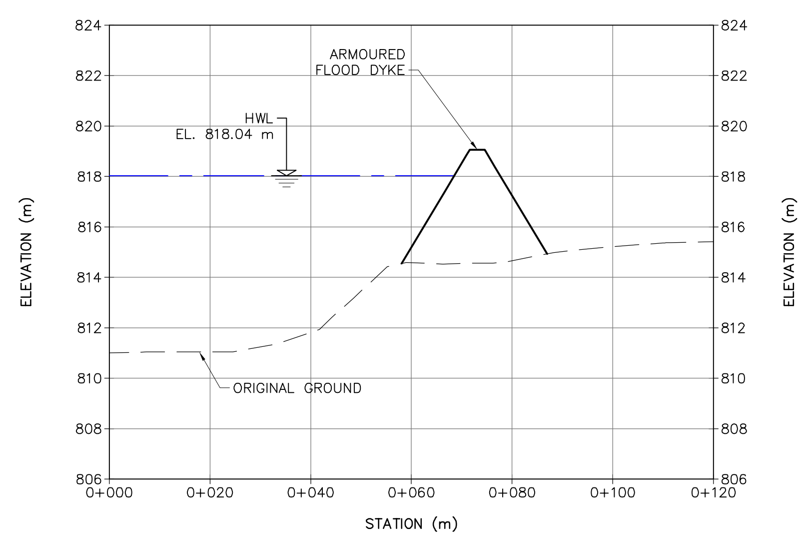

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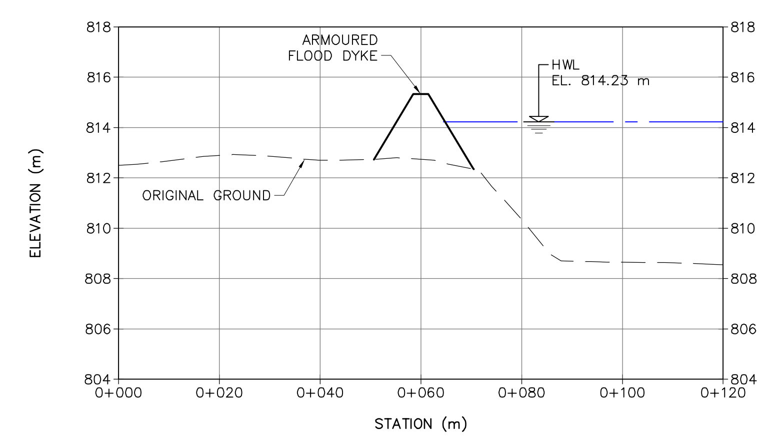

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1:750 0 5 10 15 m

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amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: SIKSIKA FLOOD DEFENCE DYKE SECTIONS

Project No.: CW2174
CADD File: 2174–N01.dwg
Date: MARCH 2014
Drawing No.: FIGURE D5
Sheet No.: 1 of 1

NOTES:

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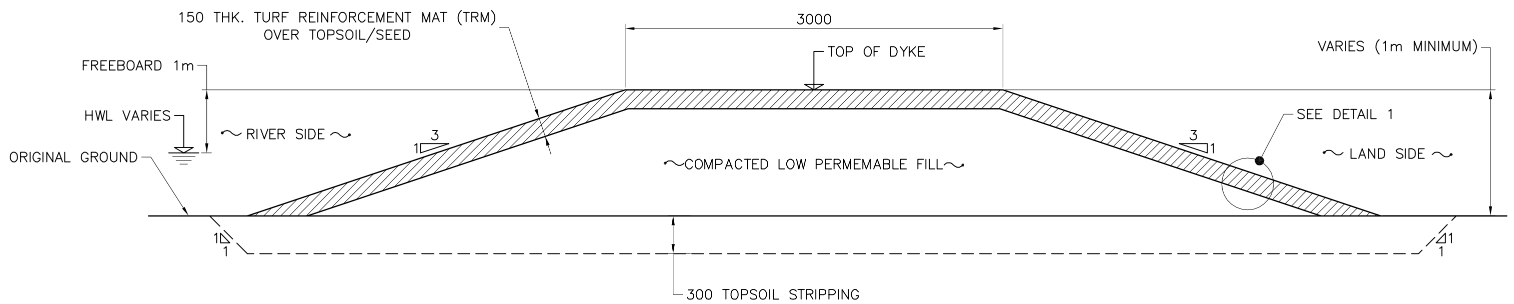

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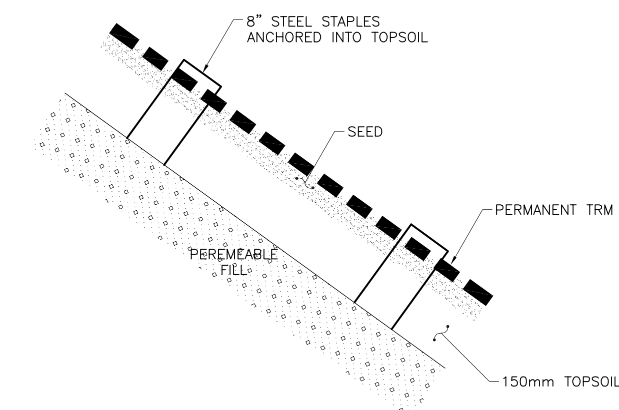
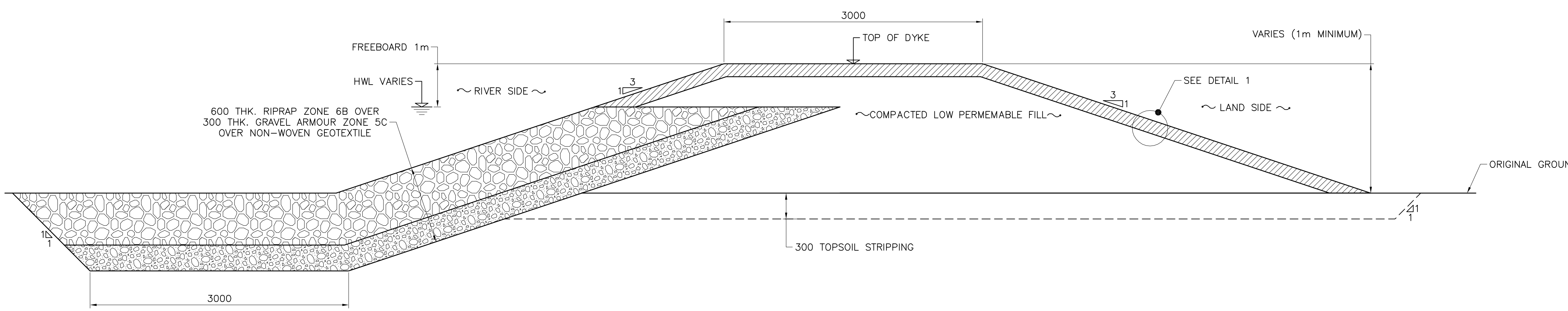
SCALE 1:30



1 DETAIL

SCALE NTS



TYPICAL SECTION – FLOOD DYKE (RIPRAP PROTECTION)

SCALE 1:30

SCALE 1:30 0 200 400 600 mm

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Designed By: H.M.
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Checked By: G.B.
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Scale: AS SHOWN

Project: **FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS**

Title: **SIKSIKA FLOOD DEFENCE TYPICALS**

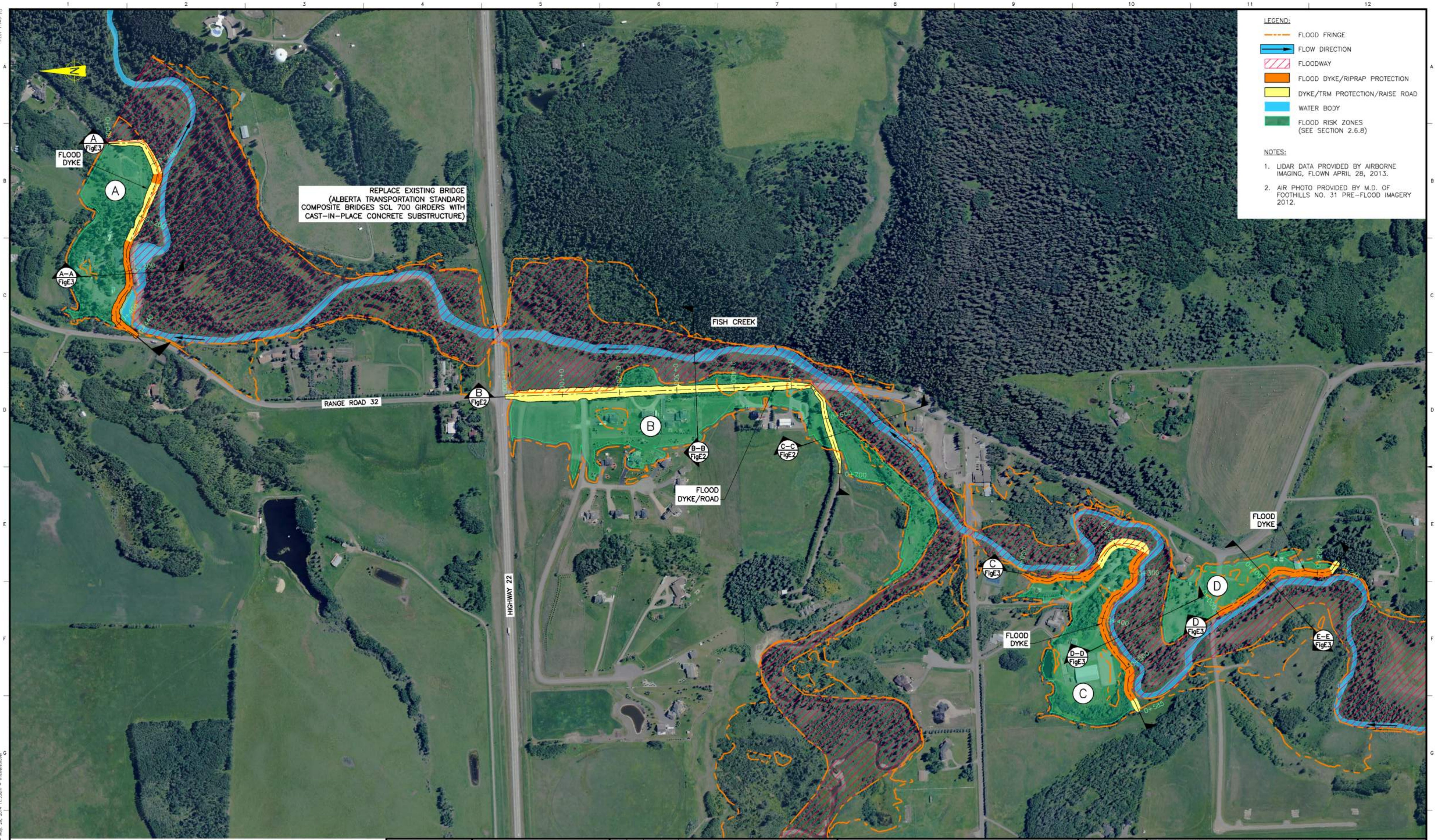
Project No.: CW2174
CADD File: 2174–N01.dwg
Date: MARCH 2014
Drawing No.: FIGURE D6
Sheet No.: 1 of 1

Appendix E

Conceptual Design of Flood Defences at Priddis

Conceptual Cost Estimate
Priddis Flood Defence Dykes & Roads

Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Bigger Size Riprap	Allow.	Allowance		$75,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$30,000
3	Existing and Temporary Roads	L.S.	1	Lump Sum	$15,000
	SITE PREPARATION				
4	Clearing & Grubbing	ha	1	$2,000.00	$2,785
5	Topsoil & Subsoil Stripping	m³	3294	$5.00	$16,470
6	Care of Water	L.S.	1	Lump Sum	$25,000
	FILL PLACEMENT				
7	Low Permeable Fill	m³	17792	$10.00	$177,918
	GRANULAR AND RIPRAP MATERIALS				
8	Riprap Zone 6B	tonnes	5827	$130.00	$757,516
9	Gravel Armour Zone 5C	tonnes	3642	$40.00	$145,676
10	Non-Woven Geotextile	m²	4338	$3.00	$13,015
	SITE CONSTRUCTION - ROAD				
11	Asphalt Concrete Pavement	tonnes	959	$250.00	$239,680
12	Surface Gravel Zone 4B	m³	137	$35.00	$4,788
13	Gravel Base Course Zone 4A	m³	2259	$15.00	$33,888
	LANDSCAPING				
14	Topsoil & Subsoil Placement	m²	8476	$1.50	$12,714
15	Turf Reinforcement Mat	m²	15130	$6.00	$90,778
16	Hydroseeding	m²	15130	$3.50	$52,954
	SUBTOTAL				**$1,693,182**
	CONTINGENCIES @ 25%				**$423,295**
	ENGINEERING @ 12%				**$203,182**
	ESTIMATED TOTAL COST				**$2,320,000**



SCALE 1:3000 0 20 40 60m

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amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

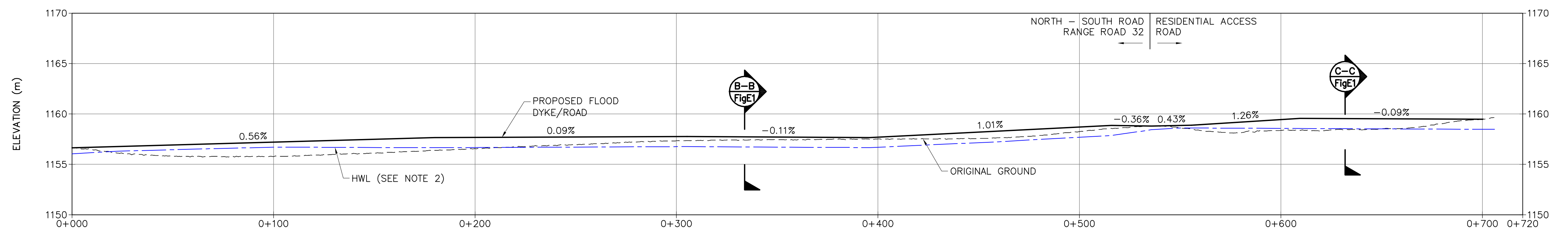
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: PRIDDIS FLOOD DEFENCE CONCEPTUAL PLAN

Project No.: CW2174
CADD File: 2174-J02.dwg
Date: MARCH 2014
Drawing No.: FIGURE E1
Sheet No.: 1 of 1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.
3. ALL SECTIONS LOOKING DOWNSTREAM.



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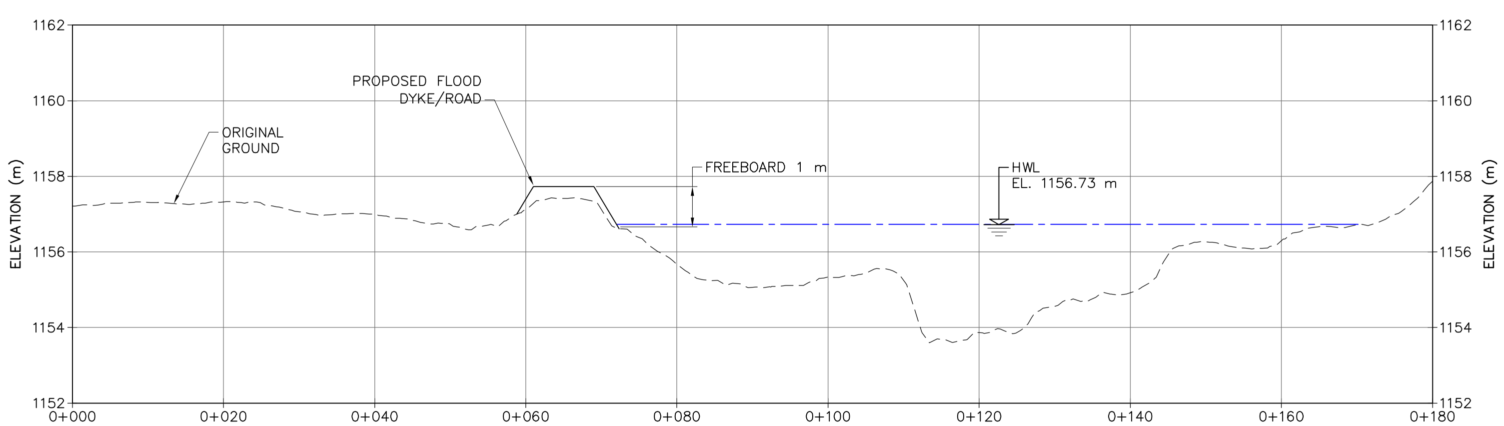

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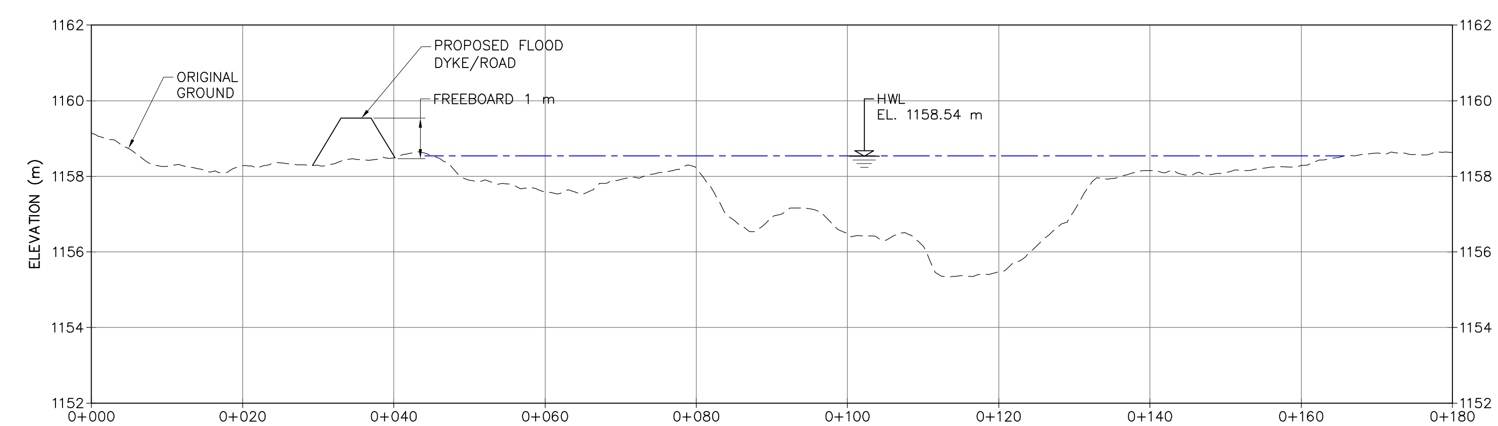

C–C FIgE1 SECTION
SCALE HOR. 1:500
VER. 1:100

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1:250 0 1 2 3 4 5m
1:500 0 5 10m
1:1250 0 10 20 25m

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Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: PRIDDIS FLOOD DEFENCE ROAD PROFILE AND SECTIONS

Project No.: CW2174
CADD File: 2174–J02.dwg
Date: MARCH 2014
Drawing No.: FIGURE E2
Sheet No.: 1 of 1

NOTES:

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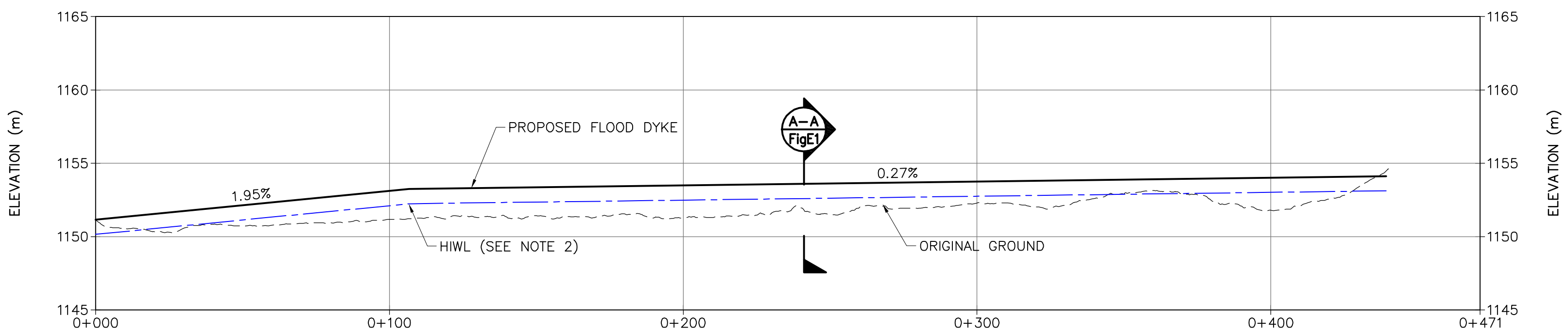

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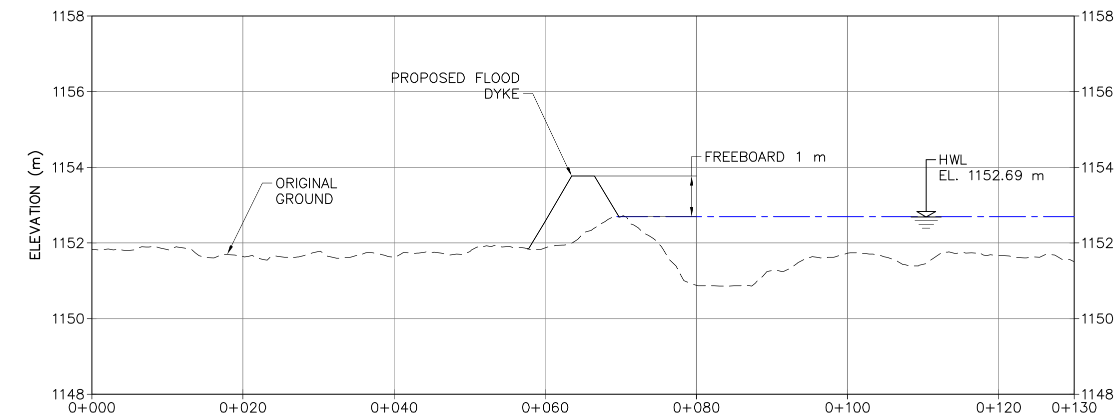

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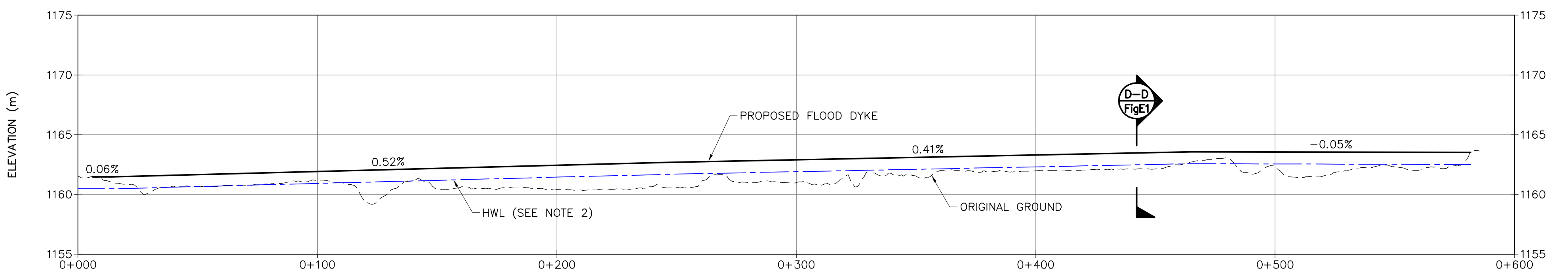

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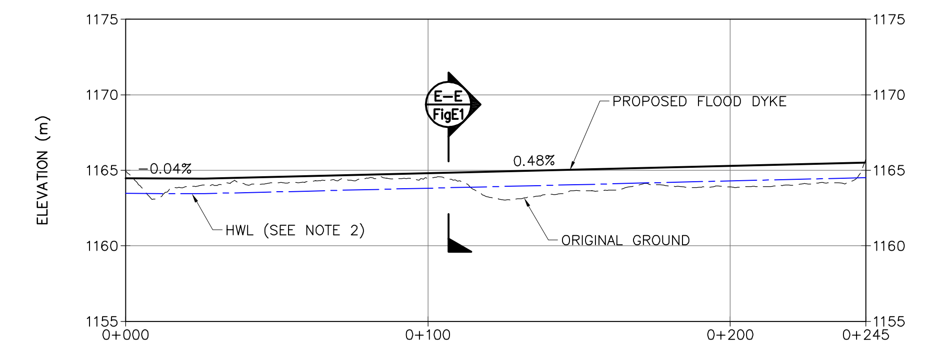

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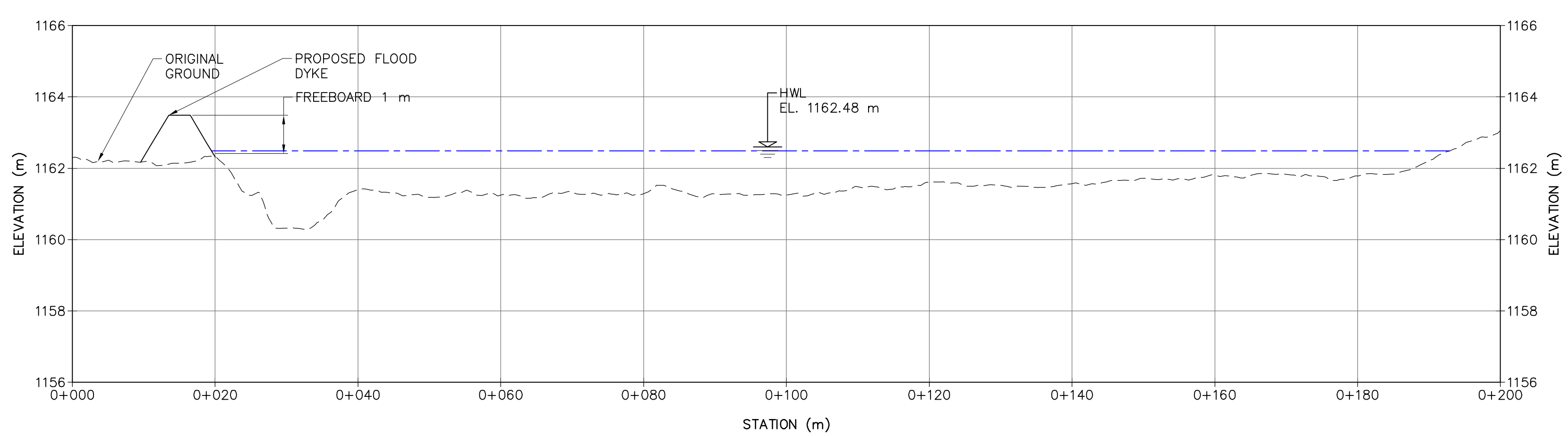

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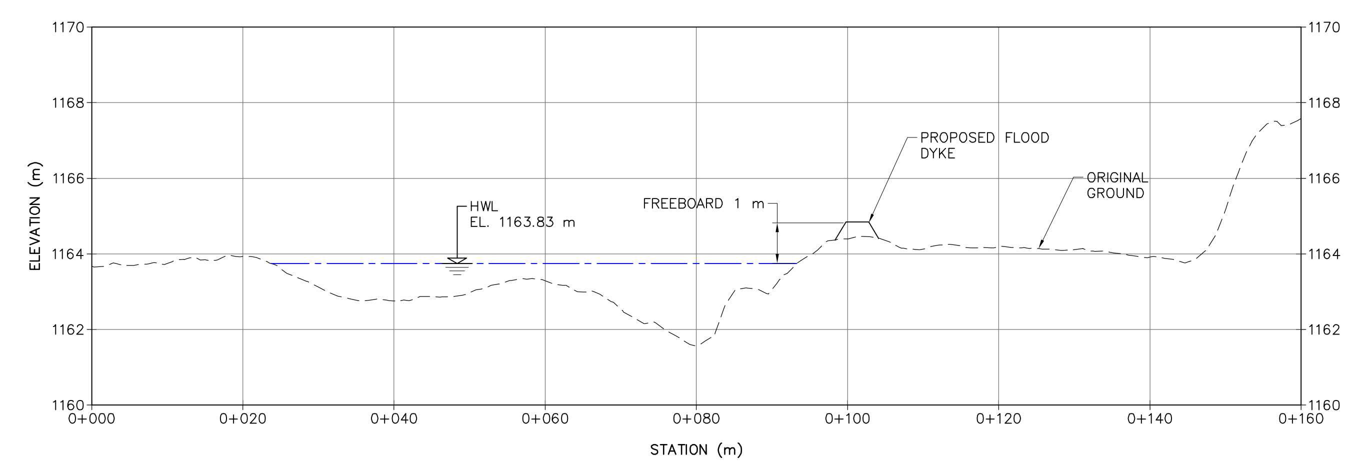

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SCALES
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1:250 0 1 2 3 4 5m
1:500 0 5 10m
1:1250 0 10 20 25m

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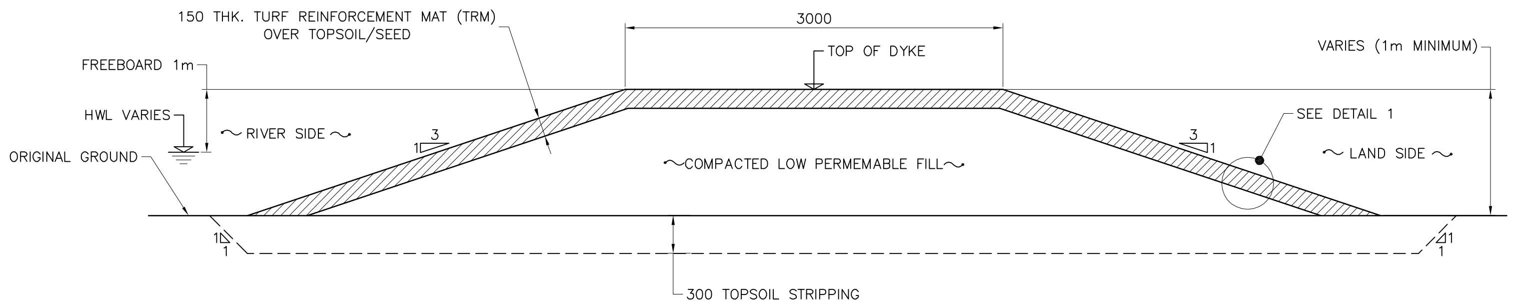
Checked By:	G.B.
Approved By:	G.G.
Scale:	AS SHOWN

Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

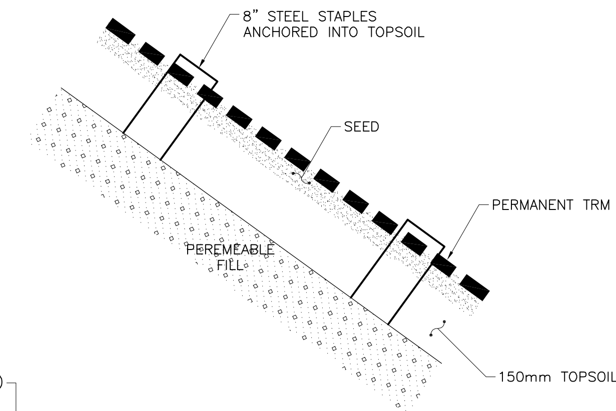
Title: PRIDDIS FLOOD DEFENCE DYKE PROFILES AND SECTIONS

Project No.:	CW2174
CADD File:	2174-J02.dwg
Date:	MARCH 2014
Drawing No.:	FIGURE E3
Sheet No.:	1 of 1



TYPICAL SECTION – FLOOD DYKE (TRM PROTECTION)

SCALE 1:30



1 DETAIL

SCALE NTS

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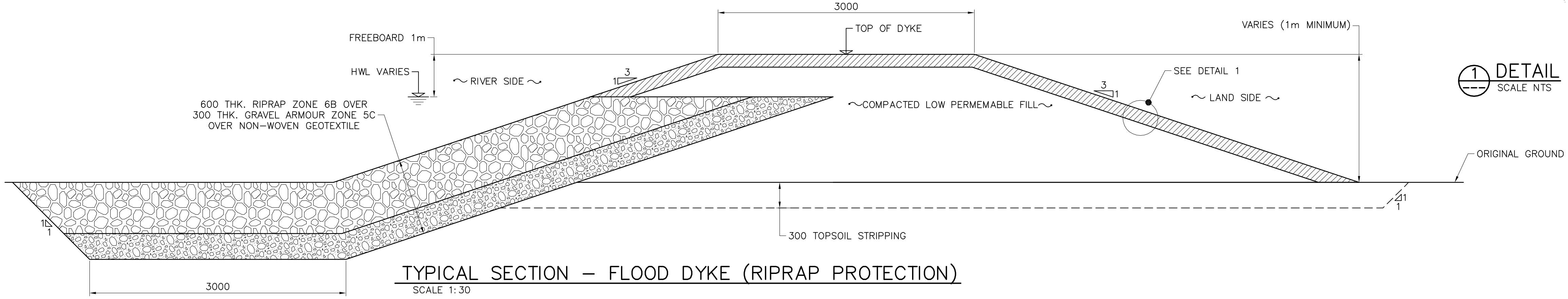

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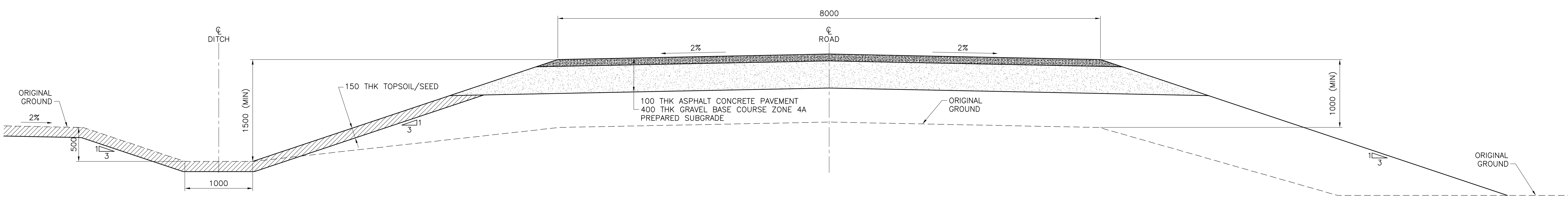

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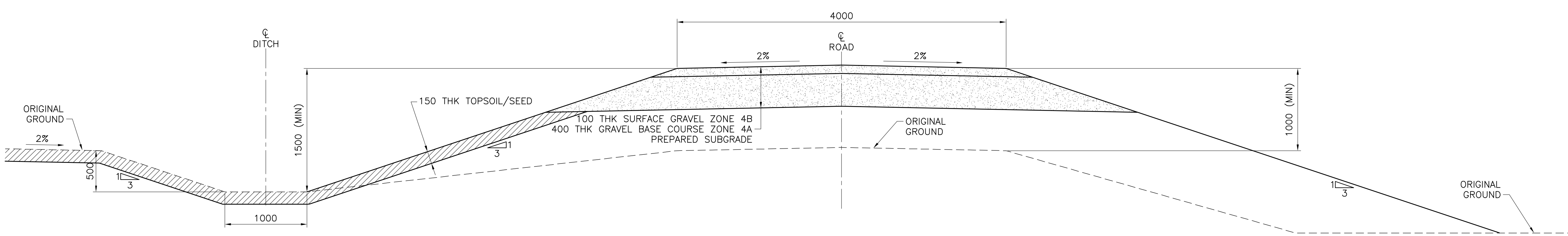

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SCALE 1:30 0 200 400 600 mm

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Checked By:	G.B.
Approved By:	G.G.
Scale:	AS SHOWN

Project: **FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS**

Title: **PRIDDIS FLOOD DEFENCE TYPICALS**

Project No.:	CW2174
CADD File:	2174–J02.dwg
Date:	MARCH 2014
Drawing No.:	FIGURE E4
Sheet No.:	1 of 1

Appendix F

Conceptual Design of the McLean Creek Flood Storage Site

Southern Alberta Flood Recovery Task Force
Volume 4 – Flood Mitigation Measures

Appendix F – Elbow River Dam at McLean Creek

Submitted to:

Southern Alberta Flood Recovery Task Force
Edmonton, Alberta

Submitted by:

AMEC Environment & Infrastructure
Calgary, Alberta

May 2014

CW2174

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LIST OF TABLES

LIST OF FIGURES

1.0 ELBOW RIVER DAM AT McLEAN CREEK

1.1 Concept Description

The Elbow River Dam at McLean Creak (MC1) site was previously identified and investigated for flood mitigation as part of the *1986 Elbow River Floodplain Management Study* by WER Engineering Ltd., IBI Group, and ECOS Engineering. The site is located in the Green Zone on Crown Land approximately 10 km upstream of the Town of Bragg Creek, and immediately upstream of the confluence of McLean Creek with the Elbow River.

