



REPORT

Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: McLean Creek Flood Storage

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group
February 18, 2015



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Dear Ms. Ziober:

**BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY:
MCLEAN CREEK FLOOD STORAGE**

Enclosed please find the draft final report for the aforementioned assignment. The report describes the benefit/cost analysis undertaken for the McLean Creek Flood Storage Mitigation Project in relation to ameliorating the City of Calgary flood damages. This analysis culminates with a comparison of the benefit/cost ratios for the three major mitigation projects under consideration of which the McLean Creek Flood Storage Project ranks second.

Should you have any questions or require additional information please do not hesitate to contact the undersigned.

Yours truly,

IBI GROUP

Stephen Shawcross
Director

SS/mp

Augusto Ribeiro, P.Eng.

cc: Cathy Maniego, Government of Alberta, Environment and Sustainable Resource Development
Andrew Wilson, Government of Alberta, Environment and Sustainable Resource Development

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Appendix A – City of Calgary Flood Damage Estimates

Appendix B – 2013 Southern Alberta Disaster Recovery Program

Executive Summary

Key Metrics

Project Costs

Item	Cost
Project Construction	\$239,581,000
Infrastructure Relocation	\$45,000,000
Environmental Impact Studies	\$4,000,000
Total 1:100 Year Protection	\$288,581,000
Additional Cost for 1:200 Year Protection	\$55,000,000
Total 1:200 Year Protection	\$343,581,000
Annual Operation and Maintenance	\$1,800,000

Benefit/Cost Analysis

Indicator	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
PV Benefits (average annual damages)	\$476,899,000	\$639,943,000	\$336,847,000	\$408,901,000
PV Costs (development & operating total cost)	\$332,708,000	\$387,699,000	\$332,708,000	\$387,699,000
Benefit/Cost Ratio	1.43	1.65	1.01	1.05
Net Present Value	\$144,191,000	\$252,244,000	\$4,139,000	\$21,202,000
Average Annual Damages	\$19,461,291	\$26,114,777	\$13,746,068	\$16,686,439

Benefit/Cost Comparison

Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

1 Introduction

1.1 Background

The flood of 2013 was a devastating event for Southern Alberta and the City of Calgary. The flood event had the largest economic impact of any extreme weather event in Canada to date. As part of the response to protect communities from future flood damage, the Province of Alberta commissioned a study through the Flood Mitigation Advisory Panel to provide engineering assessments and practical solutions on possible flood mitigation measures.

In October of 2013, AMEC Environment & Infrastructure (AMEC) was contracted to provide a flood mitigation feasibility study for the Bow River, Elbow River and Oldman River basins.

A number of mitigation schemes were considered for the Elbow River upstream of the City of Calgary, including an off-stream flood storage project at McLean Creek.

As part of the subsequent Provincial Flood Damage Assessment Study, IBI Group was commissioned by the Government of Alberta ESRD Operations, Resilience and Mitigation Branch to undertake a benefit/cost analysis of the McLean Creek Flood Storage project

1.2 Purpose

The purpose of the benefit/cost analysis is to provide a comparison of project benefits, in terms of damages averted, to project costs including capital and operating costs, to determine if the project under consideration is economically viable.