This project concept considers building an earth fill dam across the main stem of the Elbow River. It includes a combined concrete outlet/service spillway structure for discharging normal and flood flows, and includes an auxiliary earth cut channel spillway to protect the dam from extreme floods up to the probable maximum flood (PMF) event. The dam site and reservoir area are illustrated in **Drawing F1**.

The proposed earth fill dam (main embankment) traverses a river gorge which is approximately 110 m wide at the base and is steep walled for a height of about 28 m. The left abutment has a high knob-like feature falling away to an undulating plateau more-or-less equal to the height of the main gorge and then rising again to the northwest. The right abutment has a plateau at about the same elevation and then rises again to the southwest. The Kananaskis Country Highway 66 traverses the right abutment. The river valley itself bends sharply to the north-northeast at the dam site, facilitating the construction of an auxiliary earth channel spillway on the right bank. Similarly, the topography and river alignment are well suited for construction of a permanent outlet/spillway structure in the left valley abutment.

The permanent outlet/service spillway is a gated conduit structure with its intake invert located about 21 m above valley bottom. The structure concrete gates would typically be left in the wide open position thereby allowing free passage of river water with minimum reservoir level rise during normal flow conditions (i.e., non-flood). The gates would be strategically closed during flood events thereby holding back a significant portion of the flow in reservoir storage.
The concrete structure also serves as a service spillway designed to pass even more extreme flood events, if they ever occur, thereby protecting the dam from potential overtopping and associated catastrophic failure.

This conceptual design includes a small permanent pool in the valley bottom extending from river bottom elevation 1,379.0 m to the permanent outlet structure intake invert elevation 1,398.0 m, thereby permanently containing approximately 4,000 dam^3 of water as dead storage. This storage is intended to prevent incoming larger bottom sediment from plugging the intake area, and could also replace the previously existing Allen Bill Pond which was destroyed by the 2013 flood. There is no low level outlet to release the dead storage. Additional water could be contained above the dead storage El. 1,398.0 m (i.e., multi-use storage) by regulating the permanent outlet gates using pre-programmed automation methods, rather than leaving the gates in the wide open position as considered herein. The potential value and/or need for multi-use storage at this site should be evaluated as part of the future study.

2.0 HYDROLOGICAL OVERVIEW

2.1 Median and Mean Monthly Flows

Median winter and median annual flows for the Elbow River are approximately 3 and 10 m^3/s, respectively, as recorded at Alberta Environment and Sustainable Resource Development (ESRD) gauging station 05BJ004 (Elbow River at Bragg Creek). Mean monthly flows as recorded at station 05BJ004 are provided in **Table F2.1**.

Table F2.1
Elbow River Mean Monthly Flows
Gauging Station Elbow River at Bragg Creek

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Flow (m^3/s)	3.0	2.9	3.2	4.7	14.6	25.2	13.4	9.3	8.1	6.5	4.7	3.7

The MC1 site is located approximately 10 km upstream of this gauging station, resulting in a 10% reduction in drainage area. The impact of this area's reduction on median and mean monthly flows has not been estimated as a part of this study, but will be much less than 10%.

2.2 Flood Flows

Frequency analysis of flood inflows into Glenmore Reservoir (i.e., 10 km downstream of the MC1 site as discussed herein) which was completed for this study resulted in instantaneous flood peak flow and 7-day flood volume estimates as summarized in **Table F2.2**. These estimates are considered to be representative of the upstream MC1 site (i.e., assumes minimal inflow between the MC1 site and Sarcee Bridge during extreme flood events generated in higher regions of the basin). Background information which provides the basis for flood estimates is documented separately in **Appendix C** of the main report. Estimates of the June 2013 flood instantaneous peak flow and total flood volume entering Glenmore Reservoir are included for comparison in **Table F2.2**.

Table F2.2
Elbow River Instantaneous Flood Peak and Runoff Volume Estimates

Annual Flood Probability (Return Period)	Instantaneous Peak Flow (m^3/s)	7-day Volume dam^3
5% Annual Exceedence Probability (AEP; 1:20-year)	440	83,000
1% AEP (1:100-year)	930	130,000
June 2013 Flood	1,260	154,000
0.2% AEP (1:500-year)	1,625	183,000

As indicated by **Table F2.2,** the June 2013 flood instantaneous peak flow and flood volumes were larger than the estimated 1% AEP flood but smaller than the 0.2% AEP flood. More detailed frequency analysis should be performed as part of future, more detailed design study.

2.3 Probable Maximum Flood

The PMF is defined as the most severe flood that may be reasonably expected to occur at a particular location. The PMF is normally evaluated by deterministic methods that maximize the various factors contributing to the generation of a flood. The probability of such a flood occurring is very rare (e.g., once in a million years).

A PMF hydrograph at Glenmore Reservoir was previously generated by ESRD and is included in the August 1986 *Elbow River Floodplain Management Study* by WER, IBI and ECOS. The PMF entering Glenmore Reservoir was estimated to have a flood peak value of 2,175 m^3/s and a 7-day volume of approximately 464,000 dam^3, which is approximately 3.0 times the volume of the 2013 flood. ESRD cautions:

> "…that these are preliminary estimates of PMF…subject to considerable error and that a detailed assessment….would be required prior to any detailed design."

3.0 GEOLOGICAL AND GEOTECHNICAL OVERVIEW

A preliminary subsurface field investigation was completed as a part of this study as documented in a separate report entitled *Preliminary Geotechnical Investigation Report, Elbow River Dam at McLean Creek* (AMEC, 2014).

In general terms, the Elbow River valley upstream from Bragg Creek is defined by the foothills and by bedrock exposures. Bedrock is of Upper Cretaceous age, consisting of sandstones, siltstones, and mudstones of the Brazeau Formation. Valley bottom materials in the area consist of terraced modern alluviums composed of boulder to cobbly sands and gravels with fine-grained back-water deposits. Materials at higher elevations include colluvial deposits, glacial drift (till), and outwash deposits. The thickness of valley bottom materials overlying the bedrock is likely to be only a few metres. The depth of glacial deposits over adjacent bedrock topography is highly variable. The site rock exposures indicate that thickly bedded sand-stone lies above the more thinly bedded siltstones and mudstones, and that the bedrock is dipping in an east to southeast direction at about 5 to 10 degrees. The right side topography above the edge of the gorge is likely nominally capped with glacial drift materials, the left gorge wall is capped with a substantial amount of glacial drift material.

4.0 FLOOD STORAGE VOLUME

4.1 Background Considerations

Significant residential development located along the Elbow River floodplain downstream of Glenmore Reservoir is at risk during extreme flood events. Pathway closures are required when Glenmore Reservoir flood discharge reaches 40 m^3/s. Modest overbank flooding of undeveloped areas starts at 120 m^3/s discharge. Widespread basement seepage occurs for discharges of 140 m^3/s. First residents are impacted at discharges of 170 m^3/s. Evacuation of residents is initiated at a discharge of 192 m^3/s.

The most recent Glenmore Reservoir storage capacity and flooded area curves which were produced by Klohn Crippen Berger in 2013 are illustrated on **Figure F4.1**. The existing Glenmore Reservoir storage is used to attenuate flood peaks thereby protecting downstream developments. If an extreme flood is forecast, the City of Calgary opens the Glenmore Reservoir low level DOW valves thereby drawing the reservoir down to provide flood storage for the incoming flood. Maximum permissible drawdown is 5 m below FSL El. 1,076.85 m which equates to a flood storage volume of 15,400 dam^3 (KCB Glenmore Bathymetric Survey, 2013). This drawdown could be accomplished in 25 hours at the maximum discharge rate of 170 m^3/s (maximum discharge before significant downstream flood damages start to occur). In reality a portion of this storage should be drawn down well in advance of an actual flood event forecast (e.g., in the spring when significant snow pack exists in the watershed). The 15,400 dam^3 draw down was successfully achieved in anticipation of the June 2013 flood. The City of Calgary needs to use caution when drawing the reservoir down in that if they draw down the Glenmore Reservoir and the forecast flood does not develop they can be left with insufficient water supply.

Bathymetric surveys by Klohn Cripper Berger for the City of Calgary indicate that Glenmore Reservoir may have lost approximately 17% of its storage volume since 1933 as a result of sediment transport into the reservoir. This process is ongoing.

Figure F4.1

Glenmore Reservoir
Reservoir Storage Capacity and Flooded Area Curves

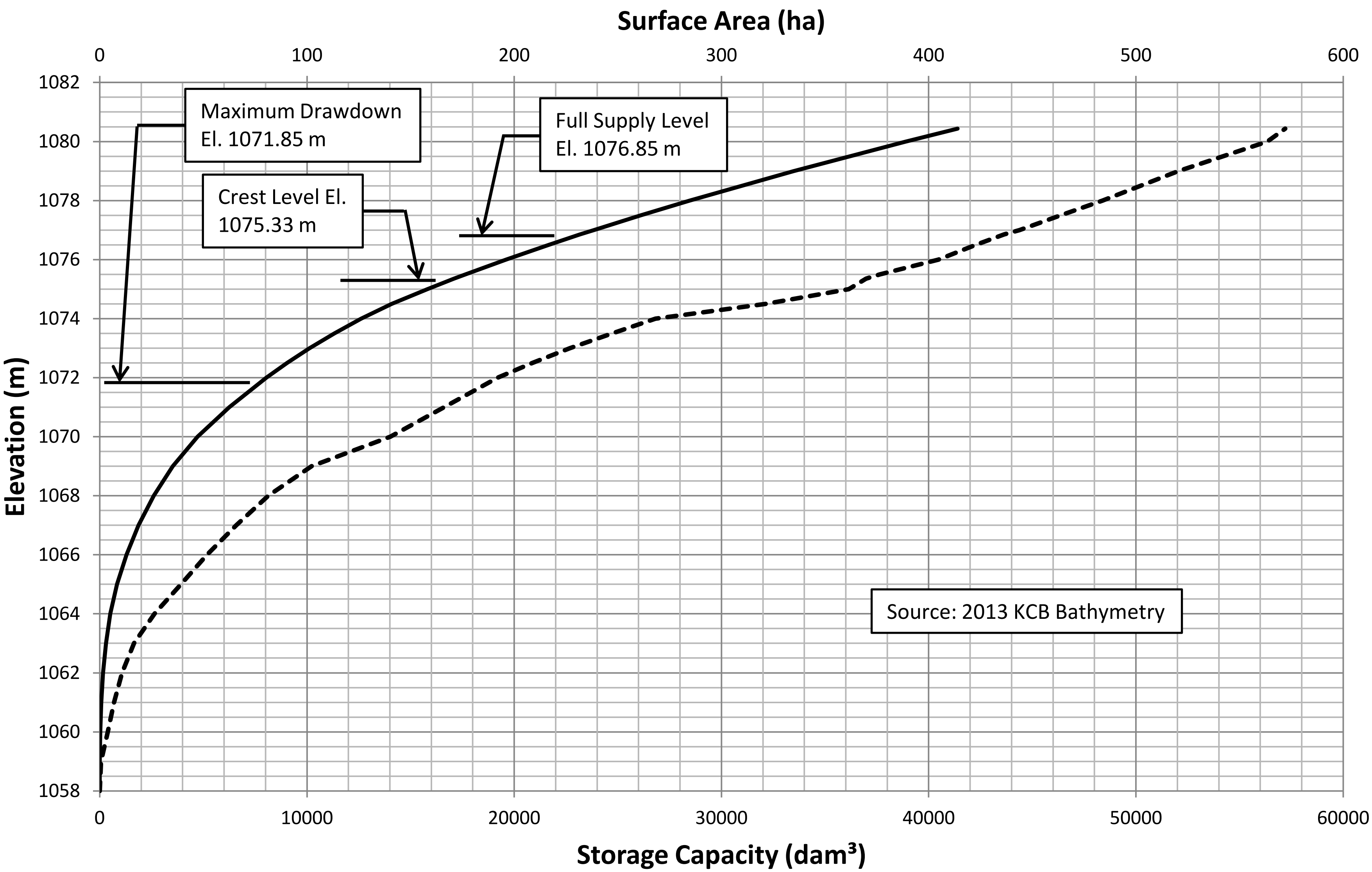

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Table F4.1 provides estimates of the flood volume required to prevent significant damages along the Elbow River downstream of Glenmore Reservoir, considering a continuous discharge of 170 m^3/s from the reservoir for the duration of the flood (i.e., discharge before first downstream residents are impacted by flood water).

Table F4.1
Required Reservoir Flood Storage Volume to Prevent Damages

Return Period (Years)	Minimum Storage Requirement
5% AEP (1:20-year)	16,800
1% AEP (1:100-year)	56,600
June 2013 Flood	83,000
0.2% AEP (1:500-year)	107,500

Based on the data presented in **Table F4.1,** one can conclude that the Glenmore Reservoir flood storage of 15,400 dam^3 is inadequate to prevent discharge from exceeding the 170 m^3/s value for flood events as small as the 5% AEP flood. The level of protection is even poorer if the City is not successful drawing Glenmore Reservoir down to its minimum El. 1,071.85 m prior to flood impact. It is therefore concluded that the existing level of protection to residences downstream of the Glenmore Reservoir is inadequate. That said, Glenmore Reservoir flood storage does provide significant flood peak attenuation and downstream development protection (e.g., as much as full protection for floods just smaller than 5% AEP, and successfully attenuated June 2013 flood inflow peak of 1,260 m^3/s to discharge of approximately 700 m^3/s).

4.2 Flood Protection Design Basis

The current Alberta minimum flood protection design standard is the 1% AEP flood, or alternatively can be based on a historical flood event (e.g., June 2013 flood). Increased protection should be considered based on economic assessment and/or when such an event would result in severe societal impact. As an example, the Red River floodway was originally sized to protect Winnipeg from the 0.2% AEP (1:500-year) flood event. It was later enlarged to provide 0.14% AEP (1:700-year) flood protection. Even greater protection was considered but costs were proven to be prohibitive.

The MC1 concept as presented herein was developed considering the 1% AEP minimum design standard (i.e., total flood storage requirement of 56,600 dam^3). As previously mentioned, Glenmore Reservoir can provide 15,400 dam^3 of that amount. As indicated in **Figure F4.2,** the remaining 41,200 dam^3 flood storage could be provided with MC1 storage reservoir water level of approximately El. 1,422.0 m. To account for operational inefficiencies a slightly higher 1% AEP El. 1,423.0 m has been used. This considers that none of the previously mentioned dead storage can be preleased. The conceptual design provides for a nominal 3.5 m additional storage above the 1% AEP El. 1,423.0 m (i.e., maximum allowable reservoir El. 1,426.5 m) resulting in a combined total flood storage capacity of 73,400 dam^3 (i.e., Glenmore and MC1 combined reservoir storage) prior to activation of the MC1 auxiliary earth channel spillway. Considering the project size presented in this conceptual design, a 2013 magnitude flood would still result in residential damages along the Elbow River floodplain downstream of Glenmore Reservoir, but these damages would be greatly reduced as compared to what was experienced in 2013. The MC1 project could be built to a higher level than investigated herein to provide enhanced flood protection (e.g., full containment for 2013 magnitude flood or larger). Alternatively, additional projects could be constructed to provide enhanced flood protection above that provided herein.

Figure F4.2

Elbow River Dam Site at McLean Creek (MC1)
Reservoir Storage Capacity and Flooded Area Curves

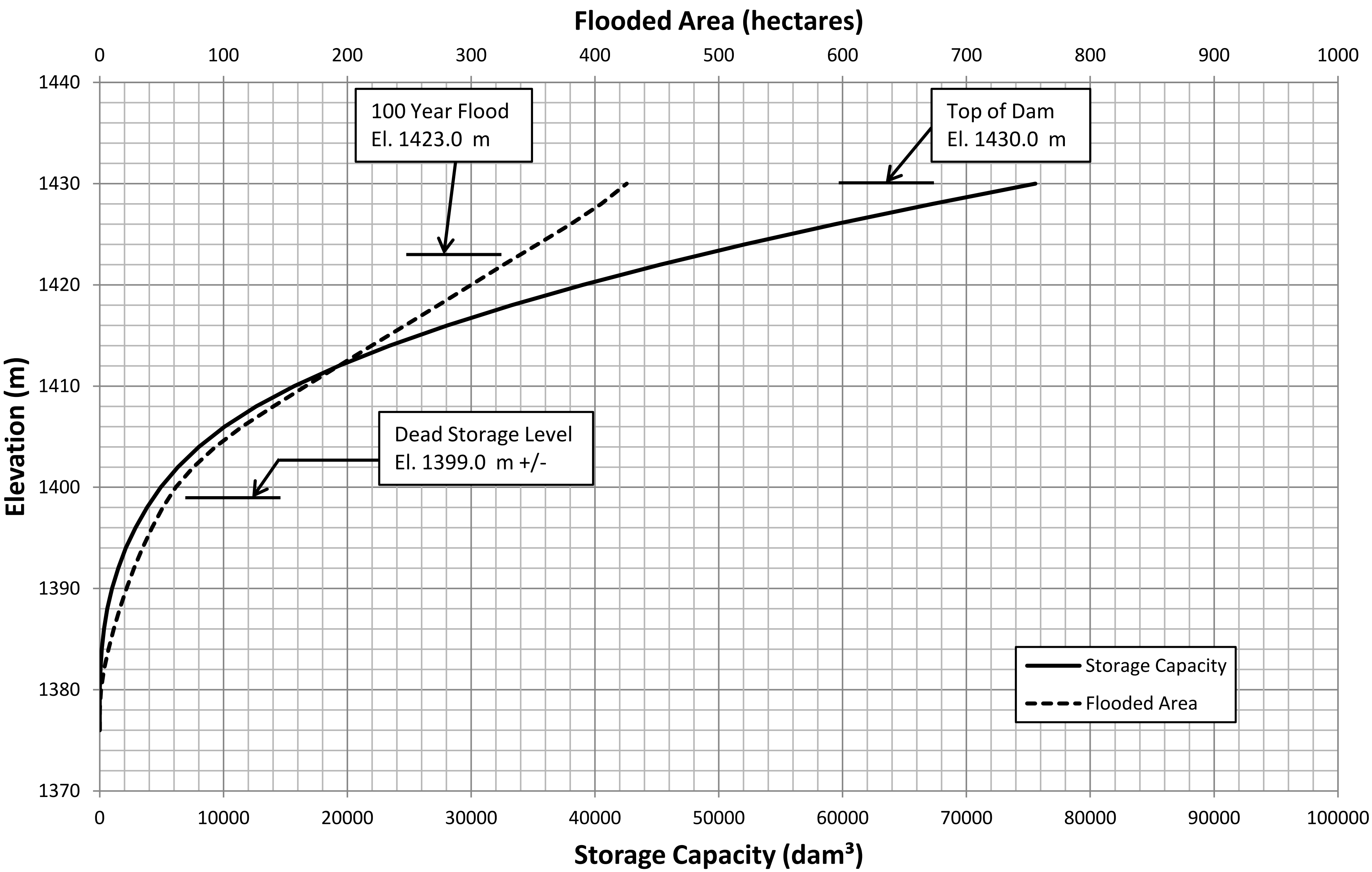

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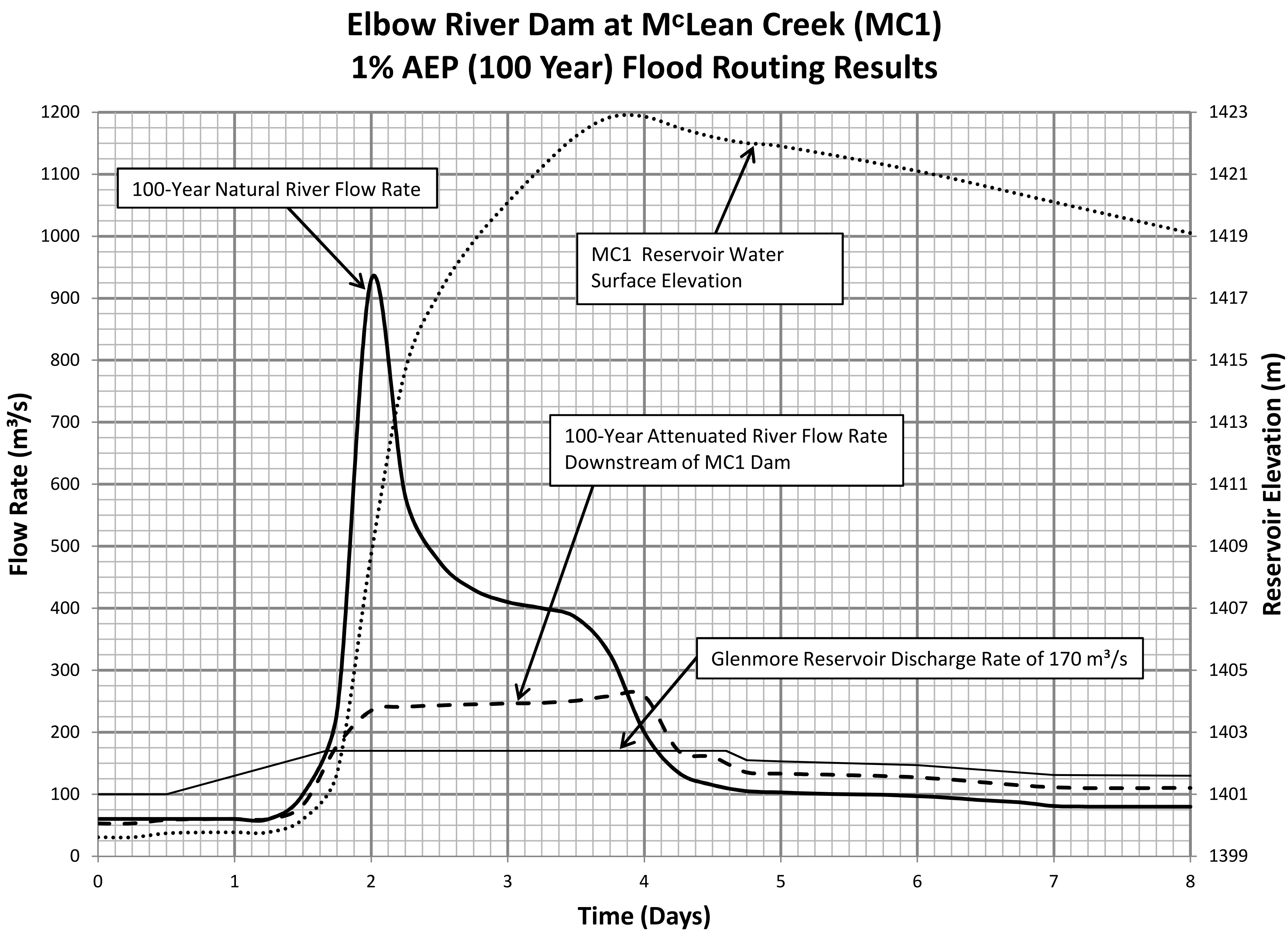
Figure F4.2 area and capacity curves were developed based on contours developed from the Canadian Digital Elevation data (CDED) illustrated on **Drawings F1**. These area and capacity curves should be updated in future design using more accurate LiDAR data.

Figure F4.3 illustrates the potential flood flow reduction benefits of the MC1 and Glenmore Reservoir storage when managing the 1% AEP flood. The figure illustrates that the MC1 peak inflow rate of 930 m^3/s is reduced to a peak discharge of 260 m^3/s downstream of the MC1 reservoir. This resulting 260 m^3/s flow rate is absorbed in Glenmore Reservoir storage. The resulting peak discharge from Glenmore Reservoir is 170 m^3/s; the maximum allowable discharge prior to residential damage.

The following additional observations are made with respect to **Figure F4.3**:

- The inflow hydrograph peaks rise rapidly emphasizing the need for improved flood forecasting methods.
- The MC1 structure gates need to be closed rapidly after the MC1 reservoir has stopped rising (i.e., inflow peak has passed and inflow rate exceeds outflow rate just before 4 days into the event) otherwise Glenmore Reservoir storage will be inadequate
- The above-noted operational considerations support building the project to greater than the 1% AEP return period protection level (i.e., increased volume and diversion rate) and/or constructing additional flood protection projects.

Figure F4.3



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5.0 PROJECT DESIGN

5.1 General

Pertinent structure data established for conceptual design and described in this report section are provided in **Table F5.1**.

Table F5.1
Elbow River Dam at McLean Creek (MC1) Pertinent Structure Data

Flood Storage Reservoir	
Dead Storage Volume	4,000 dam^3
Dead Storage Elevation	1,398.0
100-year Flood Storage Volume	41,200 dam^3
100-year Reservoir Flood Elevation	1,423.0 m
Main Embankment	
Dam Protection Design Flood	Probable Maximum Flood
Top of Dam Elevation	1,430.0 m
Maximum Dam Height	50 m
Probable Maximum Flood Elevation	1429.0 m
Freeboard above Probable Maximum Flood	1.0 m
Combined Permanent Outlet/Service Spillway Structure	
Conduit System	6 side by side openings
Intake Invert Elevation	1398.0 m
Size of Conduits	3.0 m wide x 3.0 m high each
Length of Conduit System	240 m
Gatewell Tower Height	32 m
Size of Gates	6 gates at 2.7 m wide x 3.0 m high
Length of Downstream Chute	160 m
Length of Stilling Basin	28.0 m
Width of Chute and Basin	23.0 m
Service Spillway Design Flood	0.2% AEP Period *
Maximum Service Spillway Outflow	780 m^3/s
Auxiliary Earth Channel Spillway	
Upstream Invert Elevation	1,426.0 m
Bottom Width	100 m
Fuse Plug Crest Elevation	1,426.5 m
Maximum Design Outflow	1,280 m^3/s

* Prior to activation of Auxiliary Earth Channel spillway.

5.2 Storage Dam and Reservoir

5.2.1 General

Drawing F2 illustrates the conceptual design for the main dam embankment, given the estimated geotechnical conditions, the perceived available construction materials, and the configuration of the valley cross-section at this site. The proposed 50 m high dam section considers a 10 m top width, an interior impervious core and outer random earth fill shells. Embankment slopes are estimated at 3H:1V with 10 m wide berms at 10 m vertical intervals resulting in average dam slopes of 4H:1V. As compared to a simple 4H:1V slope the berms provide the advantages of facilitating inspection, maintenance, and access to geotechnical instruments. They can also be used to build a temporary ditch system to facilitate surface water management following construction until a good grass cover is established. The need, width and spacing of such berms should be further evaluated as part of future design. The conceptual design includes an interior sand filter and drainage system, and upstream rock riprap slope protection. Rock riprap has been provided in the lower active reservoir zone (i.e., up to El. 1405.0 m). It is also provided in the top 10 m zone to protect the dam from potential failure considering the unlikely event of a PMF combined with a 50% AEP wind event. This upper zone riprap can be covered with topsoil and seeded to provide a more desirable landscape appearance. Consideration should also be given to using a more erosion-resistent impervious 1A zone material in the upstream shell/upstream dam surface to reduce flood storage wave damage risk. The extent of these features will be better established as part of more detailed future design.

During construction flood risk is always a major concern particularly when building a dam upstream of a major population centre. Allowance has been made in the cost estimate to incorporate cofferdams and other works (e.g., temporary low level conduits and additional emergency earth cut spillways) to protect a partially constructred dam from overtopping which could result in dam failure and associated catastrophic downstream damages within the City of Calgary. Finite details cannot be established until more detailed geotechnical information has been obtained.

McLean Creek presently flows into the Elbow River directly below the downstream toe of the dam; consequently it would have to be re-routed through a low height of ground such that the flow is directed away from the toe of the main embankment. The extent of relocation would be minimized by providing riprap protection at the embankment toe in this area.

5.2.2 Geotechnical Design Details

The dam embankment has been divided into three sections based on topography and subsurface conditions, namely:

- The valley section of dam in the Elbow River gorge, which is the highest section of the dam at approximately 50 m, and extends from a steep wall with bedrock exposure on the left abutment to a shallower soil slope on the right abutment area.
- The left section of the dam, which extends to the left from the river gorge along an upland area to meet with higher ground about 700 m from the Elbow River. The dam height through the left section is roughly 20 to 25 m, with variations according to the local topography.

- The right section of the dam, which extends to the right from the river gorge approximately southeast along an upland area to meet higher ground about 1,400 m south of the Elbow River. The dam height through the right section is roughly 20 m, also with variations according to local topography.

Valley Section

Subgrade conditions in the valley section include: exposed heavily jointed bedrock overlain with clay till at the left abutment, fluvial sand and gravel as well as silt and sand floodplain deposits in the valley floor and silty sandy floodplain deposits at the right abutment. Extensive excavation into the left abutment will be necessary to establish a secure interface between the constructed embankment and the native bedrock and clay till. Along the valley bottom, excavation of a core trench through the granular fluvial material to expose the underlying bedrock will be required to reduce seepage and piping potential below the impervious core of the dam. Based on the heavily jointed structure of the bedrock exposed at the left side of the gorge, it is expected that a grout curtain will be required below the impervious core of the dam. The borehole drilled approximately 150 m to the right of the existing river channel encountered approximately 6 m of sand and silt overlying the bedrock, whereas approximately 300 m farther to the right (SE) clay till was encountered from ground surface to approximately 10 m depth. In order to minimize potential for piping beneath the dam, the core trench should be excavated through surficial sand and silt deposits, and extend to the right to join with the clay till.

Based on the materials encountered in the boreholes drilled along the proposed left and right embankment areas, the locally available low to medium plastic clay till soil is suitable for constructing both impervious 1A fill, and random 2A fill. Excavated bedrock would be suitable for random 2A fill, provided particle size could be managed to accommodate controlled compaction. Since the majority of excavation in bedrock would be limited to the interface of the embankment fill with the left abutment, it is expected that the volume of bedrock excavation will be small relative to the volume of borrow required for construction of the embankment. Borrow areas have yet to be identified, but it appears that a sufficient quantity of clay till, similar to that encountered in the boreholes, is available in the area. Haulage distances will depend on whether borrow is sourced within the future inundation area and flood storage area, or from alternative sites.

Excavation of the clay till soil can be undertaken with conventional equipment such as loaders, hydraulic excavators and scrapers. The same equipment can be used to excavate the typically sandy, silty floodplain deposits, with consideration that transport of such materials is limited especially where heavy wheeled equipment is involved. The exposed sandstone on the left side of the gorge is moderately strong but heavily jointed. Excavation of weathered jointed sandstone and siltstone is likely possible with large hydraulic excavators equipped with rock teeth and/or hydraulic breakers, and also possibly with large dozers and rippers. However, for less weathered bedrock having more widely spaced joints, drilling and blasting could be required. Additional drilling, with coring of the bedrock, during the detailed stage of design will provide information regarding the need for drill and blast techniques. Even unweathered mudstone, and weaker components of the siltstone and sandstone, can normally be excavated with large hydraulic excavators and dozers equipped with rippers.

Embankment slope angles of 4H:1V average (including benches) for slopes formed of random 2A fill will provide a minimum factor of safety of greater than 1.5 against slope instability for the approximately 50 m height of the valley section of the embankment – for the condition of a permanent upstream pool. Assessment of a rapid drawdown condition from the permanent pool dead storage water elevation 1,398.0 m was not conducted since there is no outlet for the permanent pool. A factor of safety against slope instability of approximately 1.4 was calculated for the valley section of the embankment, assuming: overall 4H:1V slopes including benches and saturated soil conditions below the 1% AEP floodwater elevation. The assumption regarding embankment saturation is considered conservative, since the flood waters would be unlikely to remain against the embankment long enough to establish more than the initial transient stages of seepage through the embankment.

Previous experience with similar bedrock foundation subgrades indicates that subgrade deformations or increase in porewater pressure due to embankment construction should not be limiting factors for typical rates of embankment construction. However, porewater pressures in the foundation bedrock should be monitored during construction of the embankment.

Left and Right Sections

Stripping will be required to remove organic soil overlying the clay till. At some locations stripping of pockets of loose silt or sand from areas underlying the impervious core may also be required. Based on the boreholes drilled at the site, the subgrade conditions underlying the left and right sections of the embankment consist primarily of stiff to hard clay till. At two borehole locations along the right embankment area the clay till was underlain by a layer of gravel and sand at a depth of approximately 10 m. During the detailed design additional site drilling should be undertaken to determine the extent of the gravel layer and whether it approaches ground surface farther upstream within the reservoir area.

As discussed above for the Valley Section of the embankment, the locally available low to medium plastic clay till soil is suitable for constructing both impervious fill, and random fill. Excavated bedrock would be suitable for random fill, provided particle size could be managed to accommodate controlled compaction. Borrow areas have yet to be identified, but it appears that a sufficient quantity of clay till, similar to that encountered in the boreholes, is available in the area. Haulage distances will depend on whether borrow is sourced within the future inundation area and flood storage area, or from alternative sites.

Excavation of the clay till soil can be undertaken with conventional equipment such as loaders, hydraulic excavators and scrapers.

Embankment slope angles of 4H:1V average (including benches) for slopes formed of random 2A fill will provide a minimum factor of safety of approximately 2.3 against slope instability for the approximate 20 m to 25 m height of the left and right embankment sections – for the condition of a permanent upstream pool at elevation of 1,399 m. A factor of safety against slope instability of approximately 1.4 was calculated for the left and right sections of the embankment, assuming: overall 4H:1V slopes, including benches, and saturated soil conditions below the 100-year floodwater elevation. The assumption regarding embankment saturation is considered conservative, since the flood waters would be unlikely to remain against the embankment long enough to establish more than the initial transient stages of seepage through the embankment.

Soil moisture contents measured in the clay till soils that will form the foundation subgrade for the left and right embankment sections were generally near the plastic limit for the soil. Previous experience with similar clay till foundation subgrades indicates that subgrade deformations or increase in porewater pressure due to embankment construction should not be limiting factors for typical rates of embankment construction.

5.2.3 Construction Material Sources

As already discussed, materials suitable for the impervious core and random shell sections of the zoned embankment fill are expected to come from necessary excavations and nearby borrow sources. It is currently estimated that abundant valley bottom granular materials would be available for construction. The most easily exploited deposit appears to be on the left side of the river downstream of the site. Granular materials required for dam filters, drains, and rock riprap bedding would need to be processed. Pitrun gradation may be suitable for pervious fill zones and structure backfill. Rock riprap and cobble armour protection would need to be brought in from off-site sources.

5.3 Permanent Outlet/Service Spillway Structure

A combined permanent outlet/service spillway structure is proposed in the left abutment as illustrated in **Drawing F2**. This reinforced concrete structure consists of a six bay gated conduit system constructed within the main embankment on the left abutment plateau, and discharging into a concrete chute which terminates in a hydraulic jump stilling basin. The structure concept is illustrated in **Drawing F3**. A gatewell would be provided just upstream of the dam centerline, which would be equipped with heavy duty cast iron sluice gates, one for each of the six conduit bays. The proposed gates are standard pre-engineered products. They are robust and low maintenance. Gate system control buildings and controls automation have been allowed for in the design and cost estimate. Structure details are provided in **Drawing F4**.

The 0.2% AEP design event was selected for the service spillway design flood. The permanent outlet/spillway structure is designed to pass this flood with minimal to no damage at the project site, and prior to operation of the auxiliary earth channel spillway. The two spillways (service and auxiliary) can pass larger floods up to the PMF, but significant damage in the way of erosion along the auxiliary spillway flow path is anticipated should such an event occur. The “no damage” service spillway design flood is typically selected to be between the 0.2% AEP event and 0.05% AEP event considering factors including cost and the extent of potential damages should a larger flood ever occur. The 0.2% AEP event was initially selected for this conceptual design considering that bedrock, or other relatively erosion-resistant materials, could be present in the area of the proposed auxiliary earth channel spillway, and that the additional cost to upgrade the permanent spillway to manage a larger flood would be significant. The spillway system design and structure design flood event were further reviewed after subsurface soils information was obtained late in the conceptual design process. The results of those investigations are addressed in **Section 8.2**.

The combined permanent outlet/spillway structure provides several distinct advantages as compared to the separate low level outlet and service spillway structures previously proposed in the 1986 study report. The advantages include:

1. Upstream reservoir level fluctuations would be much less as the combined structure has six conduit bays rather than the previously proposed two low level outlet conduit bays. The permanent summer pond levels could be maintained between El. 1398.5 and 1400.0 m for up to approximately the 10% AEP flood event. This is a significant advantage over the previously proposed system (1986 study report) which would result in significant annual reservoir surface level fluctuation.
2. Winter operation could consider closing five of the six sluice gates, and including a 3 m high weir gate in the sixth gatewell tower. This weir gate would hold the winter pond level just above El. 1401.0 m without gate regulation, keeping the conduit inlet structure submerged thereby avoiding potential ice buildup issues.
3. The combined structure cost is significantly lower than the cost of two separate structures.
4. Gate control on six bays will provide significant additional flood protection for floods larger than the 1% AEP flood (i.e., the flood of 2013). Gate operating rules would be pre-conceived. Simple operations would be devised considering potential variations of extreme floods.
5. The Elbow River has significant amounts of larger bottom sediment (e.g., cobble size and larger) which is transported along the channel bottom as a result of the relatively steep river gradient and associated high water velocities which occur during extreme floods. The bottom sediment will naturally stop moving when it enters the now proposed dead storage area as a result of the water velocity rapidly reducing to near zero in this area.

Excavation for the outlet/spillway structure will range from approximately 10 to 12 m depth for the multiple conduit section, to between about 5 and 18 m for the outlet chute section. It is expected that the majority of the excavation will encounter stiff to very stiff clay till. However, bedrock and fluvial deposits will likely be present in the excavation for the outlet chute near the Elbow River. The local clay till soil will provide stable subgrade support for the conduit, and for the chute foundation. The clay till is also suitable for construction of impervious backfill around headwalls, cutoff walls and side walls for the chute.

As an option to the combined concrete conduit outlet/spillway concept presented herein, there is potential at this site for an outlet structure to be tunnelled in the left abutment. Based on the information in hand, the conduit system is estimated to be better suited to the perceived site conditions and project requirements. This can be further evaluated as part of future study.

5.4 Auxiliary Earth Channel Spillway

The auxiliary spillway is envisioned to be an earth cut channel which would connect into an upland area from where extreme flood water would make its way to McLean Creek, thereby bypassing the dam site. The spillway would have a 100 m bottom width, with 3 horizontal to 1 vertical side slopes, and an upstream invert El. 1426.0 m. A small 0.5 m high fuse plug is included at its upstream end. The spillway channel invert should be founded in a relatively hard erosion resistant material (e.g., bedrock or stiff clay till) to ensure its integrity during an extreme flood event. The combined permanent outlet/spillway structure has been sized to manage all floods up to the 0.2% AEP event, prior to activation of the auxiliary spillway. The probability of this earth channel spillway structure being activated is therefore very low.

The available subsurface information near the proposed auxiliary spillway location indicates that for a channel bed elevation of approximately 1,426 m, the channel invert and sideslopes would be excavated primarily in clay till soil. Under no-flow conditions the sideslopes of the channel would be stable at a design sideslope angle of 3H:1V. Significant erosion through the channel area and downstream McLean Creek would occur during an extreme flood event which activates the auxiliary earth channel spillway. As previously noted the probability of this channel being activated is very low. Additional geotechnical investigations are required to better establish design requirements and a preferred location for this spillway.

5.5 Reservoir Operations

A summary of proposed gate operations, and resulting reservoir water levels, and retained water volume, considering both normal summer and winter flow, and flood conditions is provided in **Table F5.2**. The table data indicates that considering the 1% AEP flood event results in a peak MC1 outflow of 260 m^3/s. This flow can be safely passed through Bragg Creek as it exists (i.e., without dykes). Similarly, this discharge can be further reduced to a peak flow-rate of 170 m^3/s downstream of Glenmore Reservoir by using available flood storage which can be made available at Glenmore Reservoir. This 170 m^3/s flow rate has been established as the no damage flow rate for the Elbow River downstream of Glenmore Reservoir. The table similarly indicates significant flood reduction for the 0.2% AEP flood event (i.e., 1,625 m^3/s inflow reduced to 636 m^3/s outflow from MC1). The dam offers little protection against the PMF should such an event occur, because the flood volume is very large (i.e., inflow peak of 2,175 m^3/s reduced to outflow peak of 2,060 m^3/s). The volume and flow rate estimates provided in **Table F5.2** are based on preliminary flood hydrograph and reservoir capacity estimates. These estimates will be updated after a more detailed hydrologic assessment is completed as part of the future design.

Table F5.2
Elbow River Dam at McLean Creek (MC1)
Pertinent Operations Data

Description (Peak Values)	Summer	Winter	Floods			
	July Mean	January Mean	20-year	100-year	500-year	PMF
Peak Reservoir Inflow Rate (m^3/s)	13.4	3.0	440	930	1,625	2,175
Permanent Outlet/Spillway Structure Outflow Rate (m^3/s)	13.4	3.0	250	260	636	780
Auxiliary Spillway Outflow Rate (m^3/s)	0	0	0	0	0	1,280
Reservoir Water Surface Elevation (m)	1,399.0	1,401.5	1,407.0	1,423.0	1,426.5	1,429.0
Total Contained Water Volume (dam^3)	4,000	5,000	12,000	47,000	62,000	72,000

The levels provided in this table are based on gate operations as follows:

1. All sluice gates wide open for normal summer flows.
2. 5 sluice gates closed and 1 weir gate in place for winter flows.
3. 4 of 6 sluice gates strategically closed if flood flow causes reservoir to rise to El. 1404.0 m and reservoir is still rising (i.e. >5% AEP event).
4. Strategically start reopening gates if reservoir reaches El. 1423.0 m (1% AEP event) and is still rising.
5. Rapidly reclose gates after MC1 reservoir level stops rising (i.e., inflow peak has passed and inflow rate exceeds outflow rate).

6.0 EXISTING INFRASTRUCTURE IMPACTS

The proposed project is located within the Green Zone and is located entirely on Crown Land. Highway 66 and numerous existing recreational facilities will be impacted by the proposed project.

The resulting reservoir will inundate a portion of existing Kananaskis Highway 66 including a bridge crossing of the Elbow River. A potential highway and bridge relocation route around the south side of the reservoir is illustrated on **Drawing F1**. Additional study is required to establish a preferred route. It may be desirable to retain a portion of the existing Highway 66 to provide access from the west, to existing and/or new facilities along the north side of the reservoir impoundment area.

The dam and reservoir area is characterized by fairly intensive recreational use, including day use and extended activities, covering all four seasons. The existing recreational facilities' locations are illustrated on **Drawing F1** and are discussed below:

- The Paddy's Flat recreational area borders the Elbow River on the north side bank and is adjacent to the flood plain. There are two campgrounds within this area, the first is a group camping facility while the second offers public camping for both tent and trailers.
  The campgrounds offer standard serviced campsites with water, vault toilets, fire pits, and tables. Paddy's Flat is a seasonal use site only (May to October) with a total of 98 public campsites. The campgrounds are above the 1% AEP flood level; however, some impacts are anticipated as a result of the Highway 66 relocation.
- River Cove is a group camping facility only. The facility is on the north side, adjacent to the Elbow River within the flood area, and features the usual picnic tables, water, fire pits, and vault toilets. Relocation or removal would be required.
- Allen Bill Pond was a combination hiking trailhead and day use picnic site located on the north side of the Elbow River, and south of existing Highway 66 immediately upstream of the Elbow River Bridge. The pond was stocked with rainbow trout and was a popular fishing site. This pond was destroyed during the 2013 flood. The proposed McLean Creek dam site permanent pond dead storage could serve similar recreational purposes.
- Station Flats is a hiking and horseback trailhead. Located on the north side of Highway 66, there is a small gravelled parking lot and vault toilets. Highway 66 provided access to this area. That access from the east will no longer exist.

- The Elbow Ranger Station is located on the north side of Highway 66 along Ranger Creek, and these facilities would be affected. The existing facilities include a large maintenance compound, a station office building which houses three departments (Alberta Forestry Services, Alberta Parks and Recreation, Alberta Fish and Wildlife), a dining hall, 8 seasonal bunk houses, 11 permanent residences, 2 mobile homes, and 1 cold compound storage building. It is not known to what extent these facilities are currently used, if at all. Requirements would need to be established and the station relocated or dismantled.

7.0 ENVIRONMENTAL AND REGULATORY OVERVIEW

The proposed project is located within the Green Zone and is on Crown land. Project components would directly affect the Elbow River and its associated riparian land. Environmental concerns to be addressed in the project design include:

- Hydrogeology – effects of ponded water on groundwater resources, including aquifers.
- Water quality and quantity – effects of potential changes in upstream (ponded water) and downstream flows, sediment load, and water quality parameters.
- Fisheries – potential for effects on fish and fish habitat, including possible populations of brook trout, brown trout, bull trout, cutthroat trout, longnose dace, mountain whitefish, rainbow trout, and white sucker. Bull trout and native, genetically pure westslope cutthroat trout are listed as “species of special concern” and “threatened” by Alberta’s Endangered Species Conservation Committee, respectively. Populations of native, genetically pure westslope cutthroat trout are also listed federally under the *Species at Risk Act* (SARA). While westslope cutthroat trout populations that are genetically pure occur in part so Canyon, Silvester, and Prairie creeks, which are tributaries of the Elbow River upstream of the McLean creek confluence, no native strains of westslope cutthroat trout have been reported in the Elbow River.
- Soils – effects of ponding and changes in flows on soils and potential for soil erosion.
- Wildlife – provincially designated Key Wildlife and Biodiversity zones are located along the Elbow River, which impose potential timing and construction constraints for the proposed project. Potential effects may occur to species using the zone, including grizzly bear, harlequin duck, and wolverine. Grizzly bear are listed as “at risk” provincially and as “special concern” under COSEWIC federally. Harlequin Duck are “sensitive” provincially. Wolverine are listed as “may be at risk” provincially and “special concern” federally under COSEWIC. None of these three species are listed under SARA. Wildlife habitat and movement patterns may be altered in proximity to the project.
- Vegetation – potential effects on vegetation will include rare non-vascular plants, which were reported in the 1960s in this area and have buffer areas around known locations. These buffer areas overlap the proposed project location.
- Traditional and non-traditional land use – potential effects include access; changes in recreational use as the Elbow River Provincial Recreational Area overlaps the proposed project location; changes in traffic patterns; and aesthetic concerns. The potential project site may be located within the Stoney Nakoda and Tsuu T’ina First Nations traditional territories.

The proposed project would require a license under the *Water Act*, which is administered by the ESRD. The project triggers Alberta Regulation 111/93 EPEA Environmental Assessment (Mandatory and Exempted Activities) Regulation, which requires an environmental impact assessment (EIA) be completed for a dam greater than 15 m in height. A water management project that requires an EIA triggers a Natural Resources Conservation Board (NRCB) review. Typically environmental studies to support the EIA would include a minimum of 1 year of site-specific data.

The proponent would submit its project application with its supporting EIA to ESRD, which makes a determination of completeness. Once deemed complete, the NRCB review process would involve a public hearing as part of its review. The NRCB and ESRD have a history of working cooperatively on environmental reviews of this kind. The ESRD/NRCB process could take between 18 to 24 months to complete. At the completion of the process, the NRCB sends its determination to cabinet, which reviews the report and issues its final approval decision.

In addition to the ESRD and NRCB, several other provincial and federal departments will have regulatory roles for the proposed project. These processes can generally occur in parallel with the ESRD/NRCB review, as much of the information required for them supports the environmental review. For example, pre-development and post-development aquatic environmental assessments would be necessary as part of the application for approval under the *Water Act*. Specific authorizations and permits would be obtained subsequent to the ESRD/NRCB decision, if the project was approved.

An overview of the regulatory process is shown in **Table F7.1**.

Table F7.1
Regulatory Process Overview

Regulator	Legislation	Requirements/Process	Schedule
Provincial			
ESRD	EPEA Environmental Assessment Mandatory and Exempted Activities Regulation 111/93	Under EPEA an EIA is required for a dam greater than 15 m in height, as specified in the Mandatory and Exempted Activities Regulation.	18 to 24 months (with data collection and surveys 30 to 36 months)
NRCB	*Natural Resources Conservation Board Act*	The NRCB review process is triggered when a water management project requires an EIA.	
ESRD	*Alberta Water Act*	Authorization	Variable
	Alberta Water Act	Licence and approval	Variable
	Public Lands Act	Dispositions following the Environmental Field Report (EFR) process	5-8 months
Alberta Culture (AC)	*Historical Resources Act*	Application for clearance	Depends on requirements; for historic resources impact assessment, expect 4 to 6 months from initial application for clearance.
Federal			
Fisheries and Oceans Canada (DFO)		Authorization pursuant to the *Fisheries Act* (habitat and fish passage)	90 days post-filing, providing submission is complete.
Miscellaneous Federal Acts		*Migratory Birds Convention Act* (MBCA)	
		Species at Risk Act (SARA)	*n/a*

As currently conceptualised, the proposed project is not listed in the *Regulations Designating Physical Activities*, under the *Canadian Environmental Assessment Act* (CEAA). It does not result in a reservoir with a surface area that would exceed the annual mean surface area of a water body by 1,500 ha or more.

8.0 CONSTRUCTION COST ESTIMATE AND PROJECT SCHEDULE

8.1 Project Cost Estimate

A detailed cost estimate is provided in **Table F8.1**. The project cost is estimated to be $239,581,000. The estimate provided herein is based on 2012 construction price data. Year 2012 prices were used considering that 2013 construction prices are skewed as a result of abnormal activity which resulted from the June 2013 flood event. It is assumed that the construction of MC1 would take place in a more competitive environment for contractors and suppliers, and as such the 2012 prices are considered indicative of realistic project cost. Additional subsurface soils investigations are required to better establish the concept details presented herein. More detailed hydrological assessment and topographic data are required to better establish the size of required works. A contingency allowance of 25% has been included in an effort to account for additional costs which could result from future additional information and the results of more detailed design work. No allowance is included for escalation until the time of construction.

To increase the flood protection above the 1% AEP, to the 2013 flood-of-record level, would require the dam crest level raised by approximately 4 m to El. 1,434.0 m, and would result in an additional cost of approximately $55 million. This amount includes contingency and engineering allowances.

8.2 Geotechnical Investigation Cost Allowances

The results of geotechnical investigations completed near the end of this conceptual design process indicated that the auxiliary spillway area consists of clay till soils. Based on this limited information, these soils are considered suitable for auxiliary earth channel spillway design but could be less erosion resistant than what was assumed for the conceptual designs presented herein. The potential consequences of these geotechnical results could include the need for a higher design standard for the service spillway (e.g., 0.1% flood passage rather than 0.2% flood passage prior to activation of the auxiliary spillway channel) and additional protection works within the auxiliary earth channel spillway. Additional nominal allowances of $18 million and $9 million were therefore included in the cost estimate for potential modifications to the service spillway structure and auxiliary earth channel spillway designs presented herein, respectively, should they be required. The amounts allow for a larger service spillway structure (i.e., more conduits) than presented in the conceptual design drawings and the inclusion of a roller compacted concrete weir drop to manage potential erosion within the auxiliary earth channel spillway. Although it has not yet been proven that these features are required, it is considered prudent to allow for them in the cost estimate at this time.

Table F8.1
Elbow River Dam at McLean Creek (MC1) Cost Estimate

Item	Unit	Quantity	Unit Price	Extension
General				
Mob./Demobilization	lump sum	1	$10,000,000.00	$10,000,000
Care of Water	lump sum	1	$8,000,000.00	$8,000,000
Clearing & Timber Salvage	hectares	60	$12,000.00	$720,000
Haul Roads	km	10	$300,000.00	$3,000,000
Power Line Relocation	lump sum	lump sum	$400,000.00	$400,000
Ranger Station Removal	lump sum	lump sum	$1,200,000.00	$1,200,000
Topsoil/Seeding etc.	m^2	1,200,000	$1.50	$1,800,000
	Subtotal General			**$25,120,000**
Main Dam Embankment				
Stripping	m^3	200,000	$6.00	$1,200,000
Rock Excavation	m^3	20,000	$20.00	$400,000
Common Excavation	m^3	20,000	$5.50	$110,000
Borrow Excavation	m^3	3,900,000	$5.50	$21,450,000
Overhaul	m^3km	3,900,000	$1.50	$5,850,000
Impervious Fill	m^3	1,800,000	$1.50	$2,700,000
Random Fill	m^3	1,700,000	$1.40	$2,380,000
Fine Filter	m^3	152,000	$80.00	$12,160,000
Coarse Filter	m^3	19,000	$80.00	$1,520,000
Pitrun Gravel	m^3	120,000	$20.00	$2,400,000
Rock Riprap	m^3	38,000	$130.00	$4,940,000
Bedding Gravel	m^3	19,000	$60.00	$1,140,000
Geotechnical Instruments	lump sum	1	$800,000.00	$800,000
Grout Curtain	lump sum	1	$2,000,000.00	$2,000,000
	Subtotal Main Dam			**$59,050,000**

Combined Outlet/Service Spillway Structure				
Stripping	m^3	7,200	$6.00	$43,200
Common Excavation	m^3	600,000	$5.50	$3,300,000
Structure Fill	m^3	20,000	$30.00	$600,000
Reinforced Concrete	m^3	25,000	$1,000.00	$25,800,000
Fine Filter	m^3	2,700	$90.00	$243,000
Coarse Filter	m^3	1,900	$90.00	$171,000
Piping System	lump sum	1	$400,000.00	$400,000
Rock Riprap	m^3	1,900	$130.00	$247,000
Bedding Gravel	m^3	600	$70.00	$42,000
Gate/Hoist Systems	each	6	$560,000.00	$3,360,000
Superstructure	lump sum	lump sum	$90,000.00	$90,000
Controls/Instrumentation	lump sum	lump sum	$300,000.00	$300,000
Electrical/Mechanical	lump sum	lump sum	$500,000.00	$500,000
	Subtotal Structure			**$34,296,000**
Auxiliary Earth Channel Spilllway				
Stripping	m^3	7,200	$6.00	$43,000
Common Excavation	m^3	100,000	$6.00	$600,000
Fuse Plug System	m^3	200	$60.00	$12,000
	Subtotal Auxiliary Spillway			**$655,000**
Highway 66 Relocation				
Grading	km	8	$600,000.00	$4,800,000
Base/Pavement	km	8	$750,000.00	$6,000,000
Elbow River Bridge	lump sum	lump sum	$4,000,000.00	$4,000,000
Mclean Creek Crossing	lump sum	lump sum	$800,000.00	$800,000
	Subtotal Highway 66			**$15,600,000**
Spillway System Allowances Considering May 2014 Geotechnical Investigations				
Service Spillway	lump sum	lump sum	$16,000,000	$16,000,000
Auxiliary Spillway	lump sum	lump sum	$9,000,000	$9,000,000
	Subtotal Spillway Design Upgrader			**$25,000,000**
	SUBTOTAL CONSTRUCTION			**$159,721,000**
	-Contingencies (25%)			$39,930,000
	Subtotal Construction and Contingencies			**$199,651,000**
	-Engineering/Environmental (20%)			$39,930,000
	TOTAL CONSTRUCTION			**$239,581,000**

8.3 Project Schedule and Contracts

Studies to date indicate that the proposed project is feasible. A potential project schedule moving forward would consider both preliminary engineering and environmental impact assessment proceeding on parallel but linked paths, and followed by a detailed design–build or a detailed design-bid-build process.

A number of issues need to be resolved in order to proceed with preliminary design and environmental impact assessment. These include:

- Establishing the level of flood protection to be provided by the project (e.g. 1% AEP flood, 2013 record flood, or larger); and
- Establishing the need for and amount of dead storage and/or multi-use storage, if any.

Stakeholder involvement is required to better define project issues and potential solutions. Initiating stakeholder involvement and gaining land access need to be initial priorities.

Design-build or design-bid-build contracting procedures can be considered for project detailed design and construction. Design-build considers that the work is both designed and built by one project team. Design-bid-build considers that a team is selected to design the project, it then goes to public tender, and is constructed by the successful bidder. Design-build process can result in a reduced time schedule, but the design-bid-build process is considered to be more conventional and appropriate for this project type. The MC1 project could be tendered as one major construction contract, or alternatively divided into two or more contracts. At this time a minimum of two contracts is recommended. One contract would address construction of all dam site works. Bridge and road works would be included in the second contract. The two contract areas do not overlap and could proceed simultaneously. The multiple contract concept would provide smaller local contractors opportunity to bid some of this work and could allow earlier initiation of some portions of project construction.

The project schedule is dependent on factors including cash flow, land access, environmental studies and regulatory processes, subsurface field investigations and engineering design, and construction. As previously mentioned, design can proceed parallel with environmental studies and regulatory processes which could require 30 to 36 months to complete. Construction will require a minimum two calendar years, but a 3-year process is preferred considering the size of this project. Of course the government would need to weigh the risk of additional flood damage against the preferred longer construction period. Construction could proceed year-round, taking advantage of both summer and winter seasons. Most of the work would be performed in the spring through fall period; however, significant quantities of work could be completed in the winter. Special measures would be required for winter construction including heating and hoarding for concrete and continuous 24-hour per day earthfill operations. A project schedule can be developed but requires additional owner input.

9.0 CLOSURE

This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

Reviewed by:

PROFESSIONAL ENGINEER K.G. KRESS ALBERTA

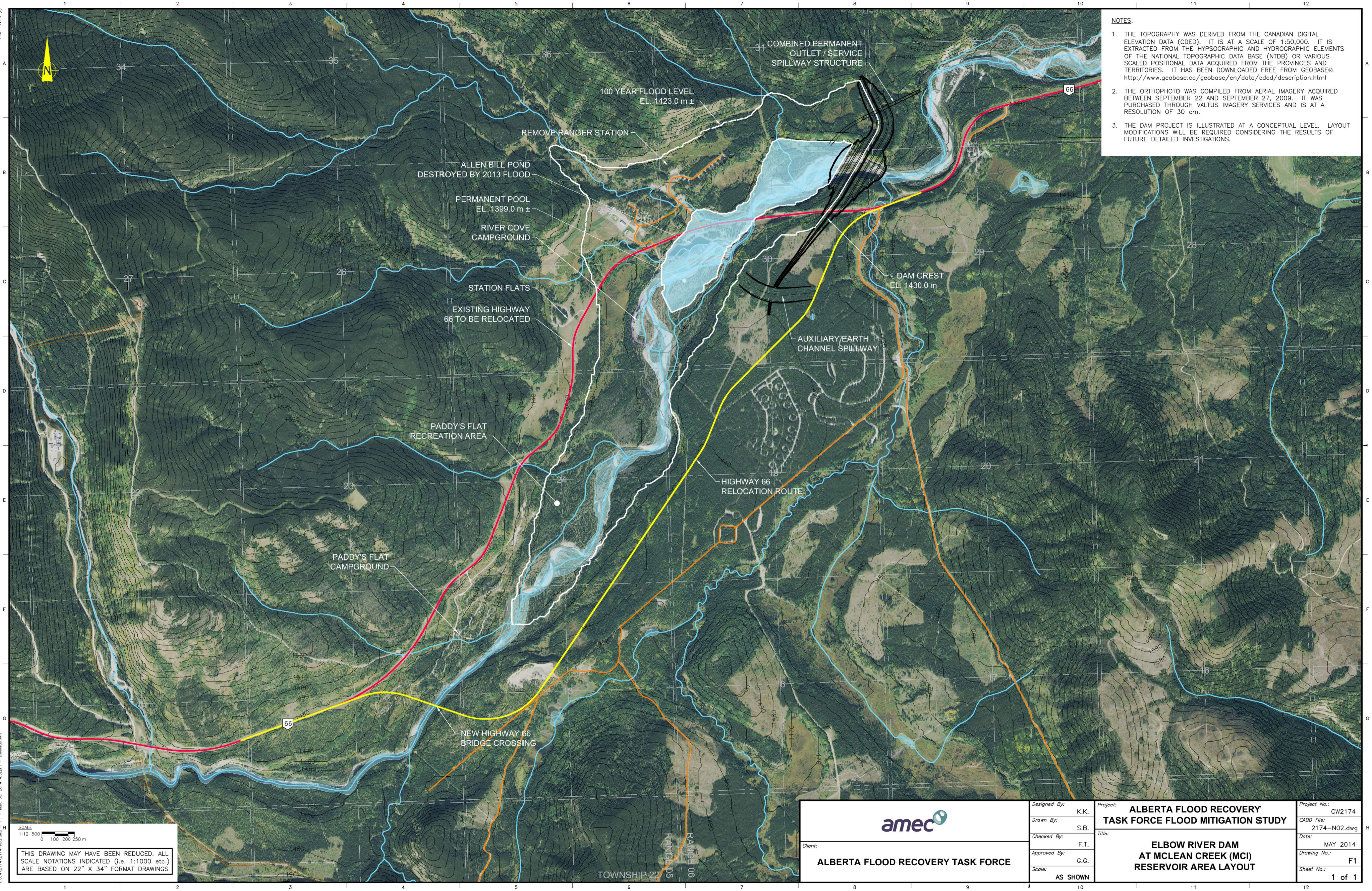
2 June 2014

Ken Kress, P.Eng.
Principal Engineer
Direct Tel.: (403) 387-1494
Direct Fax: (403) 248-1590
E-mail: ken.kress@amec.com

Geoff Graham, B.Sc. (Hons), MCIWEM C.WEM
Associate Water Resources Specialist

KK/elf

Permit to Practice No. P-4546



NOTES:

1. THE TOPOGRAPHY WAS DERIVED FROM THE CANADIAN DIGITAL ELEVATION DATA (CDED). IT IS AT A SCALE OF 1:50,000. IT IS EXTRACTED FROM THE HYPSOGRAPHIC AND HYDROGRAPHIC ELEMENTS OF THE NATIONAL TOPOGRAPHIC DATA BASE (NTDB) OR VARIOUS SCALED POSITIONAL DATA ACQUIRED FROM THE PROVINCES AND TERRITORIES. IT HAS BEEN DOWNLOADED FREE FROM GEOBASE®. http://www.geobase.ca/geobase/en/data/cded/description.html
2. THE ORTHOPHOTO WAS COMPILED FROM AERIAL IMAGERY ACQUIRED BETWEEN SEPTEMBER 22 AND SEPTEMBER 27, 2009. IT WAS PURCHASED THROUGH VALTUS IMAGERY SERVICES AND IS AT A RESOLUTION OF 30 cm.
3. THE DAM PROJECT IS ILLUSTRATED AT A CONCEPTUAL LEVEL. LAYOUT MODIFICATIONS WILL BE REQUIRED CONSIDERING THE RESULTS OF FUTURE DETAILED INVESTIGATIONS.

amec

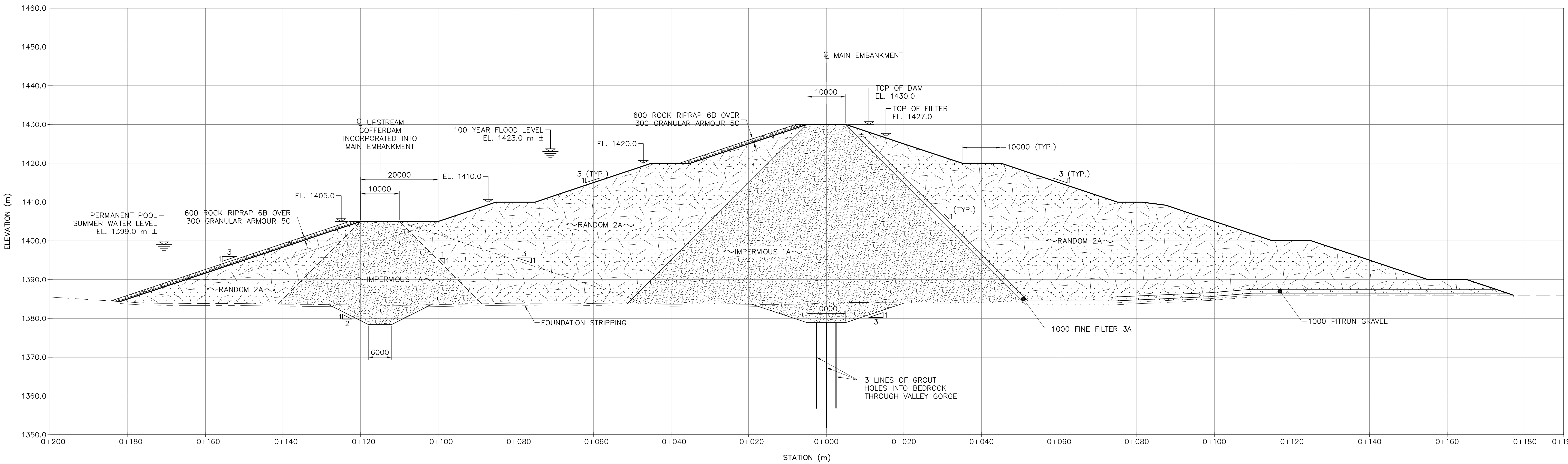
Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	K.K.
Drawn By:	S.B.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: ELBOW RIVER DAM AT MCLEAN CREEK (MCI) RESERVOIR AREA LAYOUT

Project No.:	CW2174
CADD File:	2174-N02.dwg
Date:	MAY 2014
Drawing No.:	F1
Sheet No.:	1 of 1



MAIN DAM SECTION

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SCALE
1:500 0 5 10 m

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

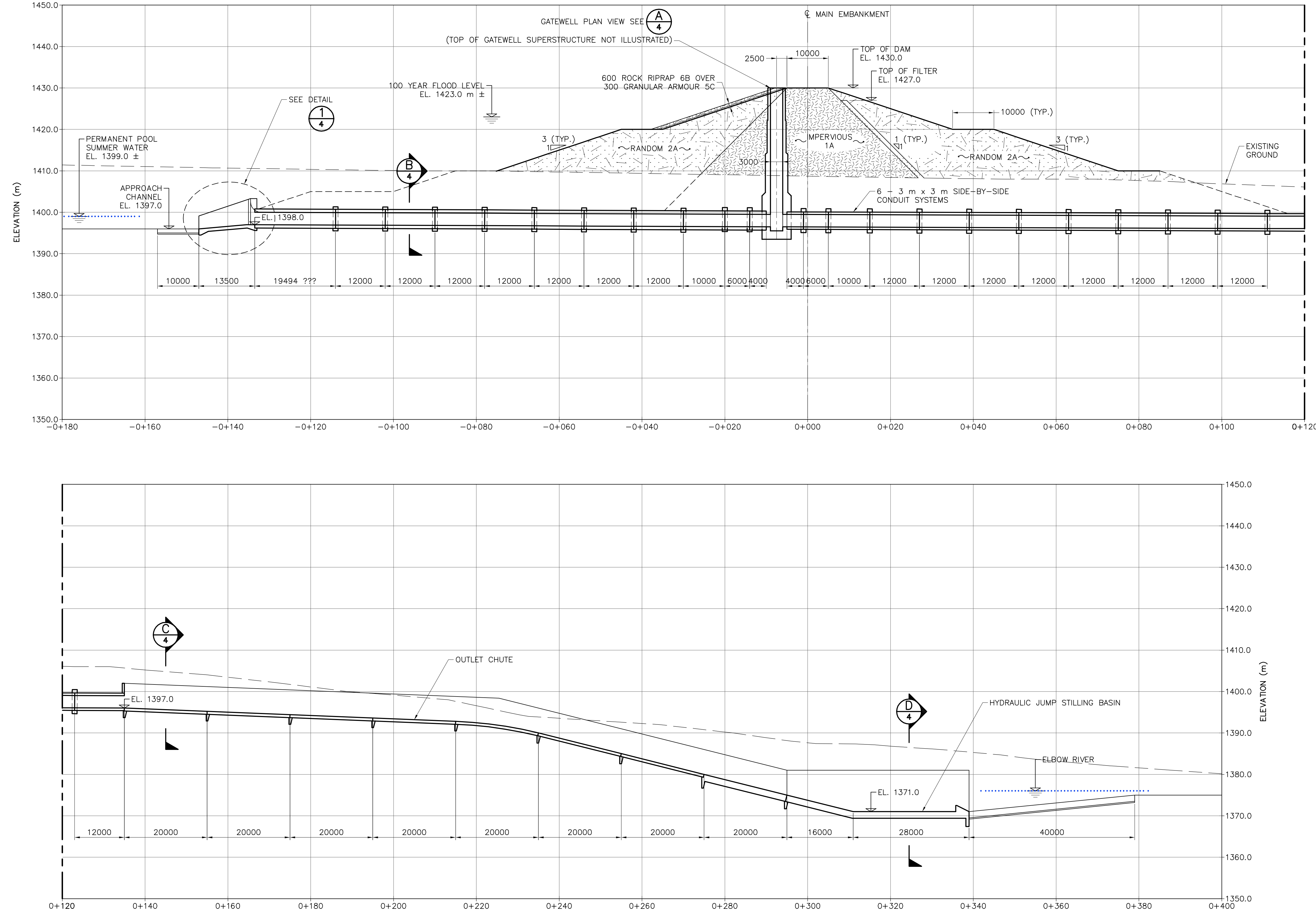
Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: M.H.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: ELBOW RIVER DAM AT MCLEAN CREEK (MCI) DAM SECTION

Project No.: CW2174
CADD File: 2174−N02.dwg
Date: MAY 2014
Drawing No.: F2
Sheet No.: 1 of 1



℄ PROFILE COMBINED PERMANENT OUTLET / SERVICE SPILLWAY STRUCTURE

SCALE 1:500

SCALE 1:500 0 5 10 m

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
0	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

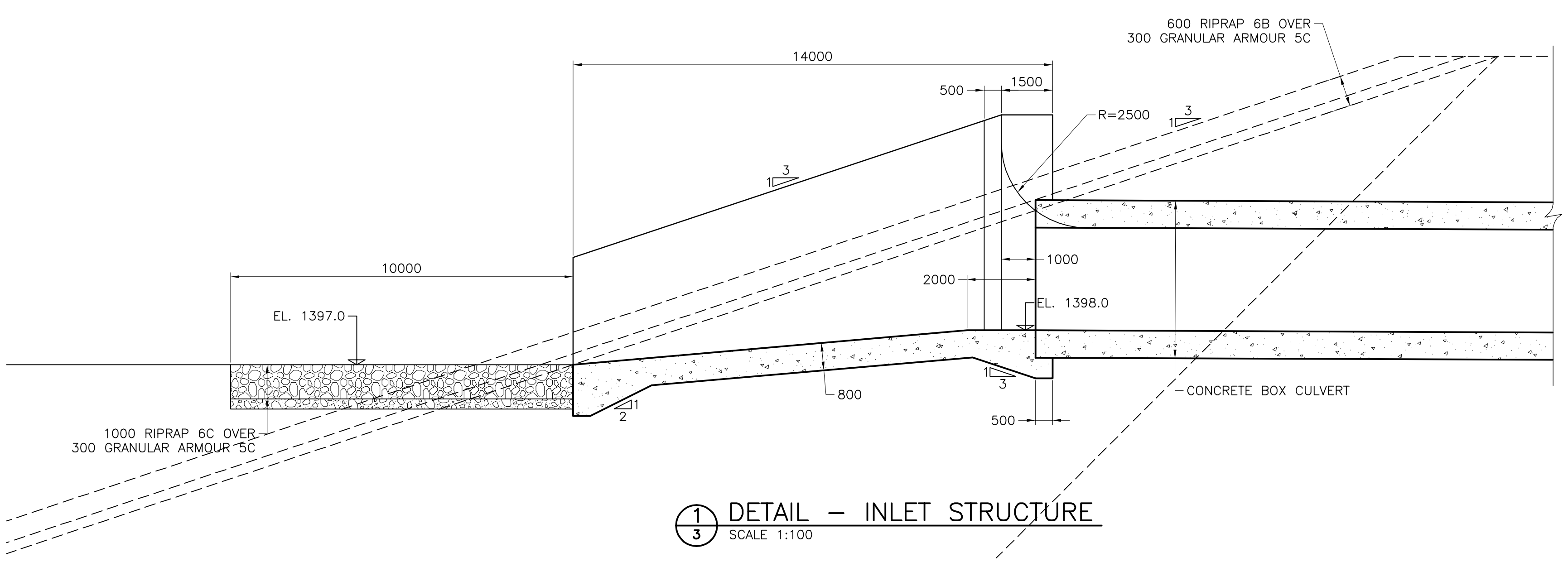
Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: ELBOW RIVER DAM AT MCLEAN CREEK (MCI) COMBINED PERMANENT OUTLET / SERVICE SPILLWAY STRUCTURE PROFILE

Project No.: CW2174
CADD File: 2174–N02.dwg
Date: MAY 2014
Drawing No.: F3
Sheet No.: 1 of 1



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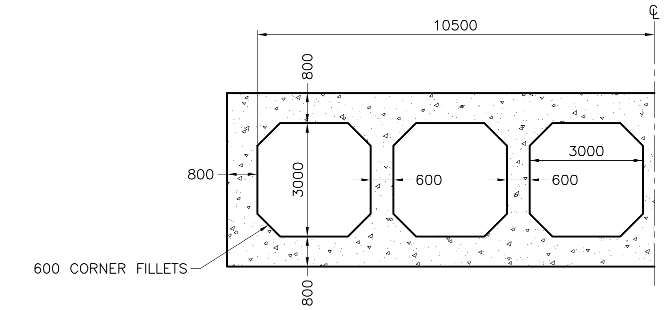

B / 3 SECTION – CONDUIT SYSTEM
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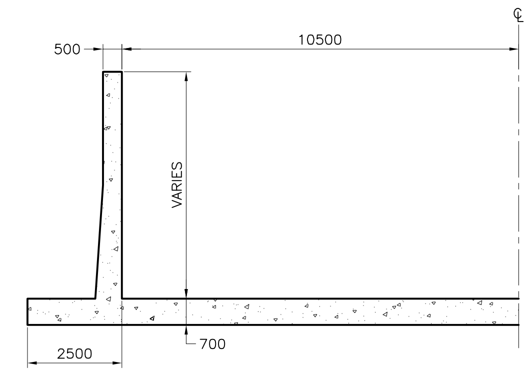
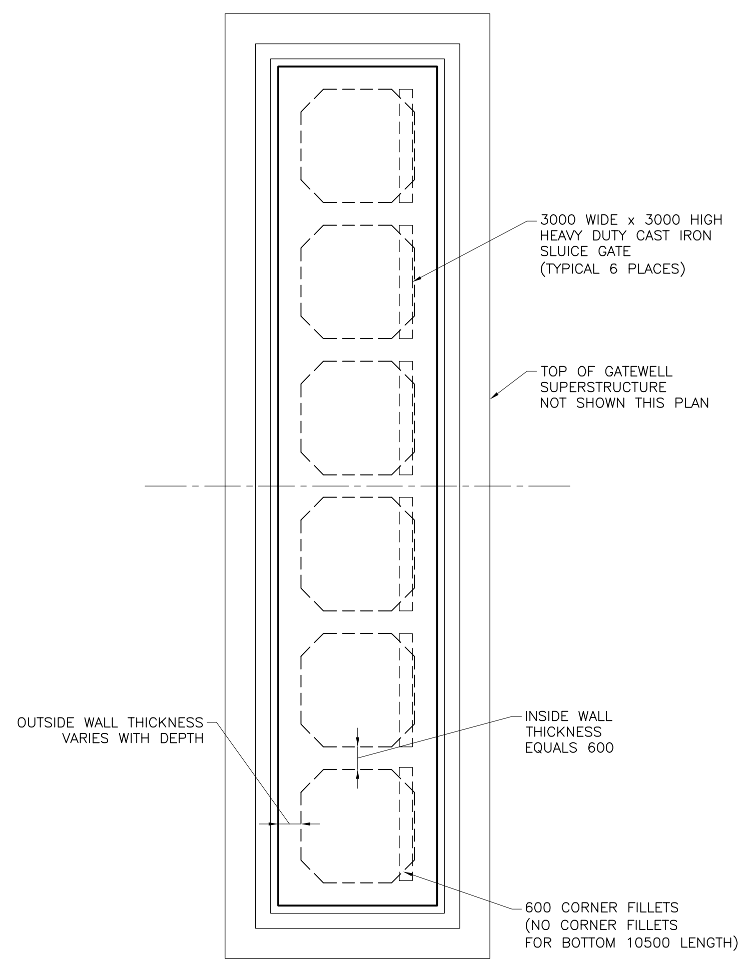
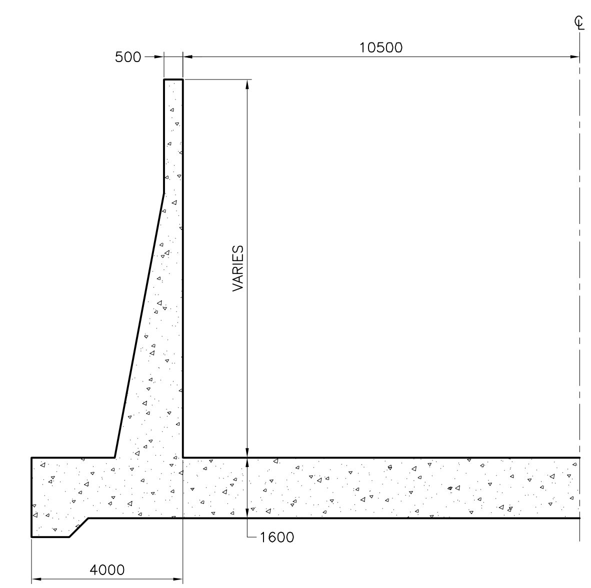


C / 3 SECTION – OUTLET CHUTE
SCALE 1:100



A / 3 PLAN VIEW – GATEWELL
SCALE 1:100



D / 3 SECTION – STILLING BASIN
SCALE 1:100

SCALE 1:100 0 1 2m

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REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	K.K.
Drawn By:	S.B.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: ELBOW RIVER DAM AT MCLEAN CREEK (MCI) COMBINED PERMANENT OUTLET / SERVICE SPILLWAY STRUCTURE DETAILS

Project No.:	CW2174
CADD File:	2174–B02.dwg
Date:	MARCH 2014
Drawing No.:	F4
Sheet No.:	1 of 1

Appendix G

Conceptual Design of the Springbank Off-Stream Flood Storage Site

Southern Alberta Flood Recovery Task Force
Volume 4 – Flood Mitigation Measures

Appendix G – Springbank Off-Stream Storage Project

Submitted to:

Southern Alberta Flood Recovery Task Force
Edmonton, Alberta

Submitted by:

AMEC Environment & Infrastructure
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CW2174

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1.0 SPRINGBANK OFF-STREAM STORAGE PROJECT

1.1 Concept Description

The Springbank Off-stream storage (SR1) site was identified as a part of the current flood mitigation study. It is located just west of Calgary approximately 18.5 km upstream of the Glenmore Reservoir in a relatively undeveloped farmland and ranchland area valley.

This SR1 concept considers diverting extreme flood flow from the Elbow River into an off-stream storage reservoir where it would be temporarily contained and later released back into the Elbow River after the flood peak has passed. Project components include a diversion structure constructed across the Elbow River, and a diversion channel excavated through the adjacent uplands to transport flood water into an off-stream storage reservoir. The storage site includes an earthfill dam to temporarily contain the diverted flood water and a low level outlet structure incorporated into the dam to later release the stored water back into the Elbow River after the flood peak has passed. The diversion system, off-stream dam site and reservoir area are illustrated in **Drawing G1**.

The SR1 could be designed as a dry pond (i.e., no storage reservoir except during flood periods) or could include permanent multi-use water storage with much larger flood storage volume above the permanent multi-use storage full supply level (FSL). The multi-use water could be used for recreational/environmental purposes, and/or an additional water supply source for the City of Calgary, and/or for other uses during periods of low river flow or drought. This storage would also serve to dissipate energy when flood water first enters the reservoir. For the purpose of this conceptual assessment a multi-use storage containment of 9,000 dam^3 has been assumed providing a maximum pond depth of 10 m.

The potential use, FSL, volume, and regulation of the permanent multi-use storage component of the reservoir requires further investigation. Future climate change and sediment infilling of Glenmore Reservoir (loss of existing storage due to long-term sedimentation) should be key considerations. Bathymetric surveys indicate that Glenmore Reservoir may have lost 17% of its storage volume since 1933 as a result of river sediment transport.

Some portion of the above-noted multi-use storage could be considered for flood storage (e.g., reservoir lowered in spring in advance of incoming flood, then refilled after flood risk has passed). Multi-use storage has not been included as available flood storage in this conceptual design.

2.0 HYDROLOGICAL OVERVIEW

2.1 Median and Mean Monthly Flows

Median winter and median annual flows for the Elbow River are approximately 4 and 10 m^3/s, respectively, as recorded at ESRD gauging station 05BJ010 (Elbow River at Sarcee Bridge). Mean monthly flows as recorded at station 05BJ010 are provided in **Table G2.1**.

Table G2.1
Elbow River Mean Monthly Flows

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Flow (m^3/s)	3.5	3.6	4.1	5.3	14.8	27.6	15.2	9.6	8.3	6.6	5.2	4.1

The Springbank Road site is located approximately 16 km upstream of this gauging station, resulting in a 30% reduction in drainage area. The impact of this area's reduction on median and mean monthly flows has not been estimated as a part of this study, but will be much less than 30%.

2.2 Flood Flows

Frequency analysis of flood inflows into Glenmore Reservoir (i.e., 21 km downstream of the Springbank Road diversion site as discussed herein) which was completed for this study resulted in instantaneous flood peak flow and 7-day flood volume estimates as summarized in **Table G2.2**. These estimates are considered to be representative of the upstream Springbank diversion site (i.e., assumes minimal inflow between diversion site and Sarcee Bridge during extreme flood events generated in higher regions of the basin). Background information which provides the basis for these flood estimates is documented separately in **Appendix C** of the main report. Estimates of the June 2013 flood instantaneous peak flow and total flood volume entering Glenmore Reservoir are included for comparison in **Table G2.2**.

Table G2.2
Elbow River Instantaneous Flood Peak and Runoff Volume Estimates

Annual Flood Probability (Return Period)	Instantaneous Peak Flow (m^3/s)	7-day Volume dam^3
5% Annual Exceedence Probability (AEP; 1:20-year)	440	83,000
1% AEP (1:100-year)	930	130,000
June 2013 Flood	1,260	154,000
0.2% (1:500-year)	1,625	183,000

As indicated by **Table G2.2,** the June 2013 flood instantaneous peak flow and flood volumes were larger than the estimated 1% AEP flood but smaller than the 500-year flood. More detailed frequency analysis should be performed as part of future, more detailed design study.

2.3 Probable Maximum Flood

The Probable Maximum Flood (PMF) is defined as the most severe flood that may be reasonably expected to occur at a particular location. The PMF is normally evaluated by deterministic methods that maximize the various factors contributing to the generation of a flood. The probability of such a flood occurring is very rare (e.g., once in a million years).

A PMF hydrograph at Glenmore Reservoir was previously generated by ESRD and is included in the August 1986 *Elbow River Floodpain Management Study* by WER, IBI and ECOS. The PMF entering Glenmore Reservoir was estimated to have a flood peak value of 3,030 m^3/s and a 7-day volume of approximately 640,000 dam^3, which is approximately 4.2 times the volume of the 2013 flood. ESRD cautions:

> "…that these are preliminary estimates of PMF…subject to considerable error and that a detailed assessment….would be required prior to any detailed design."

3.0 GEOLOGICAL AND GEOTECHNICAL OVERVIEW

A preliminary subsurface field investigation was completed as a part of this study as documented in a separate report entitled *Preliminary Geotechnical Investigation Report, Springbank Off-stream Dam Project* (AMEC, 2014).

The SR1 site is located near the eastern edge of the foothills. The bedrock underlying the area transitions from the Paleocene/Upper Cretaceous Brazeau Formation in the vicinity of the diversion structure, to bedrock of the Paleocene Porcupine Hills Formation farther east and north toward the north end of the off-stream storage dam. Both formations are non-marine deposits generally consisting of cross-bedded and interbedded sandstone, mudstone, and siltstone. A bedrock exposure approximately 12 m high overlain with glacial till is evident in the left valley wall of the Elbow River at the site of the proposed diversion structure.

The findings of the above-noted preliminary geotechnical field investigation program indicate that subsurface soils in the area of the proposed diversion channel, off-stream dam, and reservoir generally consist of medium plastic clay and clay till soil underlain by bedrock consisting of interlayed mudstone, sandstone, and siltstone. Subsurface materials underlying the proposed diversion structure system are expected to consist primarily of fluvial sand and gravel deposits, while the subgrade underlying the dam is expected to consist of a mixture of clay, silt, sand, and gravel soils. The soils encountered during the field investigation are expected to be suitable as foundation materials for the embankments and structures associated with the proposed project development. The clay and clay till soils are also suitable for use in embankment construction for the floodplain berm, diversion channel fills, and the off-stream storage dam embankment.

Granular materials required for structure backfill, dam filters, and drains would need to be brought in from off-site sources. Rock riprap and cobble armour protection would similarly need to be brought in from off-site sources.

4.0 FLOOD STORAGE VOLUME

4.1 Background Considerations

Significant residential development located along the Elbow River floodplain downstream of Glenmore Reservoir is at risk during extreme flood events. Pathway closures are required when Glenmore Reservoir flood discharge reaches 40 m^3/s. Modest overbank flooding of undeveloped areas starts at 120 m^3/s discharge. Widespread basement seepage occurs for discharges of 140 m^3/s. First residents are impacted at discharges of 170 m^3/s. Evacuation of residents is initiated at a discharge of 192 m^3/s.

The most recent Glenmore Reservoir storage capacity and flooded area curves which were produced by Klohn Crippen Berger in 2013 are illustrated on **Figure G4.1**. The existing Glenmore Reservoir storage is used to attenuate flood peaks thereby protecting downstream developments. If an extreme flood is forecast, the City of Calgary opens the Glenmore Reservoir low level DOW valves thereby drawing the reservoir down to provide flood storage for the incoming flood. Maximum permissible drawdown is 5 m below FSL El. 1,076.85 m which equates to a flood storage volume of 15,400 dam^3 (KCB Glenmore Bathymetric Survey, 2013). This drawdown could be accomplished in 25 hours at the maximum discharge rate of 170 m^3/s (maximum discharge before significant downstream flood damages start to occur). In reality a portion of this storage should be drawn down well in advance of an actual flood event forecast (e.g., in the spring when significant snow pack exists in the watershed). The 15,400 dam^3 draw down was successfully achieved in anticipation of the June 2013 flood. The City of Calgary needs to use caution when drawing the reservoir down in that if they draw down the Glenmore Reservoir and the forecast flood does not develop they can be left with insufficient water supply.

Bathymetric surveys by Klohn Crippen Berger for the City of Calgary indicate that Glenmore Reservoir may have lost approximately 17% of its storage volume since 1933 as a result of sediment transport into the reservoir. This process is ongoing.

Table G4.1 provides estimates of the flood volume required to prevent significant damages along the Elbow River downstream of Glenmore Reservoir, considering a continuous discharge of 170 m^3/s from the reservoir for the duration of the flood (i.e., discharge before first downstream residents are impacted by flood water).

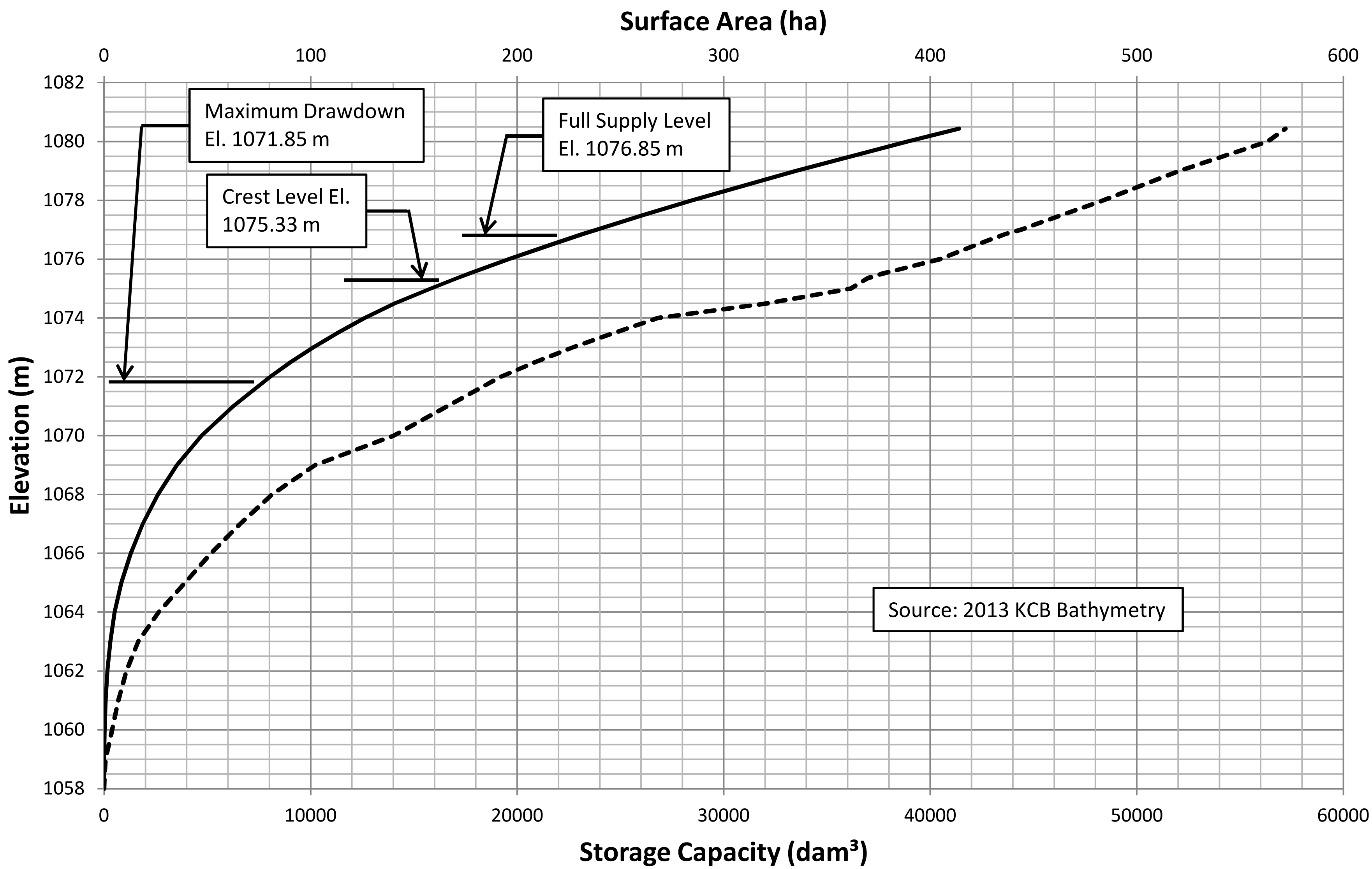
Table G4.1
Required Reservoir Flood Storage Volume to Prevent Damages

Return Period (Years)	Minimum Storage Requirement
5% AEP (1:20-year)	16,800
1% AEP (1:100-year)	56,600
June 2013 Flood	83,000
0.2% (1:500-year)	107,500

Based on the data presented in **Table G4.1,** one can conclude that the Glenmore Reservoir flood storage of 15,400 dam^3 is inadequate to prevent discharge from exceeding the 170 m^3/s value for floods events as small as the 20-year return period flood. The level of protection is even poorer if the City is not successful drawing Glenmore Reservoir down to its minimum El. 1,071.85 m prior to flood impact. It is therefore concluded that the existing level of protection to residences downstream of the Glenmore Reservoir is inadequate. That said, Glenmore Reservoir flood storage does provide significant flood peak attenuation and downstream development protection (e.g., as much as full protection for floods just smaller than 20-year return period, and successfully attenuated June 2013 flood inflow peak of 1,260 m^3/s to discharge of approximately 700 m^3/s).

Figure G4.1

Glenmore Reservoir
Reservoir Storage Capacity and Flooded Area Curves



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4.2 Flood Protection Design Basis

The current Alberta minimum flood protection design standard is the 1% AEP flood, or alternatively can be based on a historical flood event (e.g., June 2013 flood). Increased protection should be considered based on economic assessment and/or when such an event would result in severe societal impact. As an example, the Red River floodway was originally sized to protect Winnipeg from the 0.2% AEP (1:500-year) flood event. It was later enlarged to provide 0.14% AEP (1:700-year) flood protection. Even greater protection was considered but costs were proven to be prohibitive.

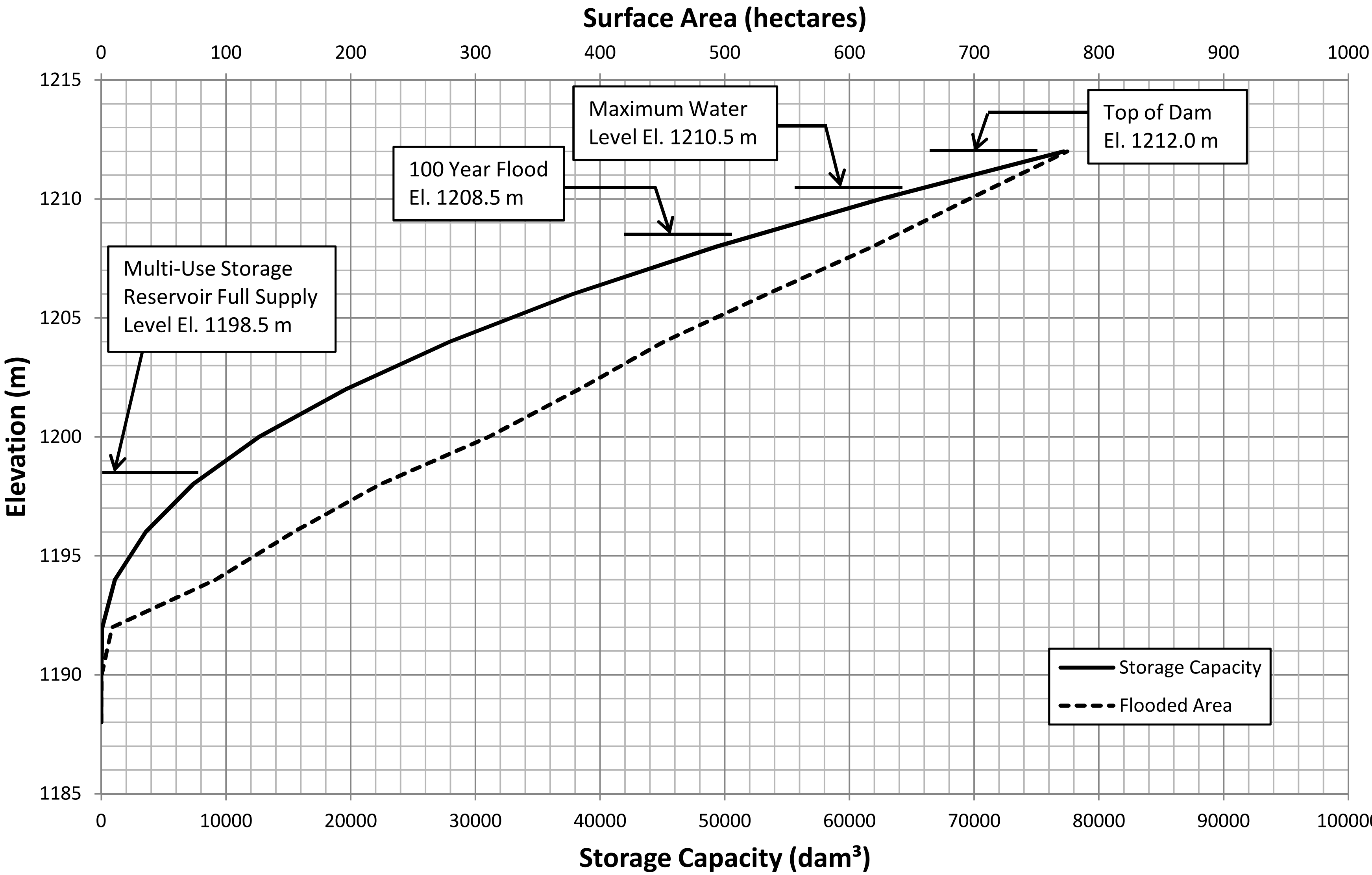
The SR1 concept as presented herein was developed considering the 1% AEP minimum design standard (i.e., total flood storage requirement of 56,600 dam^3). As previously mentioned, Glenmore Reservoir can provide 15,400 dam^3 of that amount. As indicated in **Figure G4.2,** the remaining 41,200 dam^3 flood storage could be provided with a Springbank off-stream storage reservoir water level of approximately El. 1,208.0 m. To account for operational inefficiencies a 1% AEP El. 1,208.5 m has been used. This conservatively assumes that none of the previously mentioned Springbank off-stream reservoir multi-use live storage was pre-released in anticipation of the flood. The conceptual design provides for a nominal 2 m additional storage above the 1% AEP El. 1,208.5 m (i.e., maximum allowable reservoir El. 1,210.5 m) resulting in a combined total flood storage capacity of 72,400 dam^3 (i.e., Glenmore and Springbank combined reservoir storage). Considering the project size presented in this conceptual design, a 2013 magnitude flood would still result in residential damages, but these damage would be greatly reduced as compared to what was experienced in 2013. The Springbank Road project could be built to a higher level than investigated herein to provide enhanced flood protection (e.g., full containment for 2013 magnitude flood or larger). Alternatively, additional projects could be constructed to provide enhanced flood protection above that provided herein.

Figure G4.2 area and capacity curves were developed based on contours developed from 15 m LiDAR, prior to obtaining the 1 m LiDAR illustrated on **Drawings G1** and **G8**. These area and capacity curves should be updated considering the 1 m LiDAR data in future design.

Figure G4.3 illustrates the potential flood flow reduction benefits of the Springbank and Glenmore Reservoir storage when managing the 1% AEP flood. The figure illustrates that a maximum 300 m^3/s flow would be diverted into the off-stream storage site reducing the river flow from 930 to 630 m^3/s at the diversion structure. This resulting 630 m^3/s flow rate is absorbed in Glenmore Reservoir storage. The resulting peak discharge from Glenmore Reservoir is 170 m^3/s; the maximum allowable discharge prior to residential damage. An Elbow River flow of 200 m^3/s has been set as a trigger condition to initiate diverting a portion of the Elbow River flood water into the off-stream storage site. Diversion would only be continued if a major flood develops.

Figure G4.2

Springbank Off-Stream Storage Project (SR1)
Reservoir Storage Capacity and Flooded Area Curves



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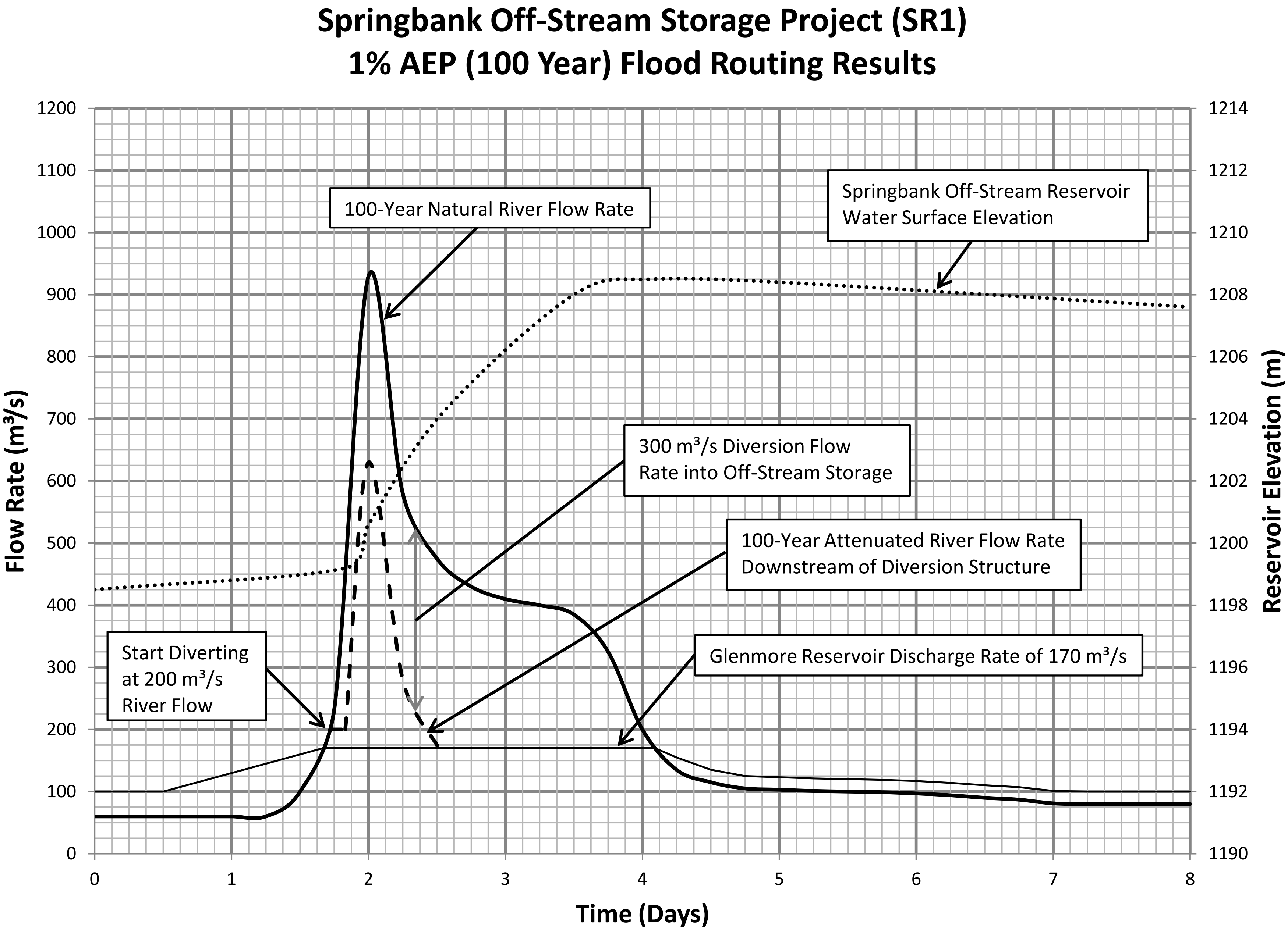
The following additional observations are made with respect to **Figure G4.3**:

- The inflow hydrograph peaks vary rapidly emphasizing the need for improved flood forecasting methods.
- The operators must be quick to open the diversion gates on receipt of a flood warning otherwise the Glenmore Reservoir storage will be filled prematurely, and the Springbank off-stream storage flood protection benefit will be significantly reduced. The gates must be fully opened within the hour of its indicated 200 m^3/s trigger level. This could occur in the middle of the night.
- The Glenmore Reservoir storage component of the design is very important as it attenuates the peak inflow from 630 to 170 m^3/s. This again emphasizes the need for improved forecasting and the importance of drawing Glenmore Reservoir down in advance of the flood. A portion of this storage should be drawn down well in advance of a flood, based on the possibility of a major flood developing (e.g., high snowpack in basin).
- The 1% AEP inflow hydrograph is numerically generated. The benefit would be reduced for an event with a hydrograph having a steeper upstream limb or a flatter downstream limb, but having the same 1% AEP peak flow rate and volume.
- The above-noted operational considerations support building the project to greater than the 1% AEP return period protection level (i.e., increased volume and diversion rate) and/or constructing additional flood protection projects.

Figure G4.3



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5.0 PROJECT DESIGN

5.1 General

Pertinent structure data established for conceptual design and described in this report section are provided in **Table G5.1**.

5.2 River Diversion Structure System

A conceptual design layout for the diversion structure system is provided in **Drawing G2**. Additional structure details are provided in **Drawing G3** and **Drawing G4**. The design is similar in concept to the Carseland Weir diversion structure located on the Bow River near the town of Carseland, Alberta, except the diversion capacity for SR1 is significantly greater than at Carseland due to the function as a flood channel. The diversion structure system would consist of a concrete overflow weir section crossing the Elbow River, a gated concrete sluiceway/fishway located adjacent to the left side valley abutment with its invert at the river thalweg level, and a gated diversion outlet structure located in the left valley abutment immediately upstream of the sluiceway. The outlet structure invert level would be located approximately 1.5 m above the river thalweg in order to exclude larger bottom sediment from entering the diversion channel. A robust trash boom has also been considered spanning across the entrance of the diversion outlet structure to manage the risk of floating debris plugging the outlet gate openings.

Detailed hydraulic and sediment transport analysis is required to better establish key structure parameters and to estimate the performance of this structure within the Elbow River flood regime. This analysis should be considered a priority in establishing parameters including weir crest and diversion invert levels, and future operating procedures to ensure that excessive volumes of larger sediment are not diverted out of the river system into the diversion channel during extreme floods. Hydraulic and sediment transport modelling assessment may be required following preliminary office study assessment which would include input from a sediment transport specialist.

Fluvial sand and gravel deposits in the river channel will provide a stable subgrade both to support the diversion structure foundations, and to provide resistance to lateral loads during flood events. Local lacustrine clay and clay till deposits excavated from the adjacent diversion channel are generally of medium plasticity, and are suitable for use in constructing low permeability compacted backfill for headwalls and wing walls that extend into adjacent embankments or native soil abutments.

The diversion weir component of the diversion structure is a relatively massive 100 m long concrete structure with an ogee crest shape and a hydraulic jump stilling basin. This structure serves to reduce approach velocities and increase the river water level to facilitate diversion through the outlet structure into the diversion channel.

Table G5.1
Springbank Road Off-stream Storage Project (SR1) Pertinent Structure Data

Diversion Structure Weir	
River Bed Elevation	1,209.5 m
Weir Crest Elevation	1,213.5 m
Top of Structure Walls Elevation	1,218.0 m
Weir Crest Length	100 m
Basin Elevation	1,208.5 m
Maximum Structure Height	9.5 m
Floodplain Berm	
Top of Containment Embankment Elevation	1,217.9 m
Maximum Height	7 m
Sluiceway/Fishway	
Number and Size of Openings	2 @ 4.0 m high × 8.0 m wide
Type of Control	Radial Gates
Normal Water Level (Non-Flood Condition)	1,210.2 m
Upstream Bottom Invert Elevation	1,209.5 m
Gate Clearance During Normal Flow Condition	3.3 m
Basin Elevation	1,208.5 m
Maximum Structure Height	9.5 m
Diversion Outlet Structure	
Number and Size of Openings	4 @ 3.0 m high × 8.0 m wide
Type of Control	Radial Gates
Gate Invert Elevation	1,211.0 m
Basin Elevation	1,207.5 m
Maximum Structure Height	10.5 m
Diversion Channel	
Upstream Invert Elevation	1,208.5 m
Bottom Width	30 m
Side Slopes (H:V)	3:1
Bed Gradient	0.001
Design Water Velocity	2.5 m/s
Reservoir Inlet Structure	
Crest Elevation	1,205.0 m
Chute Width	24 m
Structure Length	60 m
Off-stream Storage Reservoir	
Multi-use Storage Volume	9,000 dam^3
Multi-use Storage FSL	1,198.5 m
100-year Flood Storage Volume required at SR1	41,200 dam^3
100-year Reservoir Flood Elevation	1,208.5 m
Maximum Flood Storage Volume	57,000 dam^3
Maximum Reservoir Flood Level	1,210.5 m
Off-stream Storage Dam	
Top of Dam Elevation	1,212.0 m
Maximum Dam Height	24 m
Maximum Flood Water Level	1,210.5 m
Freeboard Above Maximum Water Level	1.5 m
Storage Dam Outlet Structure	
Conduit System	1 conduit at 1.5 m wide × 1.8 m high
Gatewell Tower Height	20 m
Size of Gate	1 sluice gate at 1.2 m wide × 1.8 m high
Structure Design Flow	20 m^3/s

The sluiceway/fishway component of the diversion structure is equipped with two 8 m wide radial gates. The sluice gate number and width was selected to provide free passage of fish along the Elbow River without significantly impacting water velocity during normal flow conditions. The sluiceway gates would typically be kept in the wide open position during non-flood conditions allowing free passage of sediment, fish, etc. Partial gate closure would be required as a part of flood operations to provide for adequate flow rate diversion through the outlet structure into the diversion channel, while allowing bottom sediment to pass under the sluiceway structure gates thereby keeping the majority of bottom sediment in the main river system.

The outlet diversion structure is equipped with four 8 m wide radial gates. The outlet structure gates would typically be kept in the full closed position during non-flood conditions. This conceptual design considers opening these gates when extreme flood conditions are anticipated thereby diverting a portion of the flood flow into the off-stream storage site. As previously mentioned, an Elbow River flow of 200 m^3/s has been set as a trigger condition to initiate diverting a portion of the Elbow River flood water into the off-stream storage site. Diversion would only be continued if a major flood develops.

If the flood event is large, the outlet structure gates would be opened to divert a maximum 300 m^3/s out of the Elbow River into the off-stream storage reservoir. In the case of the 1% AEP flood event, the peak flow remaining in the Elbow River would be reduced from approximately 930 to 630 m^3/s, but this flow rate would occur for only a short period of time. Glenmore Reservoir storage would be used to further attenuate this short duration peak flow rate of 630 m^3/s to a maximum reservoir outflow of 170 m^3/s. These operations and flow rates are illustrated graphically on **Figure G4.3**.

Precast concrete access decks, gate system control buildings, instrumentation controls, and automation have been allowed for on both the sluiceway/fishway and diversion outlet structure components of the diversion structure systems illustrated on **Drawing G4,** and allowed for in the cost estimate.

An earthfill floodplain containment berm with crest El. 1,217.9 m will be required across the floodplain connecting the diversion structure system to the south land form to prevent flood water creating a new channel through the floodplain, and thereby prevent flood water from bypassing the diversion area/sluiceway system. This berm would not connect to the existing ground El. 1,217.9 m, but would rather stop short leaving a low gap area for extreme flood passage. The conceptual design considers that the concrete weir and sluiceway system would pass all floods up to the 0.1% AEP flood event, prior to more extreme flood water escaping through this southern gap area. The PMF would be conveyed through the system without overtopping the diversion structure crest. Fuse plugs would not be incorporated into the floodplain berm because of the associated sudden increase in discharge and resulting downstream safety risks in the City of Calgary.

Following stripping of surface organic soils, the exposed subgrade for the floodplain berm is expected to consist of a combination of fluvial sand and gravel deposits and clay/clay till soil. Removal of fine sand or silt overbank materials in the upper portion of the subgrade may be required in some areas prior to placing embankment fill to limit potential for piping below the embankment.

The floodplain berm is a zoned fill with an impervious zone 1A compacted clay core and random compacted 2A fill upstream and downstream shells. Available local medium plastic to low plastic clay and clay till soil will provide suitable borrow material for constructing the impervious 1A compacted core. Local clay soil, as well as reworked bedrock or other excavated materials from the embankment subgrade or diversion channel excavation, will provide suitable material for construction of the upstream and downstream random fill zone 2A shells.

5.3 Diversion Channel and Reservoir Inlet Structure

The proposed diversion channel profile and a typical channel section are illustrated in **Drawing G5**. The diversion channel is designed to convey a peak diversion flow of 300 m^3/s from the Elbow River into the off-stream storage reservoir. The channel has been designed to convey this flow at a relatively high channel velocity of 2.5 m/s in order to transport any sediment which enters from the reservoir and thereby reduce the risk of plugging the diversion channel. The channel is designed with a 24 m bottom width, three horizontal to one vertical side slopes and a 3.6 m water depth. Excavation for the diversion channel will range from approximately 25 m depth near the Elbow River diversion to less than a metre where the channel alignment crosses small creeks. Construction of banks will be required over short stretches of the channel alignment to provide adequate bank height to contain the flood water within the channel. The material excavated from the diversion channel will provide the primary borrow source for construction of the off-stream storage dam and the floodplain berm.
The material excavated from the diversion channel will consist mostly of lacustrine silty clay and clayey silt, silty clay till, and bedrock of the Brazeau and Porcupine Hills Formations. It is anticipated that occasional pockets of sand will also be encountered within the lacustrine and till units. Additional geotechnical drilling during future project phases will serve to better define the relative quantities of clay soil and bedrock that will be excavated from the diversion channel.

The lacustrine and till deposits predominately consist of medium plastic silty clays with occasional instances of either low plastic or high plastic clays. Atterberg limit tests conducted on samples of clay from the area have indicated liquid limits between 34% and 38%, and plastic limits between 18% and 20%. Soil moisture contents measured in the clay have ranged from 11% to 30%. It should be recognized that the number of boreholes drilled to date was limited to five locations due to restricted land access. The laboratory test results are generally consistent with the results of tests obtained on samples of similar clay from other nearby projects.

Bedrock in the project area generally consists of inter-bedded mudstone, siltstone and sandstone. The mudstone is generally extremely weak to weak rock with a consistency similar to very hard soil. The siltstone and sandstone layers are typically discontinuous, and can range from weathered very weak rock to moderately strong rock. Bedrock of the Brazeau and Porcupine Hills formations have been excavated on previous construction projects without use of blasting, by using large hydraulic excavators and large dozers equipped with rippers. Hydraulic breakers can be required to break up stronger siltstone and sandstone layers into pieces suitable for excavation. The weathered sandstone and siltstone, and the mudstone, deteriorates over time with exposure to air and water.

Use of the locally excavated bedrock as engineered fill requires that the blocky broken out pieces of bedrock be thoroughly broken down during compaction to a soil-like consistency. This is accomplished by using thin lifts of material for compaction, moisture conditioning as necessary including turning the soil with a disc or grader and using heavy compaction equipment capable of crushing the individual pieces of material. Large pieces of strong sandstone and siltstone should be stockpiled separately during the excavation process, and not be used for construction of engineered fill.

The clay lacustrine and till deposits are suitable for construction of either impervious zone 1A, or random zone 2 type embankment construction. Soil mixing to distribute pockets of siltier or sandier materials and moisture conditioning will be required during embankment construction. Embankments constructed of the local low to medium plastic clay soil with sideslope angles of 2.5H:1V (horizontal:vertical) or flatter, will provide a factor of safety against slope instability of 1.5 or greater, depending on slope height and with no groundwater present in the slope.

In general, within the lacustrine clay, clay till and bedrock materials expected to be encountered along the diversion channel alignment, slopes excavated to an angle of 3H:1V or flatter will provide a minimum 1.5 factor of safety against slope instability, assuming a 25 m high slope and considering that less than about 40% of slope height is below the groundwater table.

Remoulded bedrock is suitable material for use in constructing random zone 2A fill. Remoulded bedrock or mixtures containing remoulded bedrock may be suitable for use in constructing impervious zone 1A fill provided specific field procedures are implemented to ensure the bedrock is broken down to the consistency of soil during compaction. Sideslope angles of 3H:1V or flatter are recommended for embankments constructed of medium to high plastic remoulded bedrock, and will provide a factor of safety of 1.5 or greater for slope heights of up to 25 m and considering a groundwater level below about 40% of the slope height.

The diversion channel design is presented at a very conceptual level. Future design should consider:

- Sideslope benching to provide improved access for maintenance;
- Further evaluation of required diversion channel velocity to manage diverted sediment;
- Sediment deposition ponds at the existing depressions at stations 3+000 and 4+500;
- Gradient flattening to manage erosion on select reaches;
- Perhaps an intermediary drop structure at approximately station 3+400 to manage erosion at the upstream bridge; and
- Channel erosion protection including topsoiling, grassing, and cobble armour in select reaches.

A concrete reservoir inlet structure will be required at its downstream end where the water is discharged into the reservoir in order to manage the extent of channel erosion. **Drawing G7** illustrates the inlet chute structure concept. The proposed multi-use storage pond allows a reduction in required inlet chute length as compared to if the concept is designed without a pool. Following stripping of organic soil, the subgrade for the inlet structure foundation is expected to consist of clay till. The local clay soil will provide stable subgrade support for the structure foundation, and is suitable for construction of impervious backfill around headwalls, cutoff walls and side walls for the structure.

Ensuring that the larger river bottom sediment is excluded from this channel, and providing high channel velocities to transport any diverted sediment through the channel are extremely important features immediately downstream of the diversion outlet; otherwise, channel plugging could occur during diversion.

5.4 Off-stream Storage Dam and Reservoir

A 3 km long earthfill storage dam having a maximum height of 24 m is required to contain the diverted flood water. The conceptual design considers a zoned earthfill dam with a clay core and random earthfill shells as illustrated in **Drawing G6**. Embankment slopes of 3H:1V are provided, with 6 m wide berms at strategic levels resulting in average dam slopes of between 3H:1V and 4H:1V. The berms are included to provide stability, and to facilitate access for inspection, maintenance, and geotechnical instrument monitoring. The need, width, and spacing of such berms should be further evaluated as part of future design. An interior filter and drainage system and upstream riprap slope protection have been provided. Rock riprap protection has been provided in the active permanent multi-use reservoir zone from reservoir bottom to the lower berm El. 1,202.0 m. It is also provided in the dam crest zone (i.e., El. 1,207.0 to 1,212.0 m) to protect the dam from potential failure in the unlikely event of full flood containment to El. 1,210.5 m combined with a minimum 50% AEP wind event. This upper zone riprap can be covered with topsoil and seeded to provide a more desirable landscape appearance. Consideration should also be given to using a more erosion resistant impervious 1A zone material in the upstream shell/upstream dam surface to reduce the risk of wave damage. The extent of these features will be better established based on more detailed future design work.

Following stripping of surface organic soils, the exposed subgrade for the storage dam embankment is expected to consist of a combination of lacustrine clay and clay till. Previous experience with similar low to medium plastic soil subgrades indicates that subgrade deformations or increase in porewater pressure due to embankment construction are not limiting factors for typical rates of embankment construction.

The main embankment is a zoned fill with an impervious zone 1A compacted clay core and random compacted zone 2A fill upstream and downstream shells. Available local medium plastic to low plastic lacustrine clay and clay till soil will provide suitable borrow material for constructing the impervious zone 1A compacted core. Local clay soil, as well as reworked bedrock or other excavated materials from the embankment subgrade or diversion channel excavation, will provide suitable borrow for construction of the upstream and downstream random zone 2A shells. As discussed previously, it may also be possible to use remoulded bedrock to construct impervious zone 1A embankment subject to demonstration of adequate field procedures.

Embankment slope angles of 3H:1V for slopes formed of random zone 2A fill will provide adequate minimum factor of safety against slope instability for the approximately 24 m height of the main embankment – for an unsaturated slope condition. Assessment of a rapid drawdown condition for the multi-use reservoir full supply water elevation of 1,198.5 m, indicated a factor of safety against slope instability of approximately 1.4 for a 3H:1V upstream embankment angle. A rapid drawdown scenario was not investigated for the 1% AEP condition since even at the maximum 20 m^3/s rate of discharge for the low level outlet, a month or more would be required to lower the stored water level to the permanent pool elevation 1,198.5 m.

The dam system will include a gated low level outlet structure. This structure will include a 1.5 m wide by 1.8 m high concrete conduit through the dam including a gatewell tower located near the dam centerline as illustrated in **Drawing G6**. This structure will be used to release stored water back into the river after the flood has passed. Channel improvements will be required along the creek connecting this outlet to the Elbow River. As previously mentioned, the conceptual design considers a low level outlet system design discharge of 20 m^3/s which could release the contained 1% AEP flood water in a period of approximately 1 month. The design and cost estimate make allowances for a gate system control building, instrumentation controls, and automation.

It is expected that the subgrade soil supporting the low level outlet will consist of either lacustrine clay or clay till soil. Since the location proposed for the low level outlet is an existing natural drainage channel, there may be unconsolidated alluvial soil present along the alignment proposed for the low level outlet. Removal of such soils to a very stiff clay subgrade would be required to provide adequate support for the outlet conduit, otherwise consideration can be given to moving the structure to a location with a better foundation as determined by future drilling. The lacustrine clay soil or glacial clay till soil will provide adequate foundation support for the discharge structure at the end of the conduit.

6.0 EXISTING INFRASTRUCTURE IMPACTS

6.1 General

A number of pipelines, power lines, telephone lines, and road systems will be impacted by the proposed works as schematically illustrated on **Drawing G1**.

6.2 Pipelines, Power Lines and Telephone Lines

Numerous oil and gas pipelines cross the proposed diversion channel route and the off-stream storage dam alignment. These lines will need to be re-routed or lowered. Pipelines identified to date include ATCO Gas distribution lines, a 114 mm Pengrowth Energy Corporation HV line, a 168 mm Alberta Ethane Development Company HV line, a 914 mm Nova Gas Transmission NG line, and a 914 mm Foothills NG line. The Nova and Foothills lines are of particular concern because of their size. Several lines are also located within the proposed reservoir area. Dependent on existing burial depth these lines could be left in-place, or may require lowering, weighting, or rerouting. These include smaller ATCO Gas distribution lines and several Plains Midstream Canada S lines varying in size between 114 and 323 mm.

The extent of necessary oil and gas pipeline relocation has not been finitely established at this level of study. A nominal cost allowance has been included to account for these items.

6.3 Telephone Lines and Power Lines

Telus trench and Fortis power lines are located throughout the project areas. These lines would need to be rerouted or otherwise modified to suit project requirements.

6.4 Road Systems

Existing highways and local roads will be impacted by the proposed project.

A new bridge will be required where the diversion channel crosses Highway 22. The proposed flood storage reservoir would flood over existing Highway 22 at its upstream end, but only during extreme floods. The highway would need to be raised such that it is above the maximum flood level. It is conceivable that Highway 22 may be upgraded to a divided highway in the future; this would need to be considered in the proposed SR1 design.

The existing Springbank road will be submerged by reservoir flood water. Several solutions are feasible including relocation as illustrated on **Drawing G1**, or leaving it at its existing location but constructing a secondary road along the relocation route for use only when the existing road is submerged by flood water. A third option which considers raising the existing road above potential flood water level at its existing location would be a relatively more expensive option. This option may result in increased safety risk so is not recommended at this time.

Several local gravel roads will also be impacted by the proposed project. Rerouting of these roads will be required. Stakeholder engagement input is required as part of the next phase.

7.0 EXISTING LANDOWNERS

The proposed project is located within farmland and ranchland areas. A number of farm and/or ranch yards will be impacted along the diversion channel route and in the area of the off-stream storage dam and reservoir. Camp Kiwanis is located in the floodplain area south of the river and east of the diversion weir. The Tsuu T'ina Nation Indian Reserve, which is located upstream of the diversion structure would not be impacted by the project.

At least one residence located in the southeast quarter of Section 24-24-4 would be submerged by the reservoir and its relocation or purchase would be required. Several residences are located in northeast quarter of Section 24-24-4 as illustrated on **Drawing G8**. Two of the yards are well above the maximum reservoir flood water level and would not be directly impacted by the proposed project. Two of the yards are just above the estimated 1% AEP flood El. 1,208.5 m and could be directly impacted dependent on the maximum flood water level and top of dam levels selected for detailed design and construction (i.e., El. 1,210.5 m considered for conceptual design needs to be investigated further). Berms could be constructed on the west periphery of these yards to protect them from the reservoir flood water. A number of graineries, sheds and other buildings associated with the above four yards exist within the reservoir flood zone and would need to be removed, relocated, or rebuilt at a new location.

8.0 ENVIRONMENTAL AND REGULATORY OVERVIEW

The proposed project is located within the White Zone and is primarily on agricultural land. Project components would directly affect the Elbow River and its associated riparian land. Environmental concerns to be addressed in the project design include:

- Hydrogeology – effects of ponded water on groundwater resources.
- Water quality and quantity – effects of potential changes in stream flows, sediment load, and water quality parameters.

- Fisheries – potential for effects on fish and fish habitat, including possible populations of brook trout, brown trout, bull trout, burbot, longnose dace, longnose sucker, mountain whitefish, and rainbow trout. Bull trout are listed as species of special concern by Alberta's Endangered Species Conservation Committee.
- Soils – effects of changes in flows on soils and potential for soil erosion.
- Wildlife – Provincially designated Key Wildlife and Biodiversity zones are located along the Elbow River, which impose potential timing and construction constraints for the proposed project. Potential effects may occur to species using the zone, including cougar. Wildlife movement patterns may be altered in proximity to the project.
- Vegetation – potential effects on vegetation will be focused on agricultural lands, grazing land. There are no recorded locations for rare plants associated with the project.
- Traditional and non-traditional land use – potential effects include access, changes in traffic patterns and aesthetic concerns. In addition to private landowners, the project site may be located within the Stoney Nakoda and Tsuu T'ina First Nations traditional territories.

The proposed project would require a license to divert water under the *Water Act*, which is administered by ESRD. The project triggers Alberta Regulation 111/93 *Envrionmental Protection and Enhancement Act* (EPEA) Environmental Assessment (Mandatory and Exempted Activities) Regulation, which requires an environmental impact assessment (EIA) be completed for a dam greater than 15 m in height. A water management project that requires an EIA triggers a Natural Resources Conservation Board (NRCB) review. Typically environmental studies to support the EIA would include a minimum of 1- year of site-specific data.

The proponent would submit its project application with its supporting EIA to ESRD, which makes a determination of completeness. Once deemed complete, the NRCB review process would involve a public hearing as part of its review. The NRCB and ESRD have a history of working cooperatively on environmental reviews of this kind. The ESRD/NRCB process could take between 18 and 24 months to complete. At the completion of the process, the NRCB sends its determination to cabinet, who reviews the report and issues the final approval decision.

In addition to the ESRD and NRCB, several other provincial and federal departments will have regulatory roles for the proposed project. These processes can generally occur in parallel with the ESRD/NRCB review, as much of the information required for them supports the environmental review. For example, pre-development and post-development aquatic environmental assessments would be necessary as part of the application for approval under the *Water Act*. Specific authorizations and permits would be obtained subsequent to the ESRD/NRCB decision, if the project was approved.

An overview of the regulatory process is shown in **Table G8.1**.

Table G8.1
Regulatory Process Overview

Regulator	Legislation	Requirements/Process	Schedule
Provincial			
ESRD	EPEA Environmental Assessment Mandatory and Exempted Activities Regulation 111/93	Under EPEA an EIA is required for a dam greater than 15 m in height, as specified in the Mandatory and Exempted Activities Regulation.	18 to 24 months
NRCB	*Natural Resources Conservation Board Act*	The NRCB review process is triggered when a water management project requires an EIA.	
ESRD	*Alberta Water Act*	Authorization	Variable
	Alberta Water Act	Licence and approval	Variable
	Public Lands Act	Dispositions following the Environmental Field Report (EFR) process	5-8 months
Alberta Culture (AC)	*Historical Resources Act*	Application for clearance	Depends on requirements; for historic resources impact assessment, expect 4 to 6 months from initial application for clearance.
Federal			
Fisheries and Oceans Canada (DFO)		Authorization pursuant to the *Fisheries Act* (habitat and fish passage)	90 days post-filing, providing submission is complete.
Miscellaneous Federal Acts		*Migratory Birds Convention Act* (MBCA)	
		Species at Risk Act (SARA)	*n/a*

As currently designed, the proposed project is not listed in the *Regulations Designating Physical Activities*, under the *Canadian Environmental Assessment Act*. It does not result in a reservoir with a surface area that would exceed the annual mean surface area of a water body by 1,500 ha or more and it does not divert 10,000,000 m^3/year or more of water from a natural water body into another natural water body.

9.0 CONSTRUCTION COST ESTIMATE AND PROJECT SCHEDULE

9.1 Project Cost Estimate

A detailed cost estimate is provided in **Table G9.1**. The project cost is estimated to be $158,168,000. This price does not include the cost of land acquisition which will be determined by others. The estimate provided herein is based on 2012 construction price data. Year 2012 prices were used considering that 2013 construction prices are skewed as a result of abnormal activity which resulted from the June 2013 flood event. It is assumed that the construction of SR1 would take place in a more competitive environment for contractors and suppliers, and as such the 2012 prices are considered indicative of realistic project cost. The estimate was produced considering the conceptual designs presented herein. Additional subsurface soils investigations are required to better establish the concept details presented herein. More detailed hydrological assessment and topographic data are required to better establish the size of required works. A contingency allowance of 25% has been included in an effort to account for additional costs which could result from future additional information and the results of more detailed design work. No allowance is included for escalation until the time of construction.

To increase the flood protection above the 1% AEP, to the 2013 flood of record level would require the dam crest level raised by approximately 2.5m to Elevation 1214.5m and would also require a larger diversion outlet structure and channel. These adjustments would result in additional project cost of approximately $55 million. This amount includes contingency and engineering allowances.

Table G9.1
Off-stream Storage Project (SR1) Cost Estimate

Item	Unit	Quantity	Unit Price	Extension
General				
Mob./Demobilization	lump sum	lump sum	7,000,000.00	$7,000,000
Care of Water	lump sum	lump sum	3,000,000.00	$3,000,000
Clearing & Timber Salvage	hectares	10	12,000.00	$120,000
Raise Highway 22	lump sum	lump sum	2,000,000	2,000,000
Local Road Modifications	km	15	250,000.00	$3,750,000
Topsoil/Seeding etc.	m^2	1,200,000	1.50	$1,800,000
	Subtotal General			**$17,670,000**
River Diversion Structure System				
Stripping	m^3	5,000	6.00	$30,000
Common Excavation	m^3	20,000	10.00	$200,000
Structure Fill	m^3	10,000	30.00	$300,000
Diversion Weir Concrete	m^3	4,900	1,000.00	$4,900,000
Sluice/Fishway Concrete	m^3	990	1,000.00	$990,000
Outlet Structure Concrete	m^3	1,900	1,000.00	$1,900,000
Precast Decks	lump sum	lump sum	560,000.00	$560,000
Fine Filter	m^3	1,200	90.00	$108,000
Coarse Filter	m^3	1,200	90.00	$108,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Rock Riprap	m^3	6,400	130.00	$832,000
Bedding Gravel	m^3	2,200	70.00	$154,000
Gate/Hoist Systems	each	6	500,000.00	$3,000,000
Controls/Instrumentation	lump sum	lump sum	300,000.00	$300,000
Electrical/Mechanical	lump sum	lump sum	500,000.00	$500,000
Superstructures	each	2	90,000.00	$180,000
	Subtotal Diversion Structure System			**$14,262,000**
Floodplain Berm				
Stripping	m^3	18,000	6.00	$108,000
Impervious Fill	m^3	90,000	1.50	$135,000
Random Fill	m^3	60,000	1.40	$84,000
Fine Filter	m^3	6,000	90.00	$540,000
Rock Riprap	m^3	8,000	130.00	$1,040,000
Bedding Gravel	m^3	4,000	60.00	$240,000
	Subtotal Floodplain Berm			**$2,147,000**

Item	Unit	Quantity	Unit Price	Extension
Diversion Channel & Reservoir Inlet Structure				
Stripping	m^3	180,000	6.00	$1,080,000
Common Excavation	m^3	1,800,000	5.50	$9,900,000
Rock Excavation	m^3	200,000	10.00	$2,000,000
Impervious Fill	m^3	10,000	20.00	$200,000
Inlet Chute Concrete	m^3	2,000	1,200.00	$2,400,000
Fine Filter	m^3	660	90.00	$59,000
Coarse Filter	m^3	1,760	90.00	$158,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Bridge Crossings	each	1	4,000,000.00	$4,000,000
Pipeline Crossings	lump sum	lump sum	4,000,000.00	$4,000,000
Power Line Relocation	lump sum	lump sum	300,000.00	$300,000
	Subtotal Diversion Channel System			**$24,298,000**
Off-stream Storage Dam				
Stripping	m^3	180,000	6.00	$1,080,000
Borrow Excavation	m^3	1,700,000	5.00	$8,500,000
Overhaul	m^3km	2,500,000	1.50	$3,750,000
Impervious Fill	m^3	1,600,000	1.50	$2,400,000
Random Fill	m^3	1,200,000	1.40	$1,680,000
Fine Filter	m^3	140,000	60.00	$8,400,000
Coarse Filter	m^3	20,000	60.00	$1,200,000
Rock Riprap	m^3	62,000	130.00	$8,060,000
Bedding Gravel	m^3	31,000	60.00	$1,860,000
Geotechnical Instruments	lump sum	lump sum	400,000.00	$400,000
	Subtotal Off-stream Dam			**$37,330,000**
Dam Outlet Structure and Downstream Channel Improvements				
Structure Excavation	m^3	20,000	20.00	$400,000
Structure Fill	m^3	15,000	30.00	$450,000
Reinforced Concrete	m^3	1,600	1,200.00	$1,920,000
Rock Riprap	m^3	600	130.00	$78,000
Bedding Gravel	m^3	300	70.00	$21,000
Gate/Hoist Systems	each	lump sum	160,000.00	$320,000
Controls/Instrumentation	lump sum	lump sum	100,000.00	$100,000
Electrical/Mechanical	lump sum	lump sum	400,000.00	$400,000
Superstructure	lump sum	lump sum	50,000.00	$50,000
	Subtotal Structure & Channel Improvements			**$3,739,000**

Item	Unit	Quantity	Unit Price	Extension
Springbank Road Relocation				
Grading	km	5	550,000.00	$2,750,000
Base/Pavement	km	5	650,000.00	$3,250,000
Creek Crossings	lump sum	lump sum	1,000,000.00	$1,000,000
	Subtotal Springbank Road Relocation			**$7,000,000**
	SUBTOTAL CONSTRUCTION			**$106,446,000**
	Contingencies (25%)			$26,661,000
	Subtotal Construction and Contingencies			**$133,107,000**
	Engineering/Environmental (20%)			$26,661,000
	TOTAL CONSTRUCTION			**$159,768,000**

9.2 Project Schedule and Contracts

Studies to date indicate that the proposed project is feasible. A potential project schedule moving forward would consider both preliminary engineering and environmental impact assessment proceeding on parallel but linked paths, and followed by a detailed design–build or a detailed design-bid-build process.

A number of issues need to be resolved in order to proceed with preliminary design and environmental impact assessment. These include:

- Land access;
- Establishing the level of flood protection to be provided by the project (e.g. 1% AEP flood, 2013 record flood, or larger); and
- Establishing the need for and amount of multi-use storage, if any.

Land access is required in order to proceed with subsurface soil investigations for use in design and cost estimates, and for environmental field investigations. Similarly stakeholder involvement is required to better define project issues and potential solutions. Initiating stakeholder involvement and gaining land access need to be initial priorities.

Key stakeholder input is required to better define the preferred reservoir storage volume which would impact the locations of the diversion structure, diversion channel, off-stream storage dam and associated facilities. As an example a larger reservoir containment would require a larger diversion outlet and channel, a higher dam, the diversion structure to be moved as much as 200 m upstream, could consider the off-stream storage dam moved about 100 m south, and the diversion channel alignment moved up to 100 m north or south of its currently proposed location. Similarly a larger reservoir volume would result in increased impacts to the previously discussed four yard complex located in the northeast of Section 24-24-4. Resolving project size and associated layout needs to be an initial priority.

This conceptual design has provided for a portion of the reservoir to be used for purposes other than, or in addition to, flood storage (i.e. multi-use storage). This concept needs to be endorsed or rejected and the amount of such multi-purpose storage established.

Sediment transport has been identified as a major factor in diversion structure design and should be addressed at the onset of preliminary design, as the results of this assessment could significantly impact the diversion structure configuration. Preliminary design would include hydraulic and sediment transport modelling, if required, to produce detailed structure outline drawings and better establish project cost. Preliminary design should include more detailed subsurface soils investigations and stakeholder involvement. Land access will be required for the preliminary design and environmental field investigations.

Design-build or design-bid-build contracting procedures can be considered for project detailed design and construction. Design-build considers that the work is both designed and built by one project team. Design-bid-build considers that a team is selected to design the project, it then goes to public tender, and is constructed by the successful bidder. Design-build process can result in a reduced time schedule, but the design-bid-build process is considered to be more conventional and appropriate for this project type. The SR1 project could be tendered as one major construction contract, or alternatively divided into two or more contracts. At this time a minimum of three contracts is recommended. One contract would include the diversion structure, floodplain berm, and upstream end of the diversion channel. A second contract would include the remainder of the diversion channel, reservoir inlet chute, off-stream storage dam and associated outlet works. Bridge and road works would be included in the third contract. The contract areas do not overlap and could proceed simultaneously. The multiple contract concept would provide smaller local contractors opportunity to bid this work and could allow earlier initiation of some portions of project construction.

The project schedule is dependent on factors including cash flow, land access/purchase, environmental and regulatory processes, subsurface field investigations (drilling), engineering design and construction. As previously mentioned, engineering design can proceed parallel with environmental studies and regulatory processes which could require 30 to 36 months to complete.

Construction will require a minimum one calendar year, but a 2 or 3-year schedule is preferred considering the size of this project. Of course the government would need to weigh the risk of additional flood damage against the preferred longer construction period. Construction could proceed year-round, taking advantage of both summer and winter seasons. Most of the work would be performed in the spring through fall period; however, significant quantities of work could be completed in the winter. Special measures would be required for winter construction including heating and hoarding for concrete and continuous 24-hour per day earthfill operations. A project schedule can be developed but requires additional owner input.

10.0 CLOSURE

This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

Reviewed by:

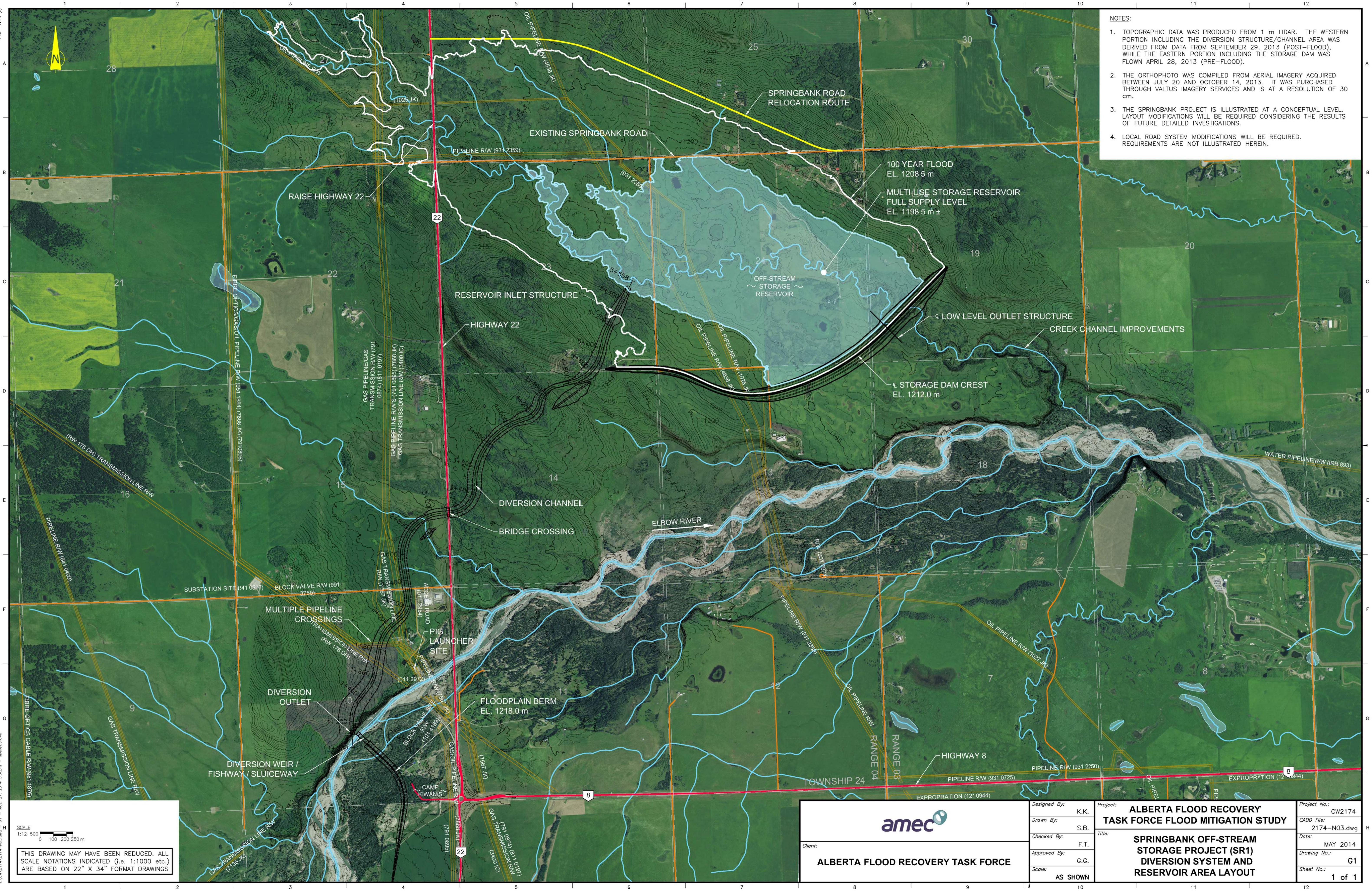
PROFESSIONAL ENGINEER
K.G. KRESS
ALBERTA

Ken Kress, P.Eng.
Principal Engineer
2 June 2014
Direct Tel.: (403) 387-1894
Direct Fax: (403) 248-1590
E-mail: ken.kress@amec.com

Geoff Graham, B.Sc. (Hons), MCIWEM C.WEM
Associate Water Resources Specialist

KK/elf

Permit to Practice No. P-4546



THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

NOTES:

1. TOPOGRAPHIC DATA WAS PRODUCED FROM 1 m LIDAR. THE WESTERN PORTION INCLUDING THE DIVERSION STRUCTURE/CHANNEL AREA WAS DERIVED FROM DATA FROM SEPTEMBER 29, 2013 (POST-FLOOD), WHILE THE EASTERN PORTION INCLUDING THE STORAGE DAM WAS FLOWN APRIL 28, 2013 (PRE-FLOOD).
2. THE ORTHOPHOTO WAS COMPILED FROM AERIAL IMAGERY ACQUIRED BETWEEN JULY 20 AND OCTOBER 14, 2013. IT WAS PURCHASED THROUGH VALTUS IMAGERY SERVICES AND IS AT A RESOLUTION OF 30 cm.
3. THE SPRINGBANK PROJECT IS ILLUSTRATED AT A CONCEPTUAL LEVEL. LAYOUT MODIFICATIONS WILL BE REQUIRED CONSIDERING THE RESULTS OF FUTURE DETAILED INVESTIGATIONS.
4. LOCAL ROAD SYSTEM MODIFICATIONS WILL BE REQUIRED. REQUIREMENTS ARE NOT ILLUSTRATED HEREIN.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	K.K.
Drawn By:	S.B.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

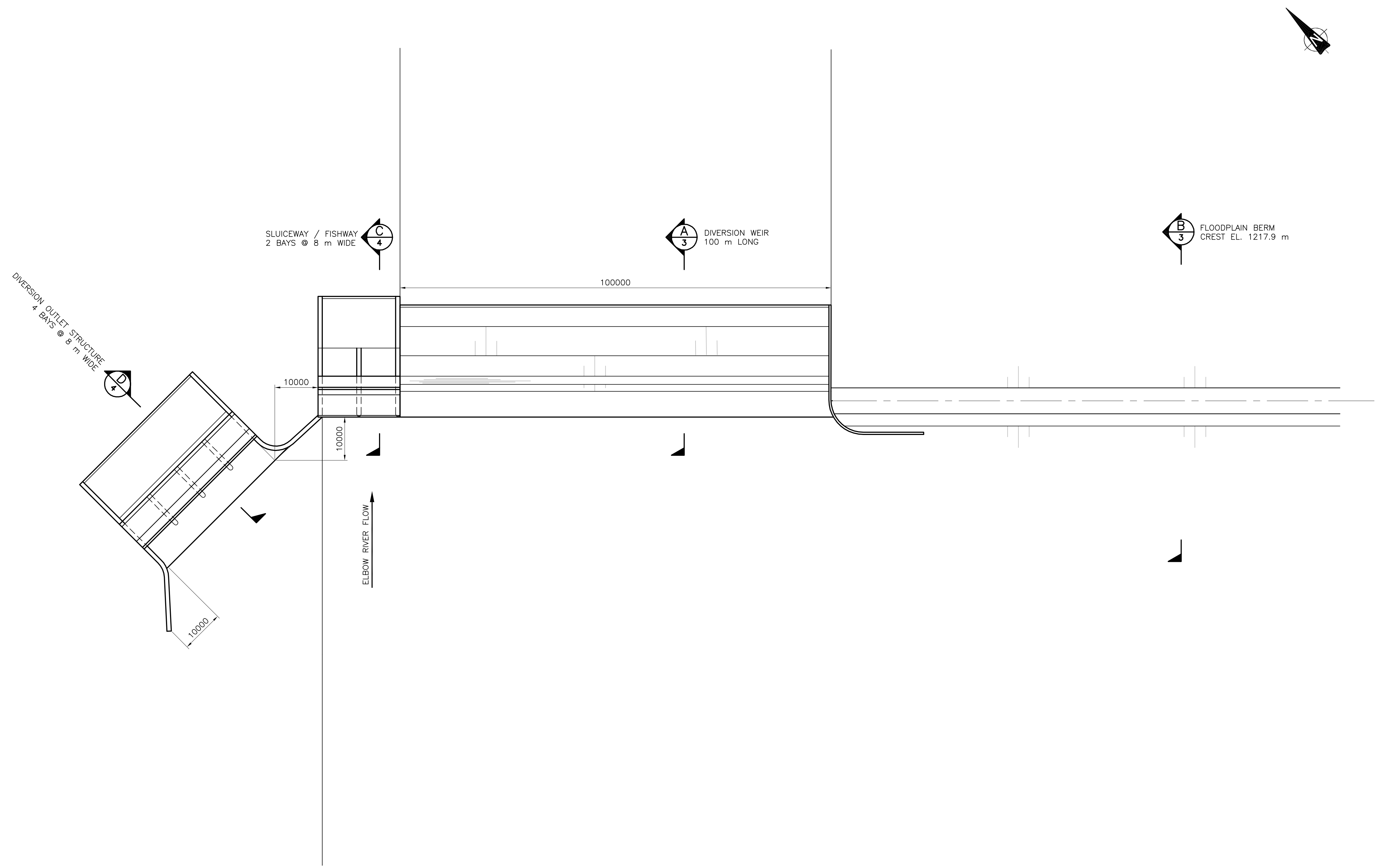
Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION SYSTEM AND RESERVOIR AREA LAYOUT

Project No.:	CW2174
CADD File:	2174–N03.dwg
Date:	MAY 2014
Drawing No.:	G1
Sheet No.:	1 of 1

NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



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F						
E						
D						
C						
B						
A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
DIVERSION WEIR / SLUICEWAY / FISHWAY / OUTLET STRUCTURE SYSTEM

Project No.: CW2174
CADD File: 2174–B08.dwg
Date: MAY 2014
Drawing No.: G2
Sheet No.: 1 of 1

NOTES:

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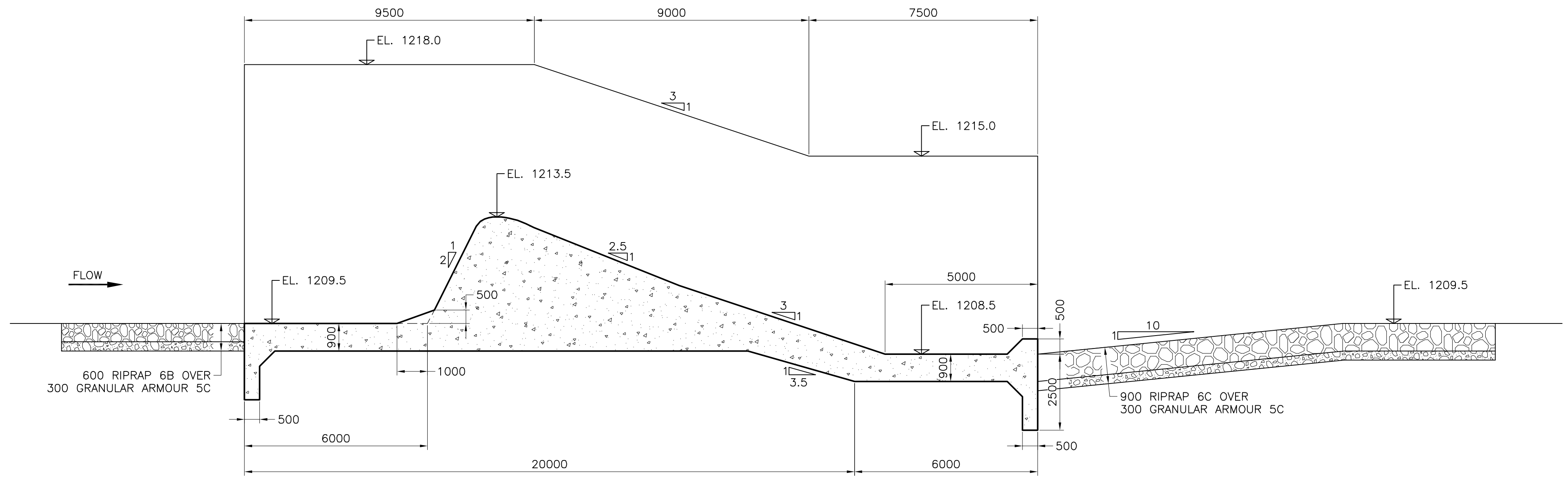
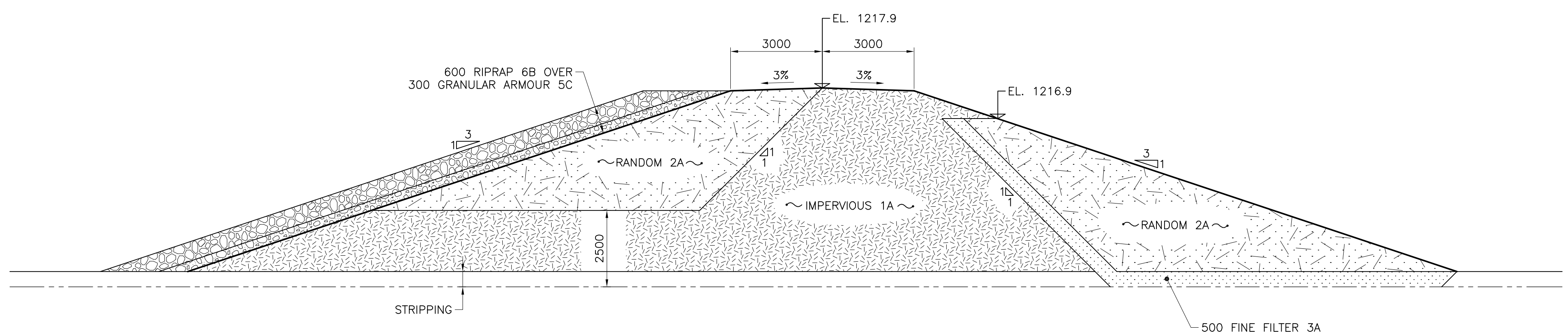


A/2 SECTION – DIVERSION WEIR
N.T.S.



B/2 SECTION – FLOODPLAIN BERM
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THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

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amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

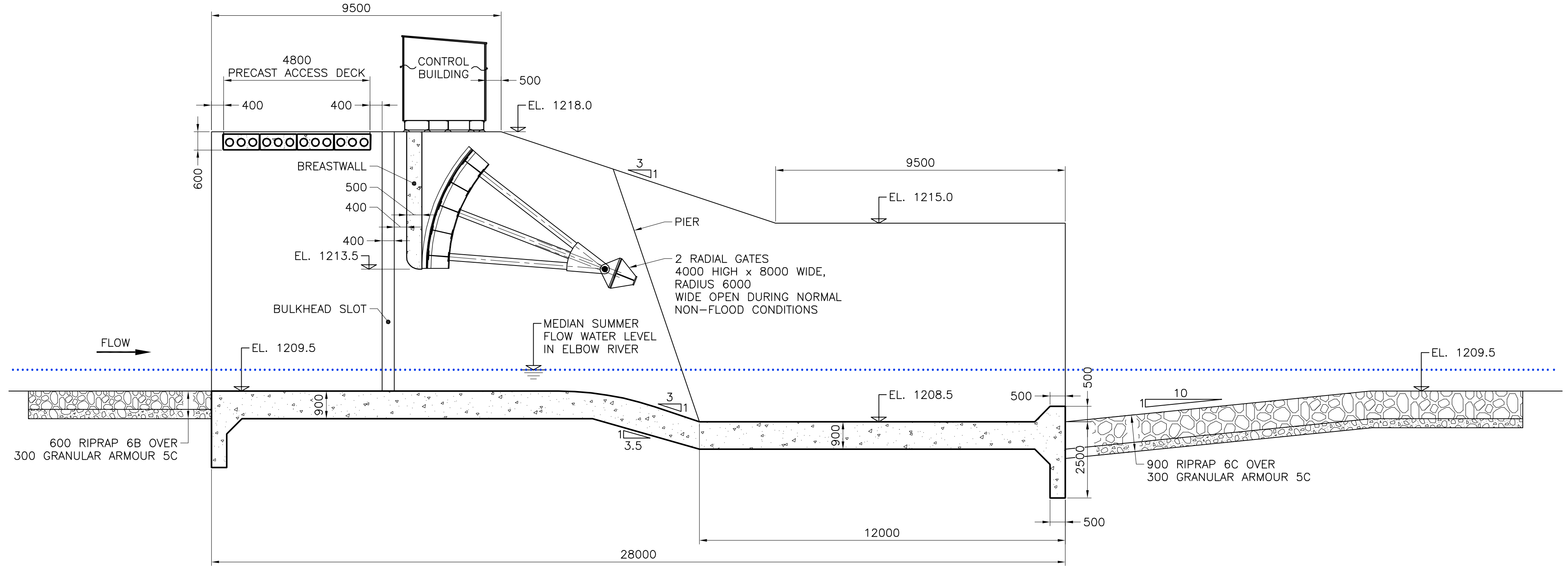
Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 1 of 2)

Project No.: CW2174
CADD File: 2174–B03.dwg
Date: MAY 2014
Drawing No.: G3
Sheet No.: 1 of 1

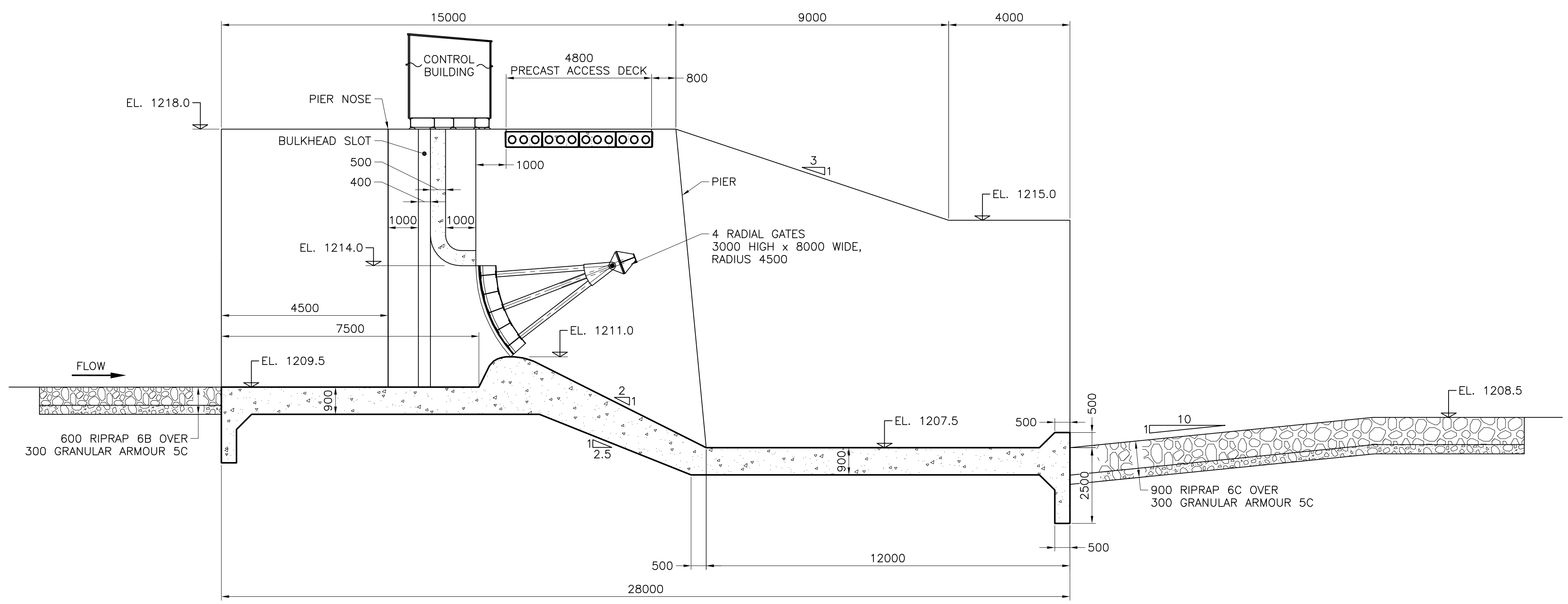
NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



C/2 SECTION – SLUICEWAY / FISHWAY

SCALE 1:100



D/2 SECTION – DIVERSION OUTLET STRUCTURE

N.T.S.

SCALE
1:100
0 1 2m

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
0	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

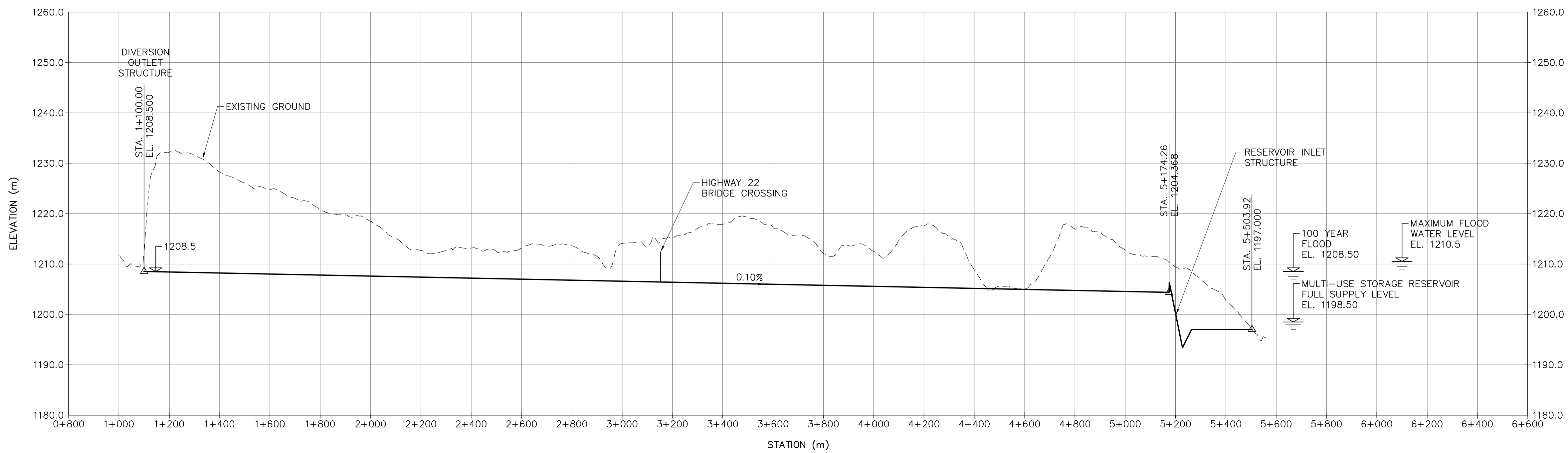
Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 2 of 2)

Project No.: CW2174
CADD File: 2174–B05.dwg
Date: MAY 2014
Drawing No.: G4
Sheet No.: 1 of 1

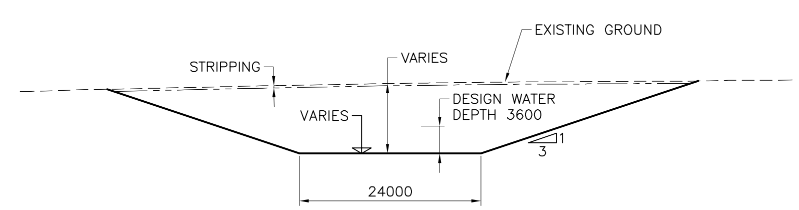
NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



DIVERSION CHANNEL PROFILE

SCALE HOR. 1:10000
VER. 1:500



DIVERSION CHANNEL TYPICAL CROSS SECTION

SCALE 1:500

SCALES
1:10 000 0 100 200m
1:500 0 5 10m

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0	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

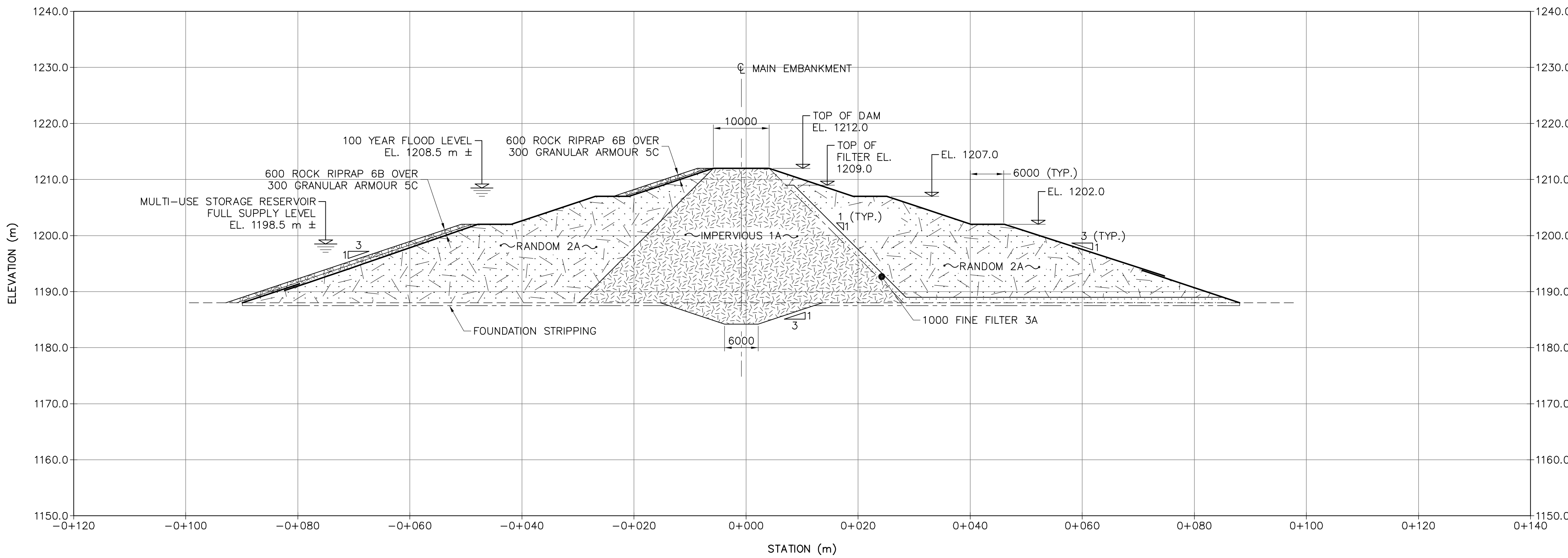
Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION CHANNEL

Project No.: CW2174
CADD File: 2174-N03.dwg
Date: MAY 2014
Drawing No.: G5
Sheet No.: 1 of 1

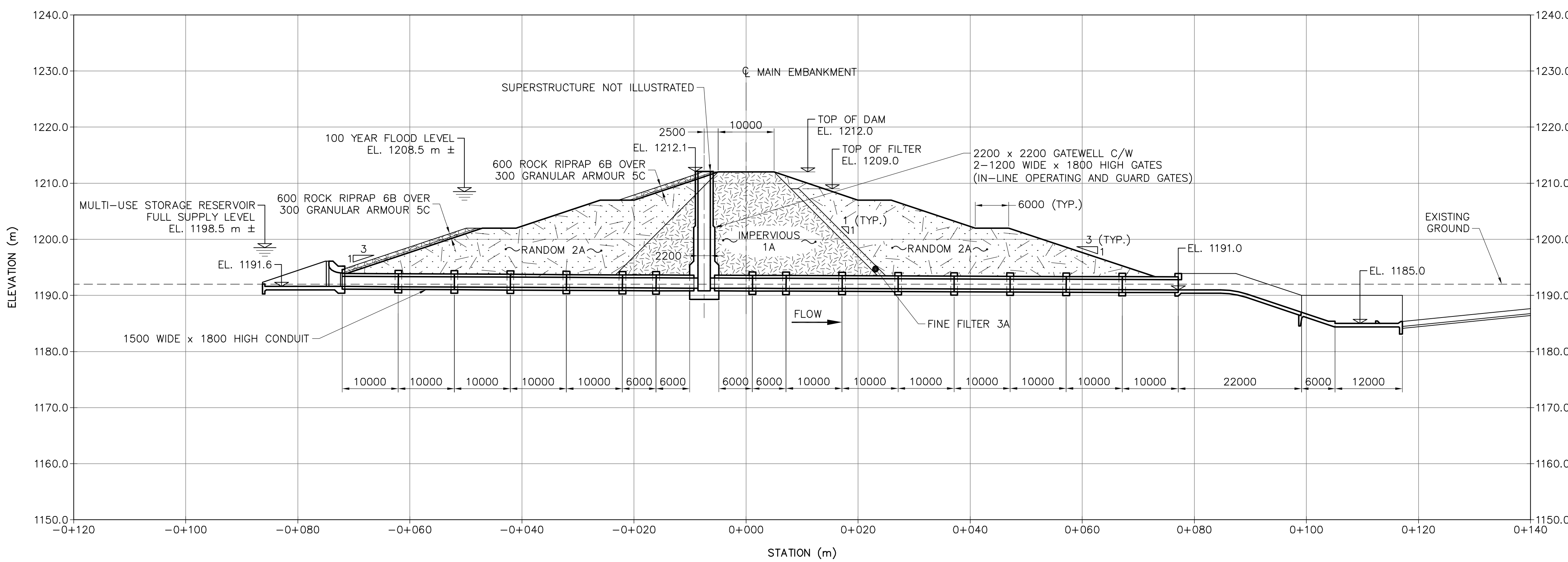
NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



OFF-STREAM STORAGE DAM

SCALE 1:500



LOW LEVEL OUTLET STRUCTURE

SCALE 1:500

SCALE 1:500 0 5 10 m

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REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
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Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	K.K.
Drawn By:	S.B.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

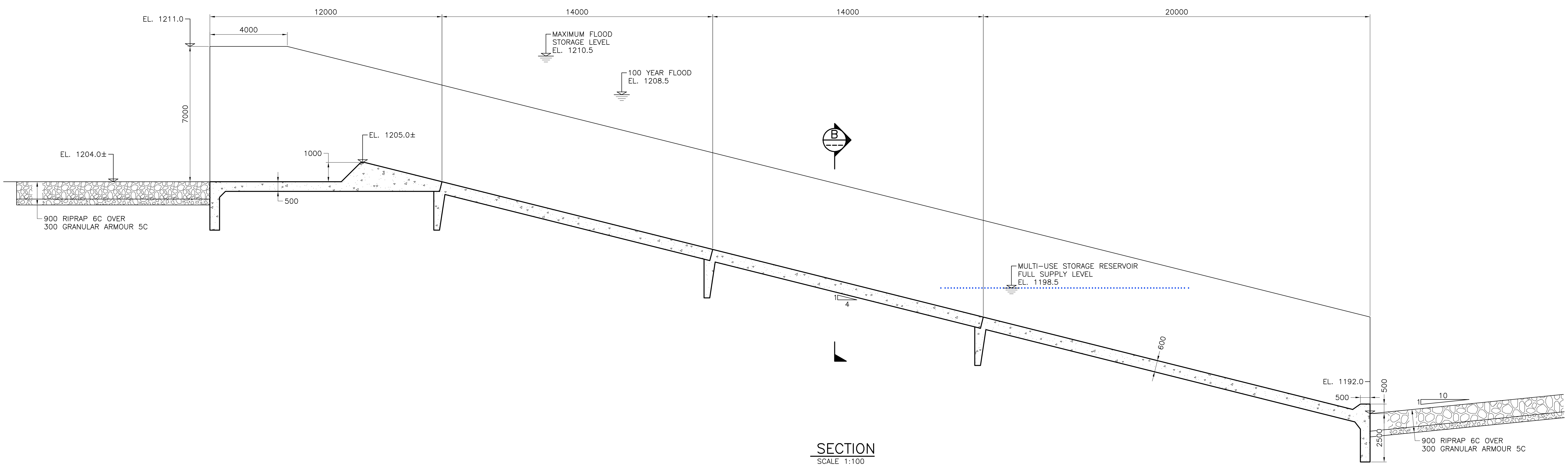
Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) OFF-STREAM STORAGE DAM & LOW LEVEL OUTLET

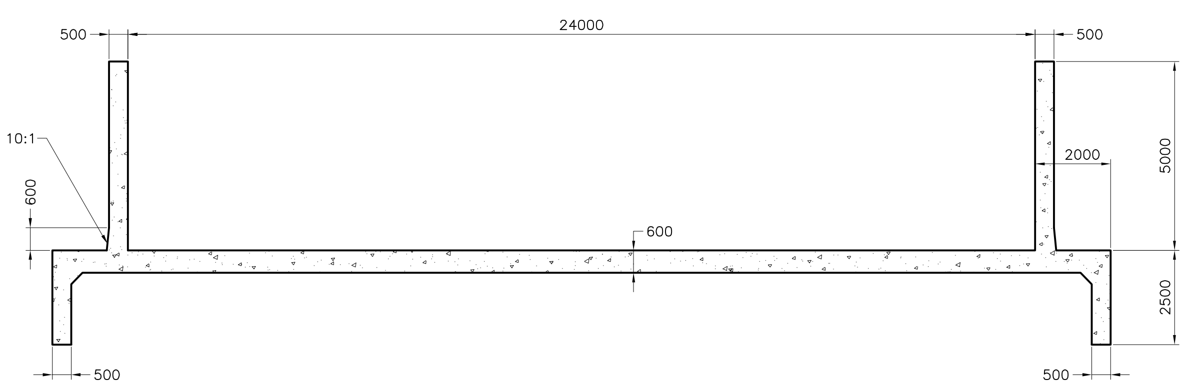
Project No.:	CW2174
CADD File:	2174–N03.dwg
Date:	MAY 2014
Drawing No.:	G6
Sheet No.:	1 of 1

NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



SECTION
SCALE 1:100



B SECTION
SCALE 1:100

SCALE 1:100

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A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) RESERVOIR INLET STRUCTURE

Project No.: CW2174
CADD File: 2174-B06.dwg
Date: MAY 2014
Drawing No.: G7
Sheet No.: 1 of 1

NOTES:

1. TOPOGRAPHIC DATA WAS PRODUCED FROM 1 m LIDAR. THE WESTERN PORTION INCLUDING THE DIVERSION STRUCTURE/CHANNEL AREA WAS DERIVED FROM DATA FROM SEPTEMBER 29, 2013 (POST–FLOOD), WHILE THE EASTERN PORTION INCLUDING THE STORAGE DAM WAS FLOWN APRIL 28, 2013 (PRE–FLOOD).
2. THE ORTHOPHOTO WAS COMPILED FROM AERIAL IMAGERY ACQUIRED BETWEEN JULY 20 AND OCTOBER 14, 2013. IT WAS PURCHASED THROUGH VALTUS IMAGERY SERVICES AND IS AT A RESOLUTION OF 30 cm.
3. THE SPRINGBANK PROJECT IS ILLUSTRATED AT A CONCEPTUAL LEVEL. LAYOUT MODIFICATIONS WILL BE REQUIRED CONSIDERING THE RESULTS OF FUTURE DETAILED INVESTIGATIONS.
4. LOCAL ROAD SYSTEM MODIFICATIONS WILL BE REQUIRED. REQUIREMENTS ARE NOT ILLUSTRATED HEREIN.

SCALE
1:1000
0 10 20m

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A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

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Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFFSTREAM STORAGE PROJECT (SR1) FLOODED AREA DETAIL IN NE¼-24-24-4

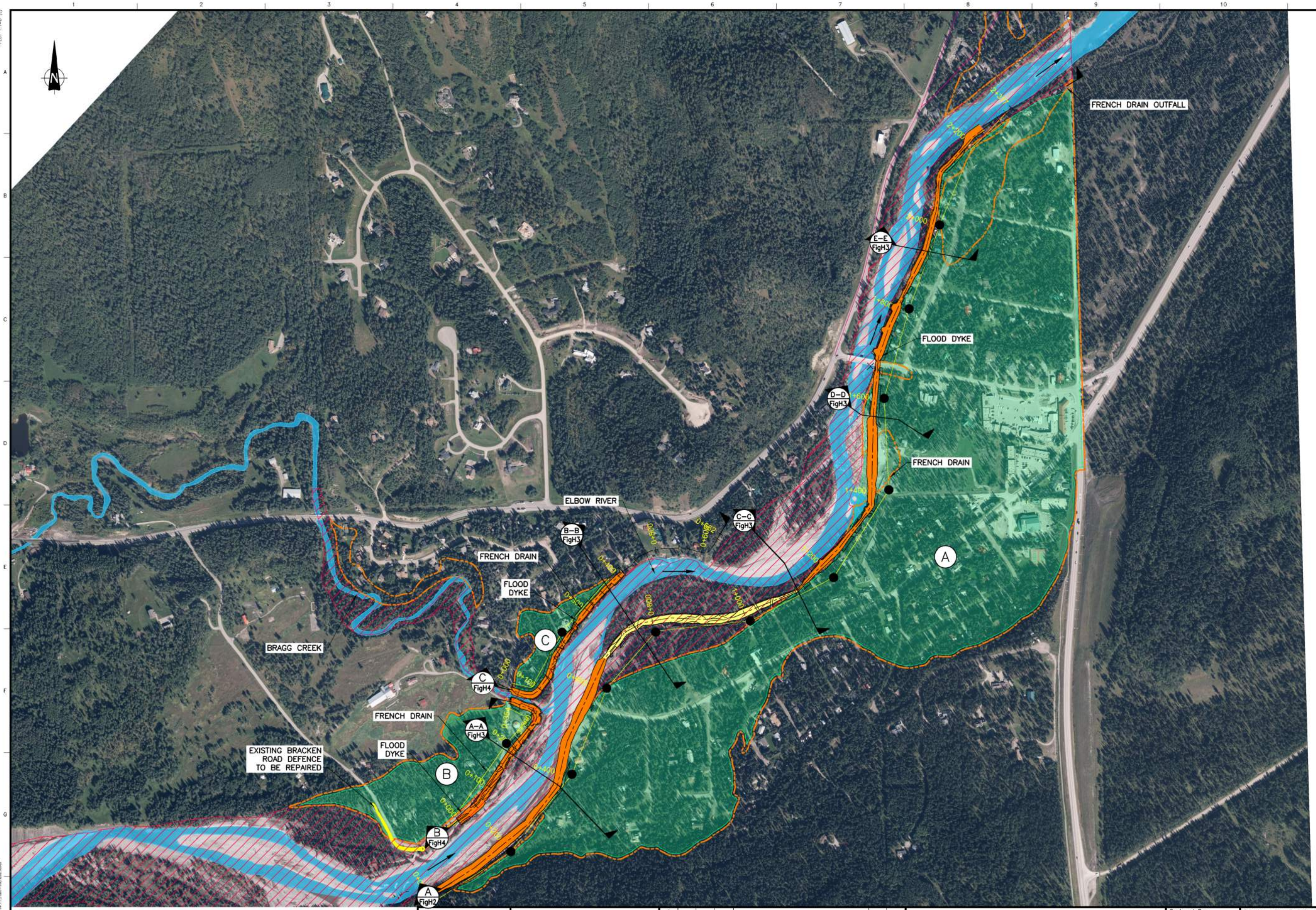
Project No.: CW2174
CADD File: 2174–J03.dwg
Date: MAY 2014
Drawing No.: G8
Sheet No.: 1 of 1

Appendix H

Conceptual Design of Flood Defences at Bragg Creek

Conceptual Cost Estimate
Bragg Creek Flood Defence Dykes & French Drain

Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Larger Riprap sizing	Allow.	Allowance		$200,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$50,000
3	Existing and Temporary Roads	L.S.	1	Lump Sum	$10,000
	SITE PREPARATION				
4	Clearing & Grubbing	ha	3	$2,000.00	$6,251
5	Topsoil & Subsoil Stripping	m³	11315	$5.00	$56,577
6	Care of Water	L.S.	1	Lump Sum	$75,000
	EXCAVATION				
7	Common Excavation	m³	13820	$6.50	$89,831
	FILL PLACEMENT				
8	Low Permeable Fill	m³	56263	$10.00	$562,628
9	Common Fill	m³	9577	$6.00	$57,461
	GRANULAR AND RIPRAP MATERIALS				
10	Granular Drain Rock	tonnes	5456	$35.00	$190,966
11	Riprap Zone 6B	tonnes	14770	$130.00	$1,920,103
12	Riprap Zone 6A	tonnes	202	$110.00	$22,176
13	Gravel Armour	tonnes	9231	$40.00	$369,251
14	Non-Woven Geotextile	m²	15385	$3.00	$46,156
	SITE CONSTRUCTION				
15	600 Dia. Perforated HDPE Pipe	m	2947	$120.00	$353,606
16	CSP Well Supply and Installation	L.S.	12	$15,000.00	$180,000
	LANDSCAPING				
17	Topsoil & Subsoil Placement	m²	15390	$1.50	$23,084
18	Turf Reinforcement Mat	m²	30779	$6.00	$184,674
19	Hydroseeding	m²	30779	$3.50	$107,727
	SUBTOTAL				**$4,505,490**
	CONTINGENCIES @ 25%				**$1,126,373**
	ENGINEERING @ 12%				**$540,659**
	ESTIMATED TOTAL COST				**$6,173,000**



LEGEND:

- CSP WELL
- FLOOD FRINGE
- FLOW DIRECTION
- FLOODWAY
- FLOOD DYKE / RIPRAP PROTECTION
- DYKE / TRM PROTECTION
- WATER BODY
- FLOOD RISK ZONES (SEE SECTION 3.4.1)

NOTES:

1. LIDAR DATA PROVIDED BY THE M.D. OF ROCKYVIEW COUNTY.
2. AIR PHOTO PROVIDED BY ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT, DECEMBER 2013.

SCALE
1:4000
0 20 40 60 80 m

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NOT FOR CONSTRUCTION

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G						
F						
E						
D						
C						
B	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.B.
A	14	03	14	ISSUED FOR CLIENT REVIEW	H.M.	G.B.

amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

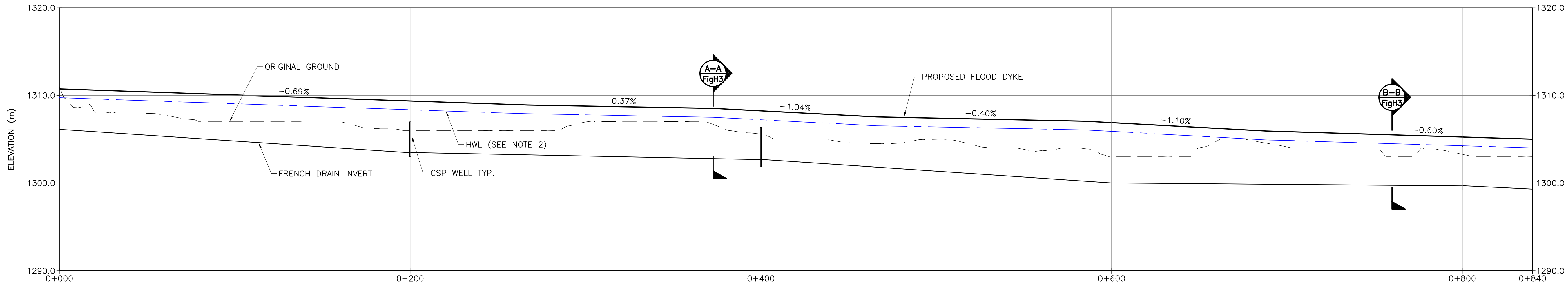
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: BRAGG CREEK FLOOD DEFENCES CONCEPTUAL PLAN

Project No.: CW2174
CADD File: 2174-S02.dwg
Date: MARCH 2014
Drawing No.: FIGURE H1
Sheet No.: 1 of 1

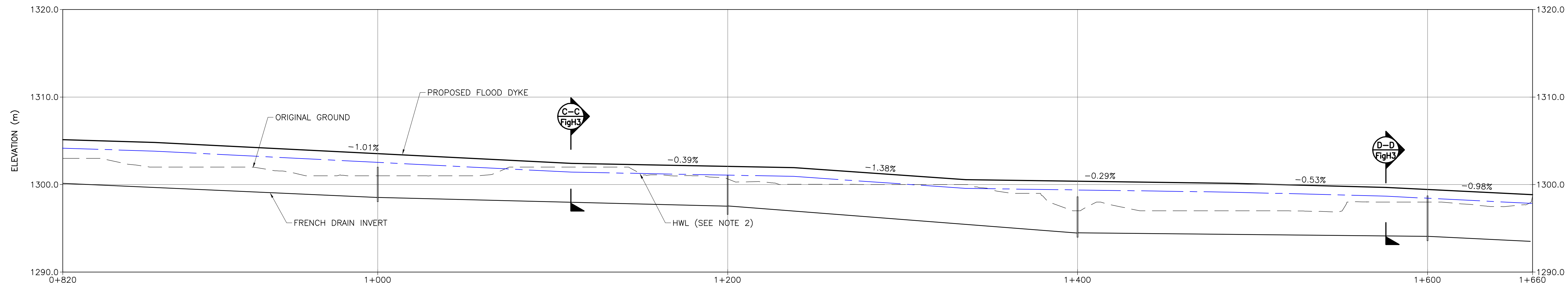
NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100-YEAR) FLOOD EVENT.



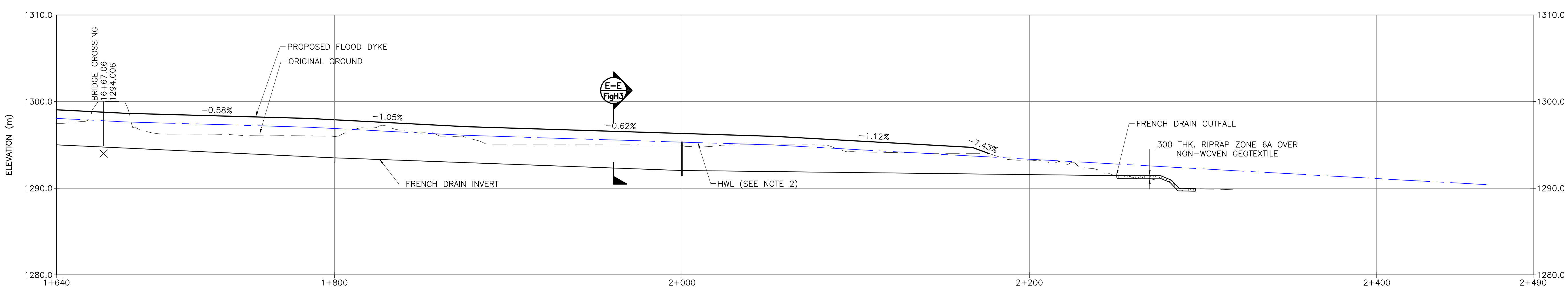
A FigH1 PROFILE – BRAGG CREEK RIGHT SIDE DYKE STA.0+000 – 0+840

SCALE HOR. 1:1250
VER. 1:250



A FigH1 PROFILE – BRAGG CREEK RIGHT SIDE DYKE STA.0+820 – 1+660

SCALE HOR. 1:1250
VER. 1:250



A FigH1 PROFILE – BRAGG CREEK RIGHT SIDE DYKE STA.1+640 – 2+490

SCALE HOR. 1:1250
VER. 1:250

SCALE 1:250 0 1 2 3 4 5 m

SCALE 1:1250 0 10 20 25 m

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REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG.	APPR.
	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.B.
	14	03	14	ISSUED FOR CLIENT REVIEW	H.M.	G.B.

amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

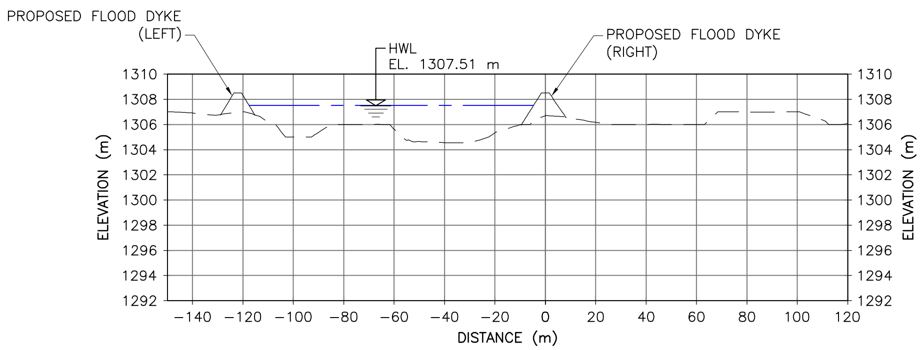
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: BRAGG CREEK FLOOD DEFENCES RIGHT SIDE PROFILE

Project No.: CW2174
CADD File: 2174-S03.dwg
Date: MARCH 2014
Drawing No.: FIGURE H2
Sheet No.: 1 of 1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.
3. ALL SECTIONS LOOKING DOWNSTREAM.



A–A FigH1 SECTION – BRAGG CREEK RIGHT SIDE DYKE
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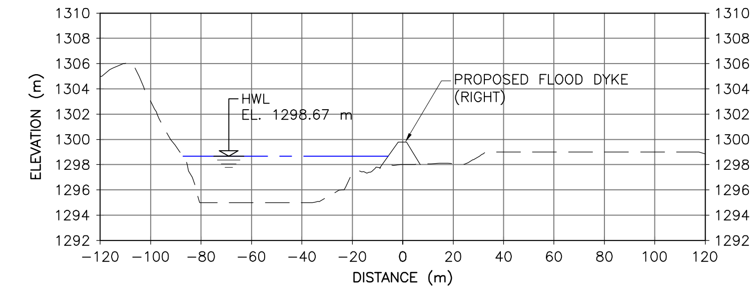
VER. 1:300



D–D FigH1 SECTION – BRAGG CREEK RIGHT SIDE DYKE
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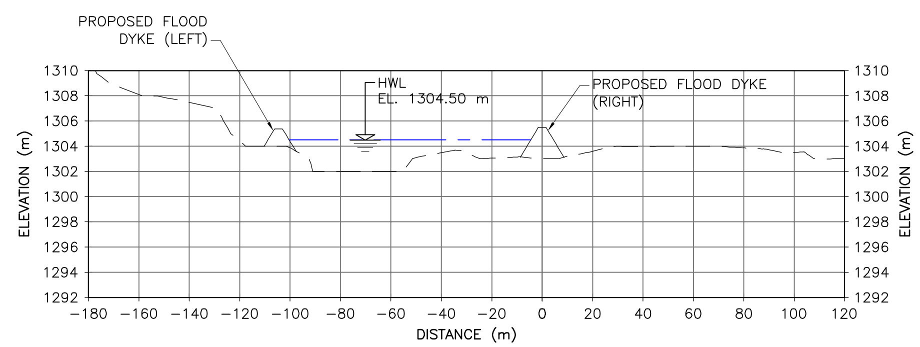

B–B FigH1 SECTION – BRAGG CREEK RIGHT SIDE DYKE
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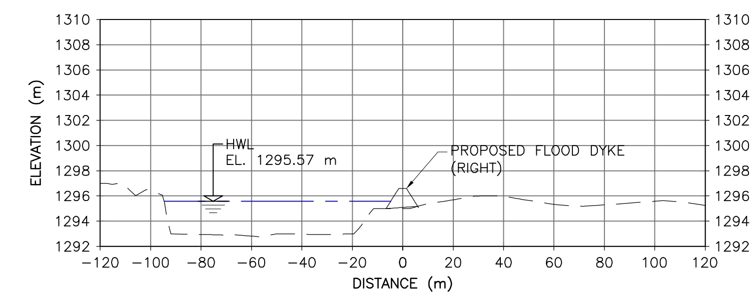
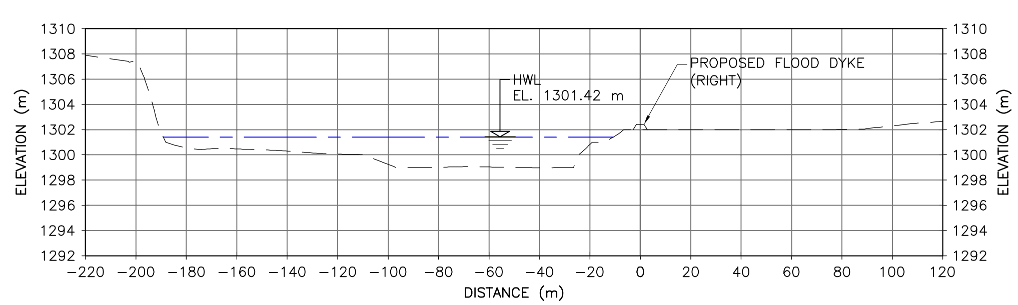
VER. 1:300



E–E FigH1 SECTION – BRAGG CREEK RIGHT SIDE DYKE
SCALE HOR. 1:1500
VER. 1:300



C–C FigH1 SECTION – BRAGG CREEK RIGHT SIDE DYKE
SCALE HOR. 1:1500
VER. 1:300

SCALE 1:300 0 2 4 6 m
SCALE 1:1500 0 10 20 30 m

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B	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.B.
A	14	03	14	ISSUED FOR CLIENT REVIEW	H.M.	G.B.

amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

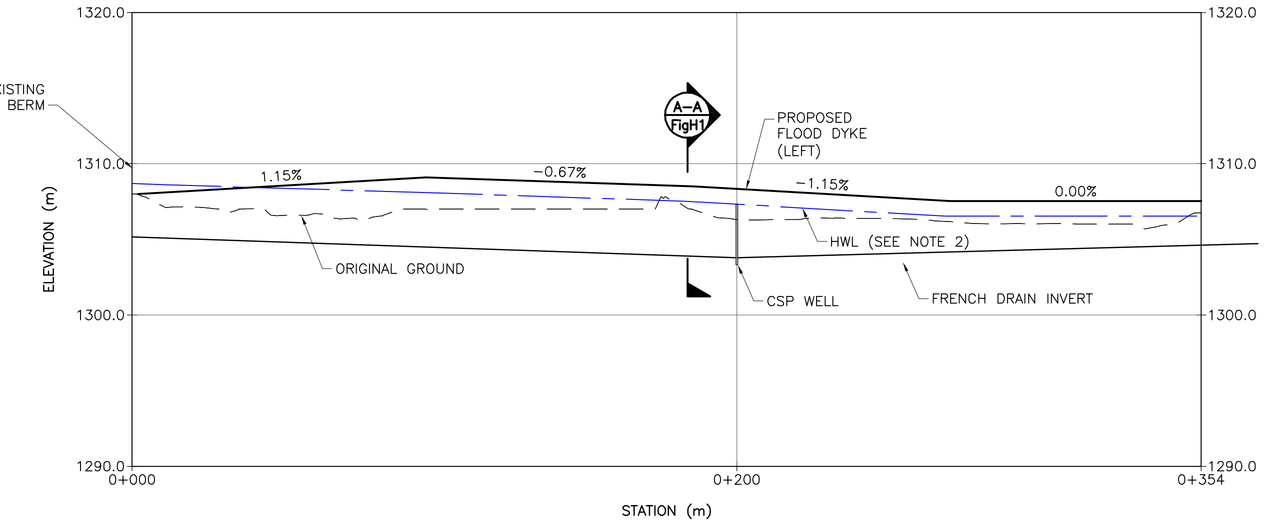
Project: **FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS**

Title: **BRAGG CREEK FLOOD DEFENCE BERM SECTIONS**

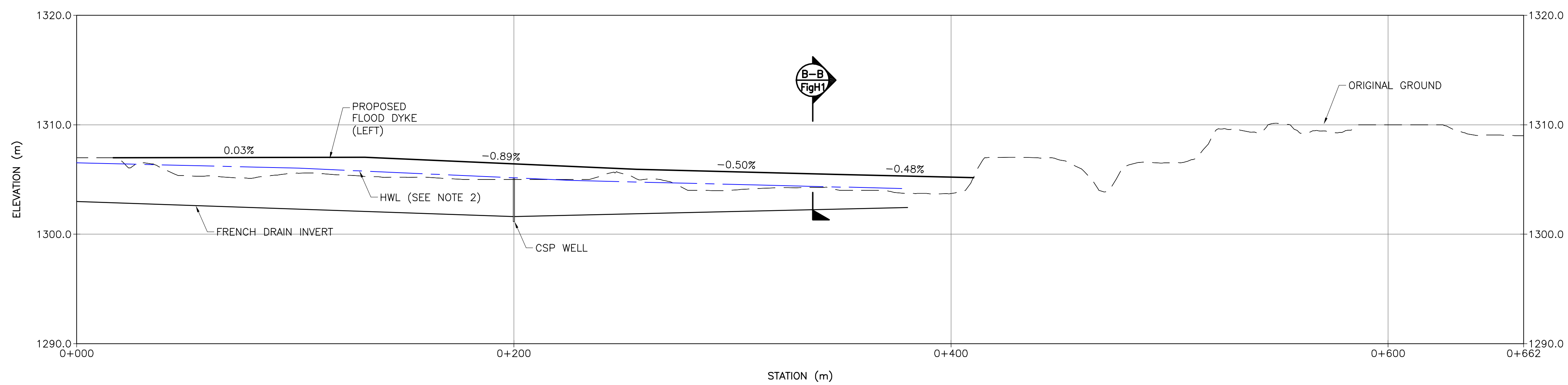
Project No.: CW2174
CADD File: 2174–S03.dwg
Date: MARCH 2014
Drawing No.: FIGURE H3
Sheet No.: 1 of 1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.



B FigH1 PROFILE – BRAGG CREEK LEFT SIDE DYKE BRACKEN ROAD
SCALE HOR. 1:1250
VER. 1:250



C FigH1 PROFILE – BRAGG CREEK LEFT SIDE DYKE
SCALE HOR. 1:1250
VER. 1:250

SCALE 1:250 0 1 2 3 4 5 m
SCALE 1:1250 0 10 20 25 m

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amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: H.M.
Drawn By: M.H.
Checked By: G.B.
Approved By: G.G.
Scale: AS SHOWN

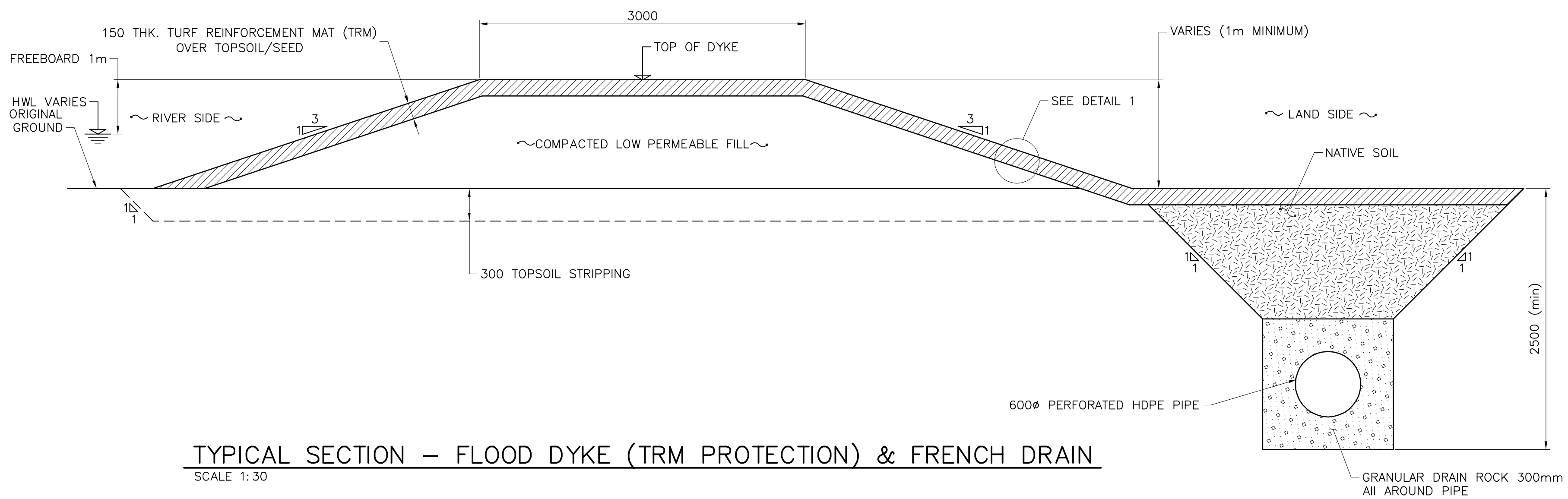
Project: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

Title: BRAGG CREEK FLOOD DEFENCES LEFT SIDE PROFILES

Project No.: CW2174
CADD File: 2174–S03.dwg
Date: MARCH 2014
Drawing No.: FIGURE H4
Sheet No.: 1 of 1

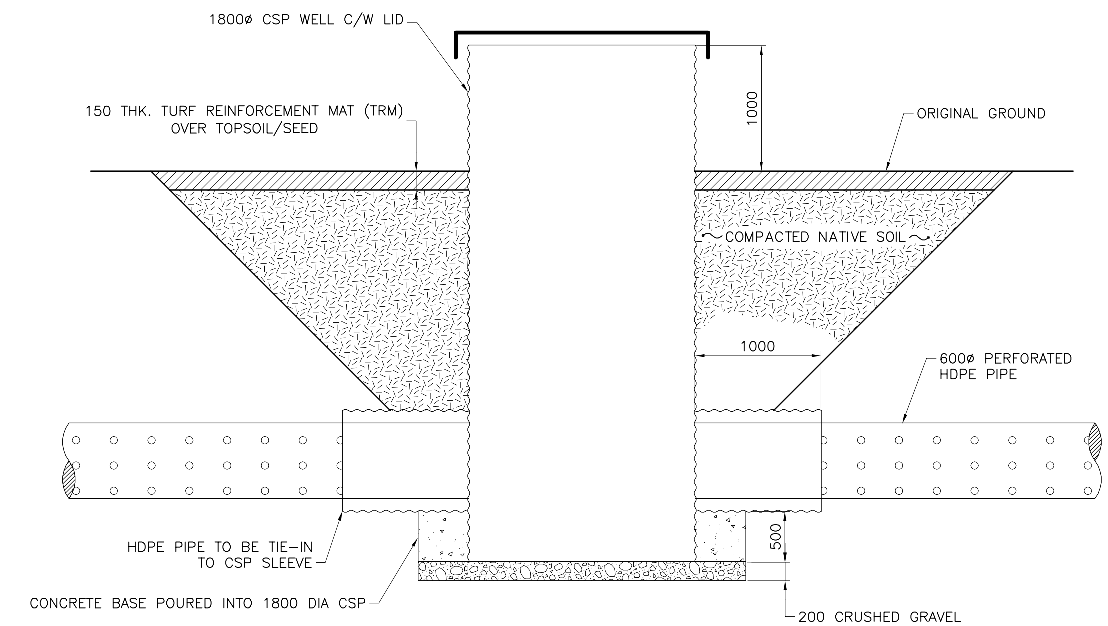
NOTES:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. HIGH WATER LEVEL (HWL) IS BASED ON 1% EXCEEDANCE (100–YEAR) FLOOD EVENT.



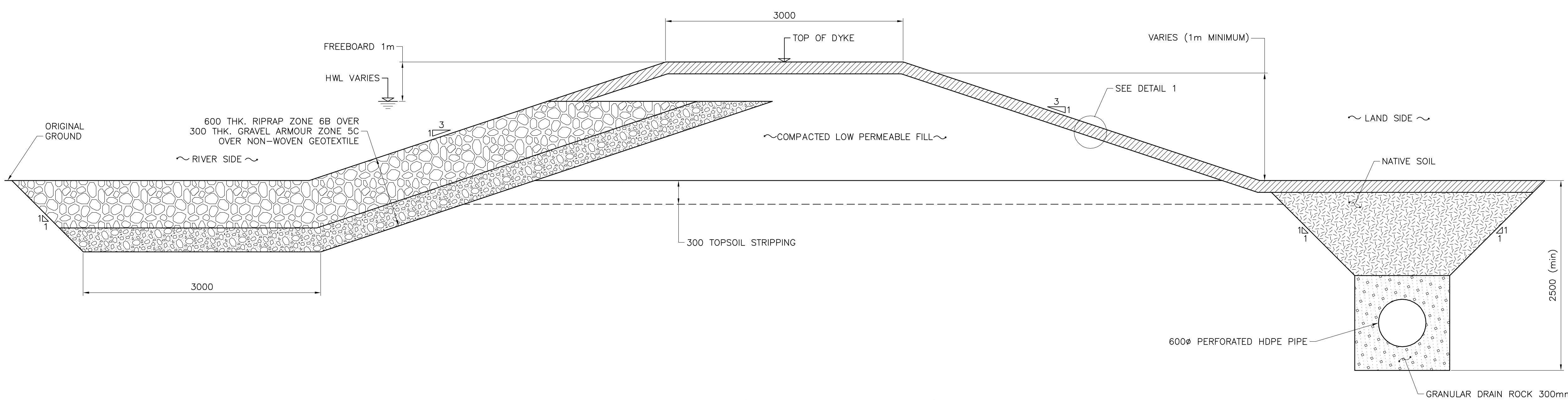
TYPICAL SECTION – FLOOD DYKE (TRM PROTECTION) & FRENCH DRAIN

SCALE 1:30



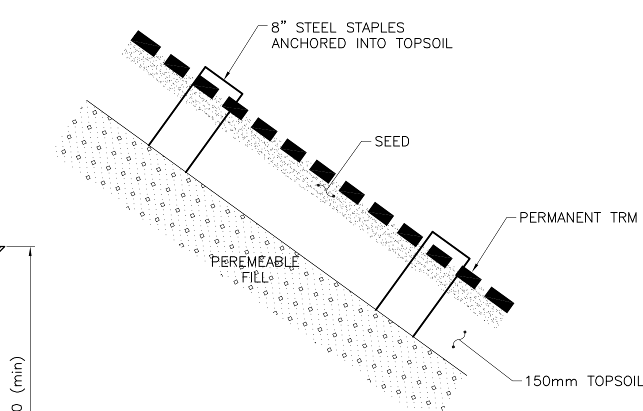
TYPICAL SECTION – CSP WELL

SCALE 1:30



TYPICAL SECTION – FLOOD DYKE (RIPRAP PROTECTION) & FRENCH DRAIN

SCALE 1:30



1 DETAIL

SCALE NTS

SCALE 1:30 0 200 400 600 mm

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B	13	05	14	ISSUED FOR FINAL REPORT	H.M.	G.B.
A	14	03	14	ISSUED FOR CLIENT REVIEW	H.M.	G.B.

amec

Client: SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	H.M.
Drawn By:	M.H.
Checked By:	G.B.
Approved By:	G.G.
Scale:	AS SHOWN

Project: **FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS**

Title: **BRAGG CREEK FLOOD DEFENCES TYPICALS**

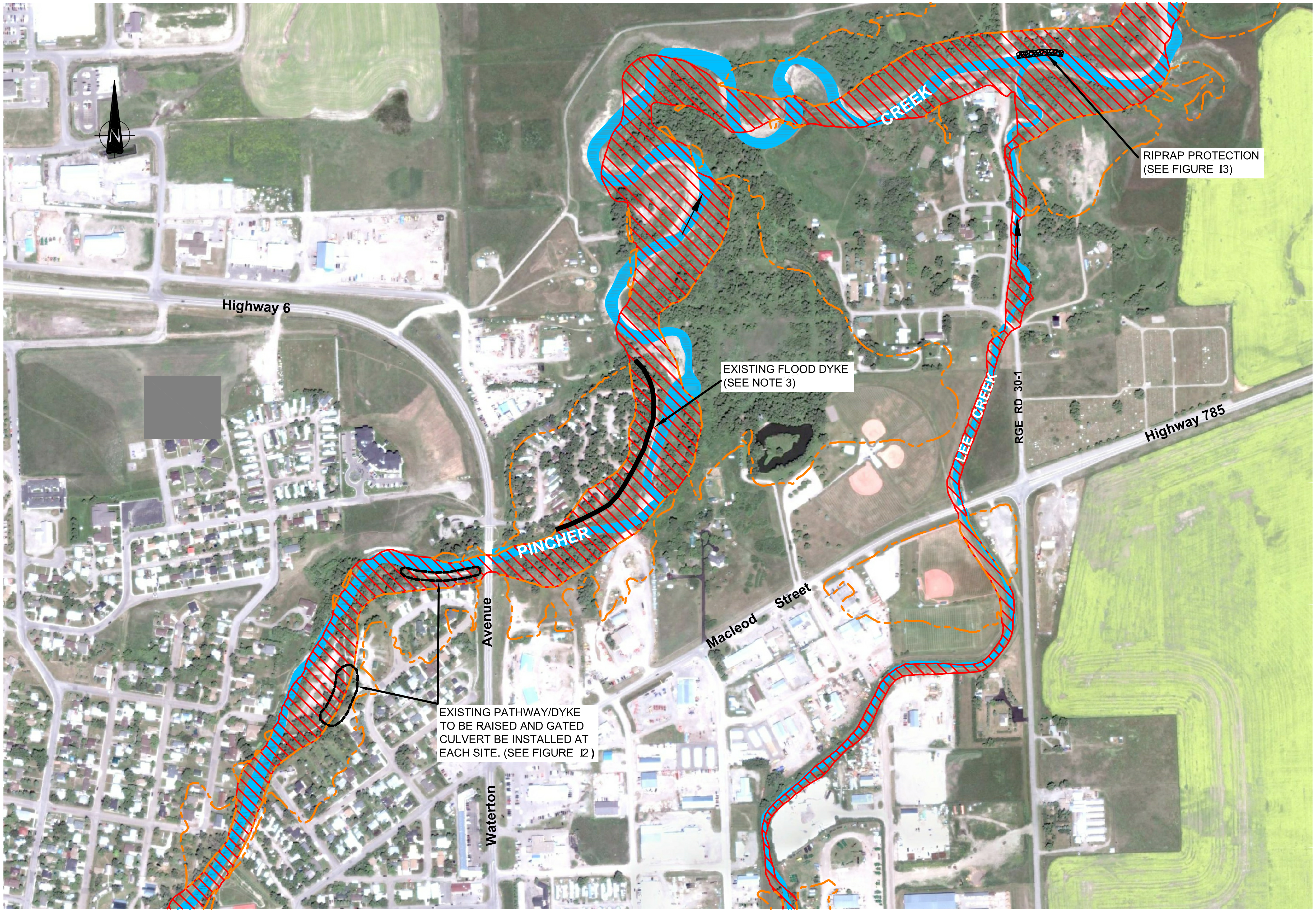
Project No.:	CW2174
CADD File:	2174–J00.dwg
Date:	MARCH 2014
Drawing No.:	FIGURE H5
Sheet No.:	1 of 1

Appendix I

Conceptual Design of Mitigation Measures at Pincher Creek

Conceptual Cost Estimate
Pincher Creek Flood Defence Pathway/Dyke & Riprap Protection

Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Bigger Size Riprap	Allow.	Allowance		$25,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$35,000
3	Existing and Temporary Roads	L.S.	1	Lump Sum	$10,000
	SITE PREPARATION				
4	Clearing & Grubbing	ha	0	$2,000.00	$204
5	Topsoil & Subsoil Stripping	m³	306	$5.00	$1,530
6	Care of Water	L.S.	1	Lump Sum	$15,000
	EXCAVATION				
7	Common Excavation	m³	100	$6.50	$650
	FILL PLACEMENT				
8	Low Permeable Fill	m³	2000	$10.00	$20,000
	GRANULAR AND RIPRAP MATERIALS				
9	Riprap Zone 6B	tonnes	899	$130.00	$116,896
10	Riprap Zone 6A	tonnes	16	$110.00	$1,760
11	Gravel Armour Zone 5C	tonnes	540	$40.00	$21,600
12	Non-Woven Geotextile	m²	963	$3.00	$2,889
	SITE CONSTRUCTION				
13	Ashphalt Concrete Pavement	tonnes	60	$250.00	$15,000
14	Gravel Base Course Zone 4A	tonnes	128	$15.00	$1,920
15	Tideflex Check Valve	ea	2	$5,000.00	$10,000
16	600 Dia. CSP Culvert Supply and Installation	m	20	$200.00	$4,000
	LANDSCAPING				
17	Topsoil & Subsoil Placement	m²	1020	$1.50	$1,530
18	Turf Reinforcement Mat	m²	1020	$6.00	$6,120
19	Hydroseeding	m²	1020	$3.50	$3,570
	SUBTOTAL				**$292,669**
	CONTINGENCIES @ 25%				**$73,167**
	ENGINEERING @ 12%				**$35,120**
	ESTIMATED TOTAL COST				**$401,000**



LEGEND:

- WATER BODY
- FLOW DIRECTION
- RIPRAP PROTECTION
- FLOODWAY
- FLOOD FRINGE
- EXISTING FLOOD DYKE

NOTES:

1. LIDAR DATA PROVIDED BY AIRBORNE IMAGING, SEPTEMBER 10, 2006
2. AIR PHOTO PROVIDED BY GOOGLE EARTH PRO, JULY 2013.
3. EXISTING FLOOD DYKE SHALL BE SURVEYED TO CHECK THE TOP ELEVATION OF DYKE IS HIGHER THAN HIGH WATER LEVEL, PER PINCHER CREEK FLOOD RISK MAPPING STUDY, (PHILIPS 1993).

Scale:
1:3000

0 37.5 75 Meters

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SOUTHERN ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: MG
Drawn By: BJ
Checked By: GB
Approved By : GG
Scale: AS SHOWN

PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: PINCHER CREEK FLOOD DEFENCES CONCEPTUAL PLAN

Project No.: CW2174
CADD File: CW2174-PC01.dwg
Date: MAY 2014
Drawing No.: FIGURE I1
Sheet No.: 1 of 3

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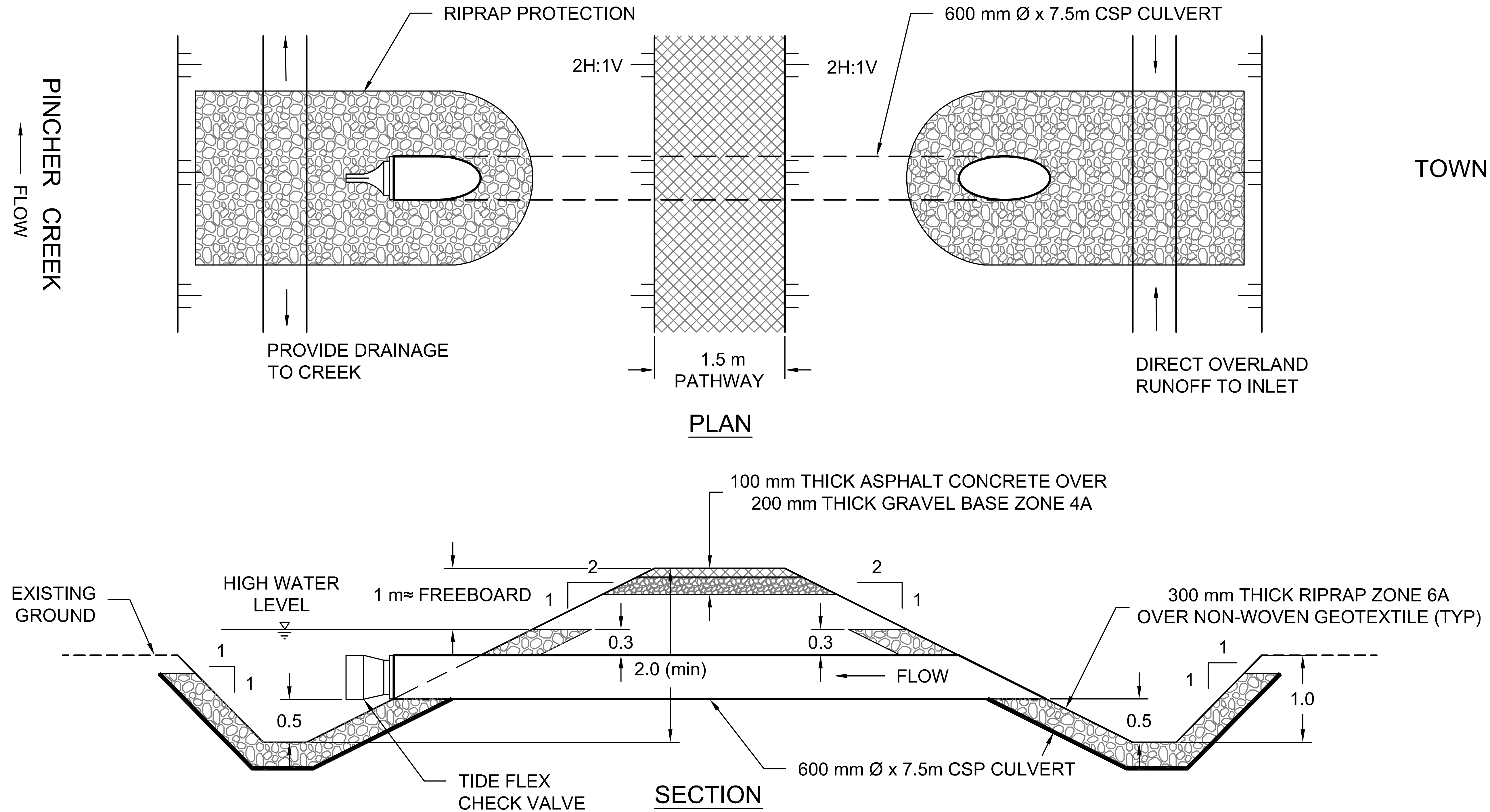

TYPICAL DETAILS - GATED CULVERT

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Scale:	AS SHOWN

PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: PINCHER CREEK FLOOD DEFENCES TYPICAL DETAILS

Project No.:	CW2174
CADD File:	CW2174-PC01.dwg
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Drawing No.:	FIGURE I2
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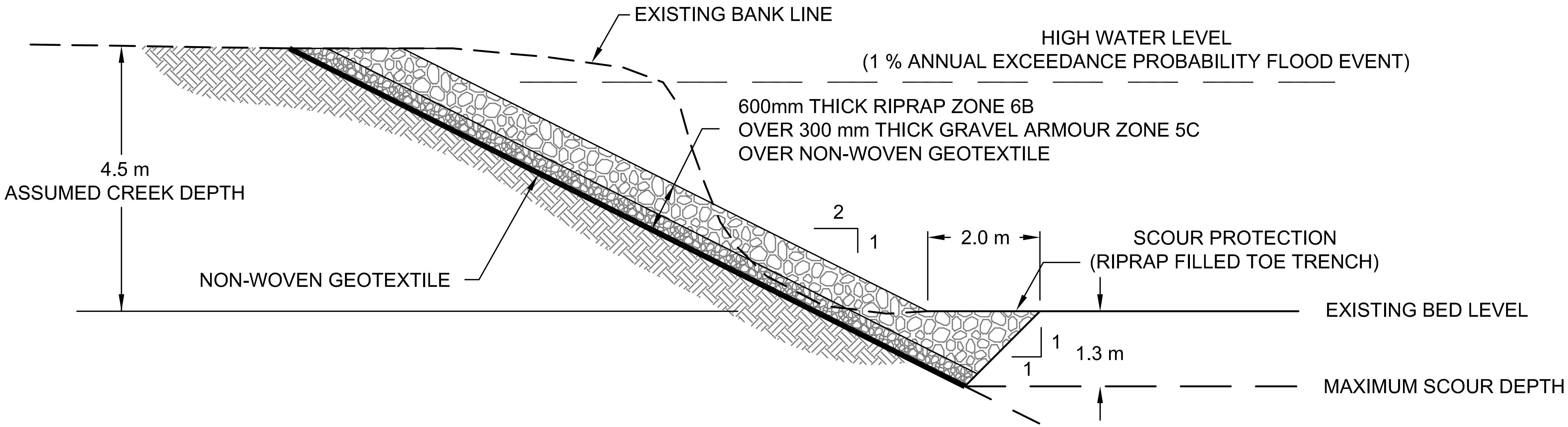

A
Fig1

CROSS SECTION OF TYPICAL RIPRAP REVETMENT

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PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: PINCHER CREEK FLOOD DEFENCES TYPICAL DETAILS

Project No.: CW2174
CADD File: CW2174-PC01.dwg
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Drawing No.: FIGURE I3
Sheet No.: 3 of 3

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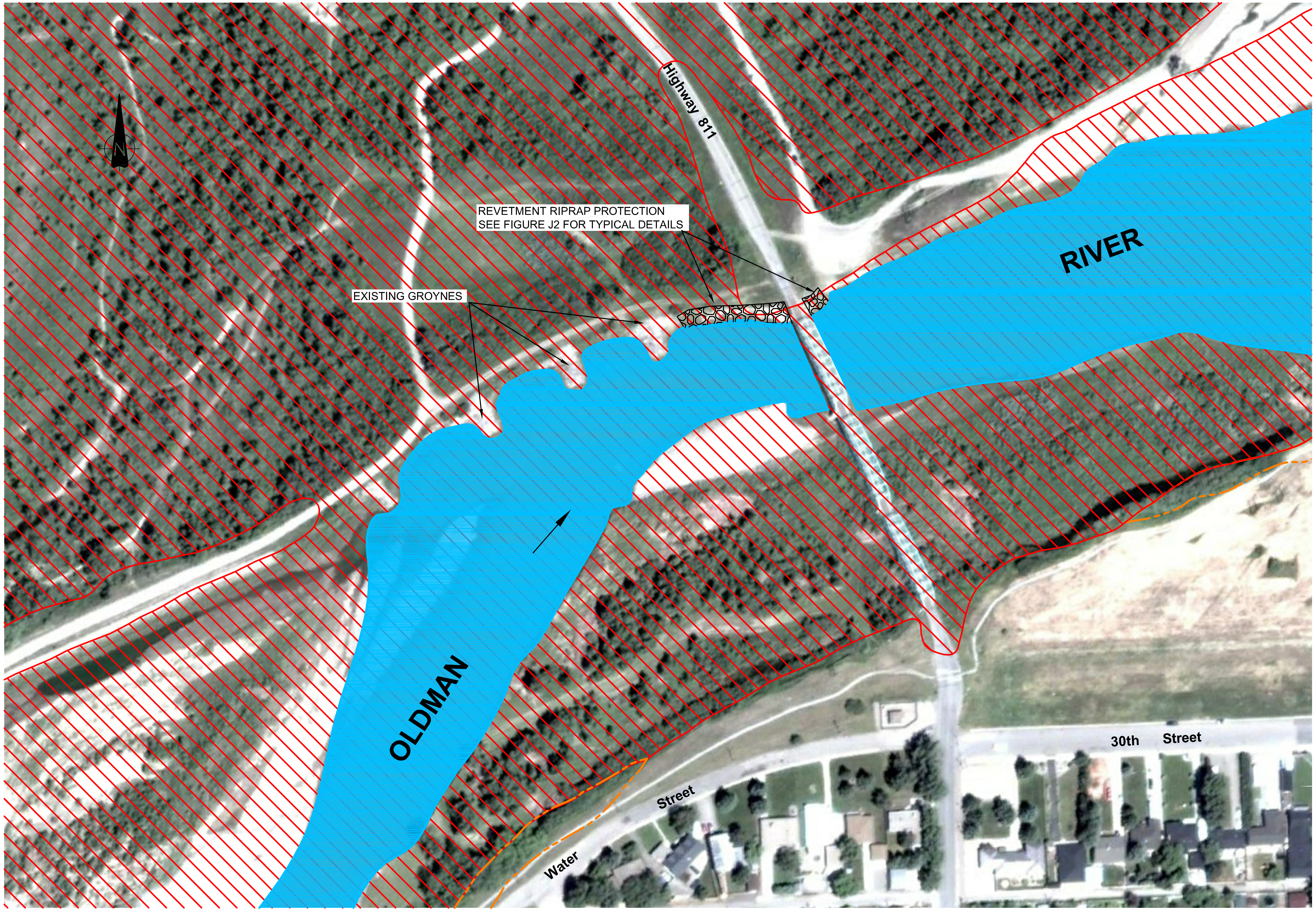
T:\Drafting\Brent\CW2174 – Flood Mitigation Study\FINAL REPORT\CW2174 – PC01.dwg – PchrCkFIG3 – May. 29, 2014 10:08am – brent.johnson

Appendix J

Conceptual Design of Mitigation Measures at Fort MacLeod

Conceptual Cost Estimate
Fort Mcleod Flood Defence

Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Bigger Size Riprap	Allow.	Allowance		$35,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$25,000
	SITE PREPARATION				
3	Care of Water	L.S.	1	Lump Sum	$15,000
	GRANULAR AND RIPRAP MATERIALS				
4	Riprap Zone 6C	tonnes	1414.40	$150.00	$212,160
5	Gravel Armour Zone 5C	tonnes	404.00	$40.00	$16,160
6	Non-Woven Geotextile	m²	878.00	$3.00	$2,634
	SUBTOTAL				**$305,954**
	CONTINGENCIES @ 25%				**$76,489**
	ENGINEERING @ 12%				**$36,714**
	ESTIMATED TOTAL COST				**$419,000**



LEGEND:

- WATER BODY
- FLOW DIRECTION
- RIPRAP PROTECTION
- FLOODWAY
- FLOOD FRINGE

NOTES:

1. PROPOSED FLOOD DEFENCE TO CONTINUATION OF THE BRIDGE ABUTMENT CONSIDERED IN CONJUNCTION WITH AN OVERALL MORPHOLOGY OF RIVER ENGINEERING. REVIEW OF RIVER TRAINING AT THIS BRIDGE CROSSING SHALL BE STUDIED FOR FURTHER FLOOD PROTECTION.

Scale:
1:1000

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Checked By: GB
Approved By : GG
Scale: AS SHOWN

PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: FORT MACLEOD FLOOD DEFENCES CONCEPTUAL PLAN

Project No.: CW2174
CADD File: CW2174-FM01.dwg
Date: MAY 2014
Drawing No.: FIGURE J1
Sheet No.: 1 of 2

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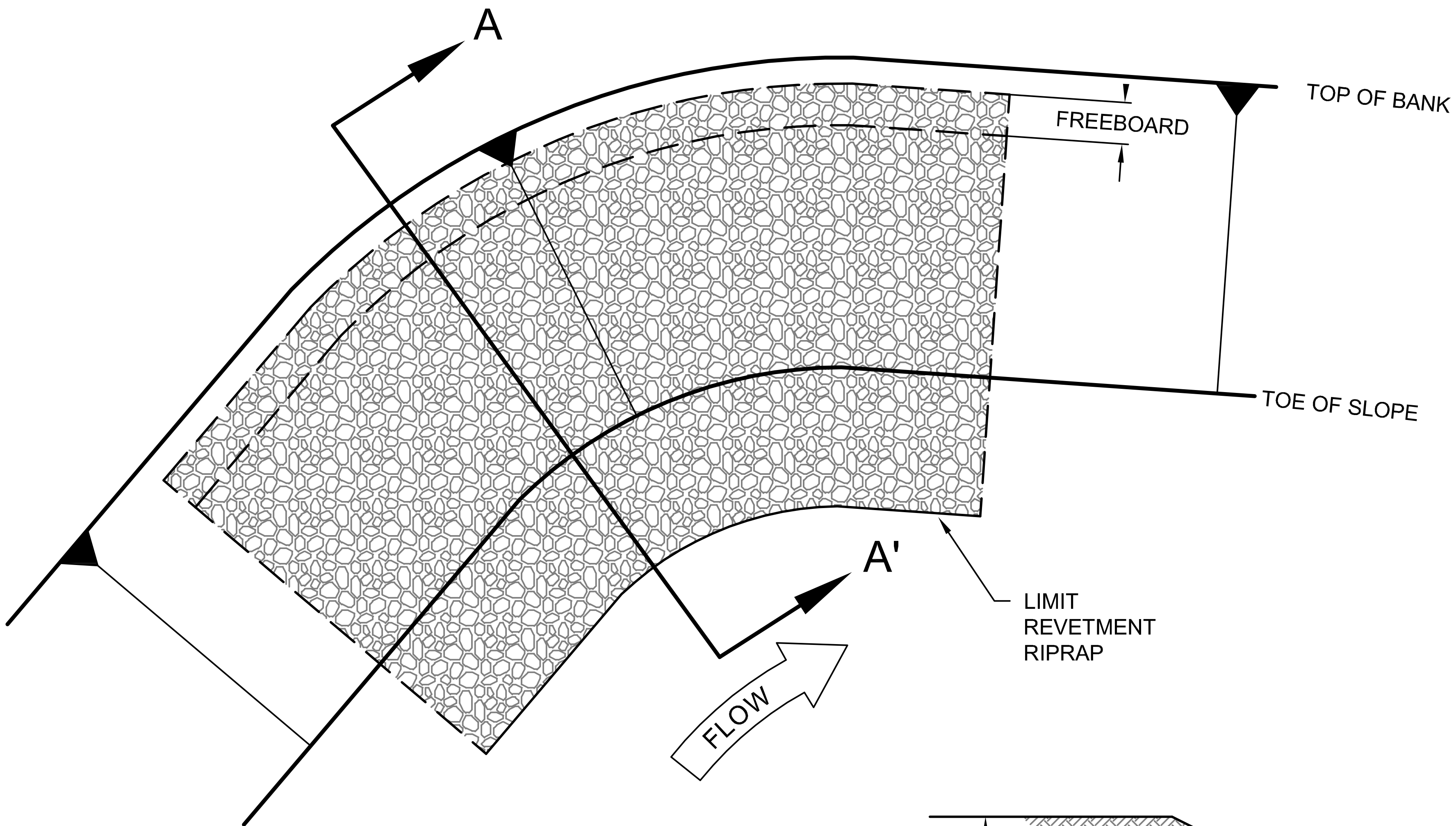
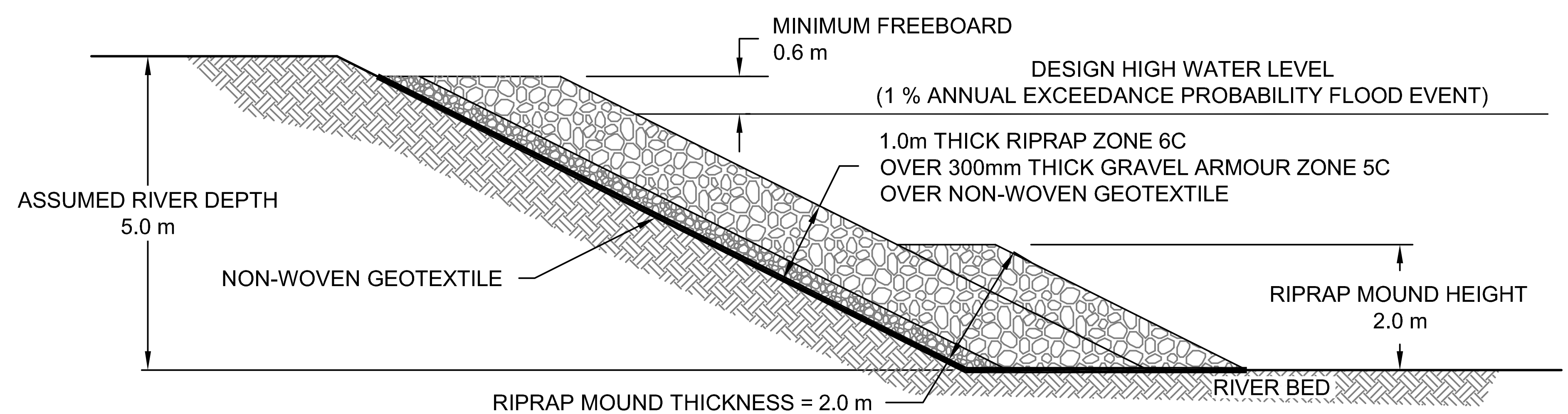


PLAN VIEW

N.T.S.



SECTION A-A' - REVETMENT RIPRAP

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Approved By: GG
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PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: FORT MACLEOD FLOOD DEFENCES TYPICAL DETAILS

Project No.: CW2174
CADD File: CW2174-FM01.dwg
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Drawing No.: FIGURE J2
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Appendix K

Conceptual Design of Mitigation Measures at Cardston

Conceptual Cost Estimate
Cardston Flood Defence

Item No.	Item Description	Unit	Quantity	Unit Price	Extension		
	ALLOWANCES						
1	Bigger Size Riprap	Allow.	Allowance		$50,000		
	TEMPORARY FACILITIES						
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$25,000		
	SITE PREPARATION						
3	Care of Water	L.S.	1	Lump Sum	$15,000		
	GRANULAR AND RIPRAP MATERIALS						
4	Riprap Zone 6C	tonnes	2672.00	$150.00	$400,800	1670	m3
5	Gravel Armour Zone 5C	tonnes	746.00	$40.00	$29,840	373	m3
6	Non-Woven Geotextile	m²	1863.00	$3.00	$5,589		
	SUBTOTAL				**$526,229**		
	CONTINGENCIES @ 25%				**$131,557**		
	ENGINEERING @ 12%				**$63,147**		
	ESTIMATED TOTAL COST				**$721,000**		

LEGEND:

- WATER BODY
- FLOW DIRECTION
- RIPRAP PROTECTION

Scale:
1:1000
0 12.5 25 Meters

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Checked By: GB
Approved By: GG
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PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: CARDSTON FLOOD DEFENCES CONCEPTUAL PLAN

Project No.: CW2174
CADD File: CW2174-CA01.dwg
Date: MAY 2014
Drawing No.: FIGURE K1
Sheet No.: 1 of 2

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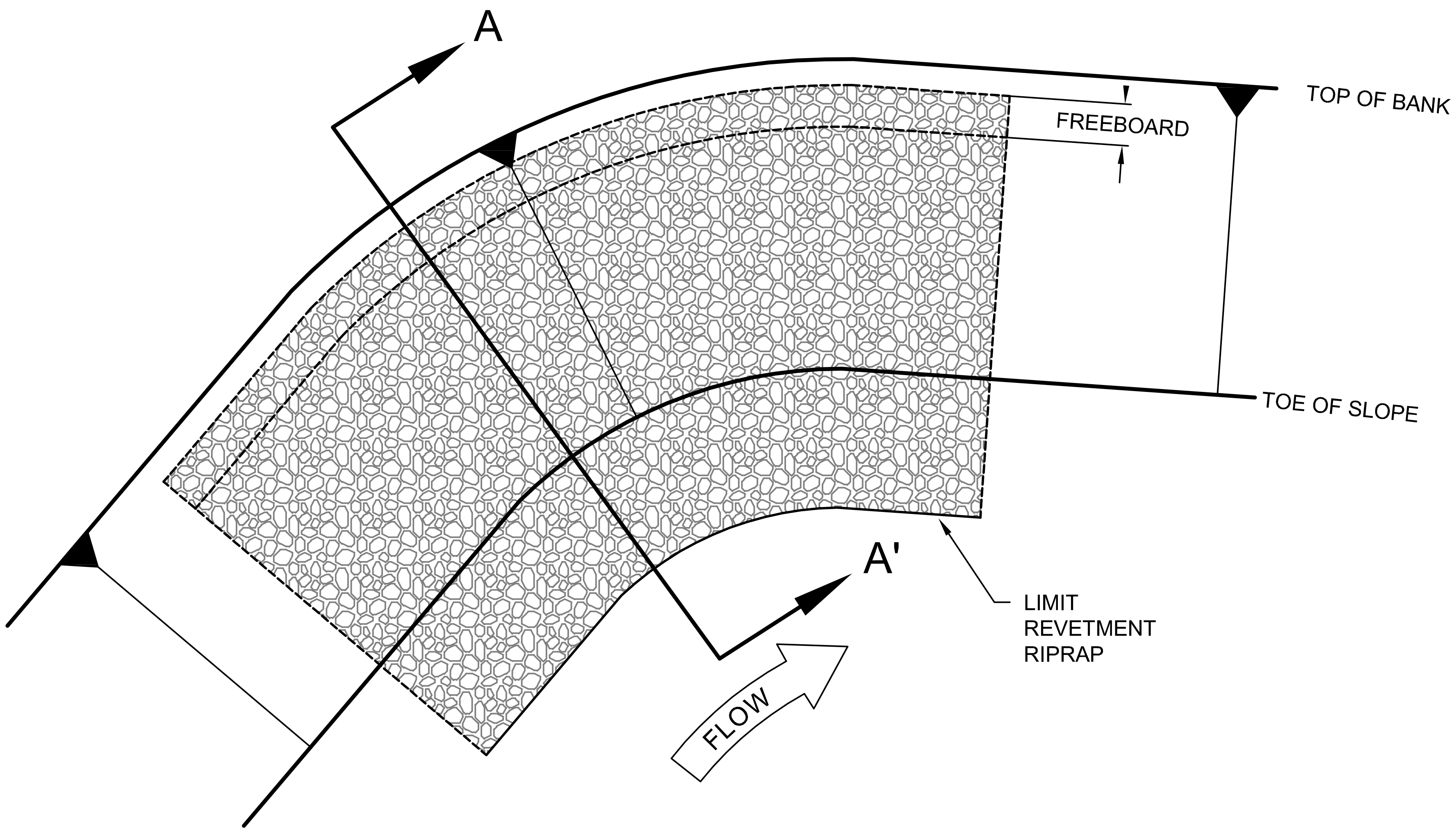
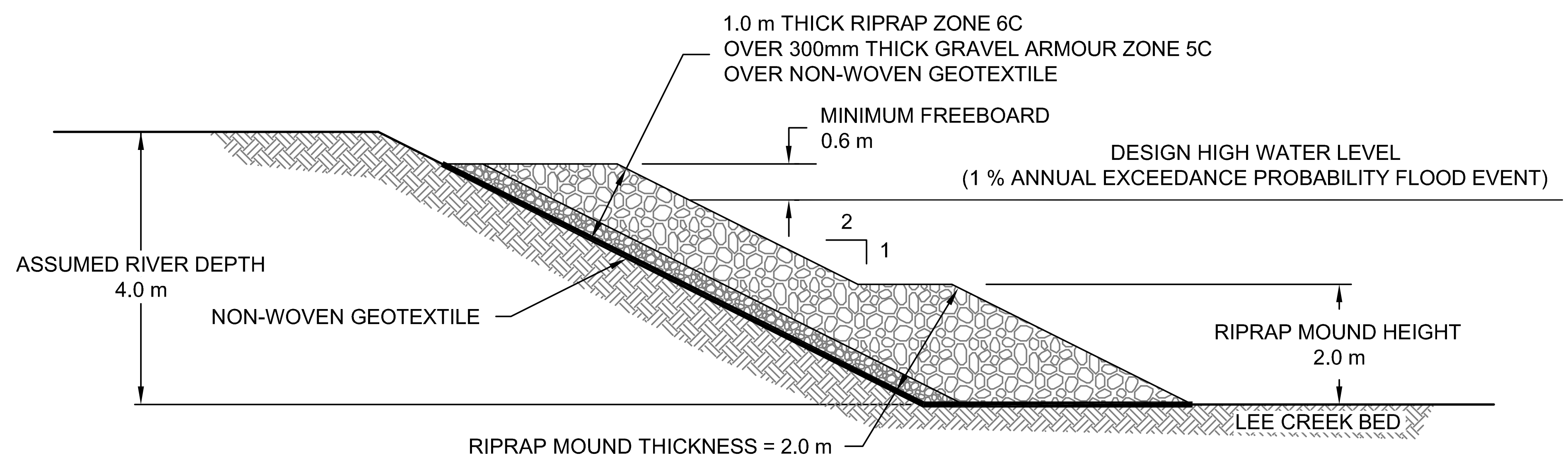


PLAN VIEW

N.T.S.



SECTION A-A' - REVETMENT RIPRAP

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PROJECT: FLOOD MITIGATION FEASIBILITY STUDY FOR BOW, ELBOW AND OLDMAN RIVER BASINS

TITLE: CARDSTON FLOOD DEFENCES RIPRAP PROTECTION TYPICALS

Project No.: CW2174
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Drawing No.: FIGURE K2
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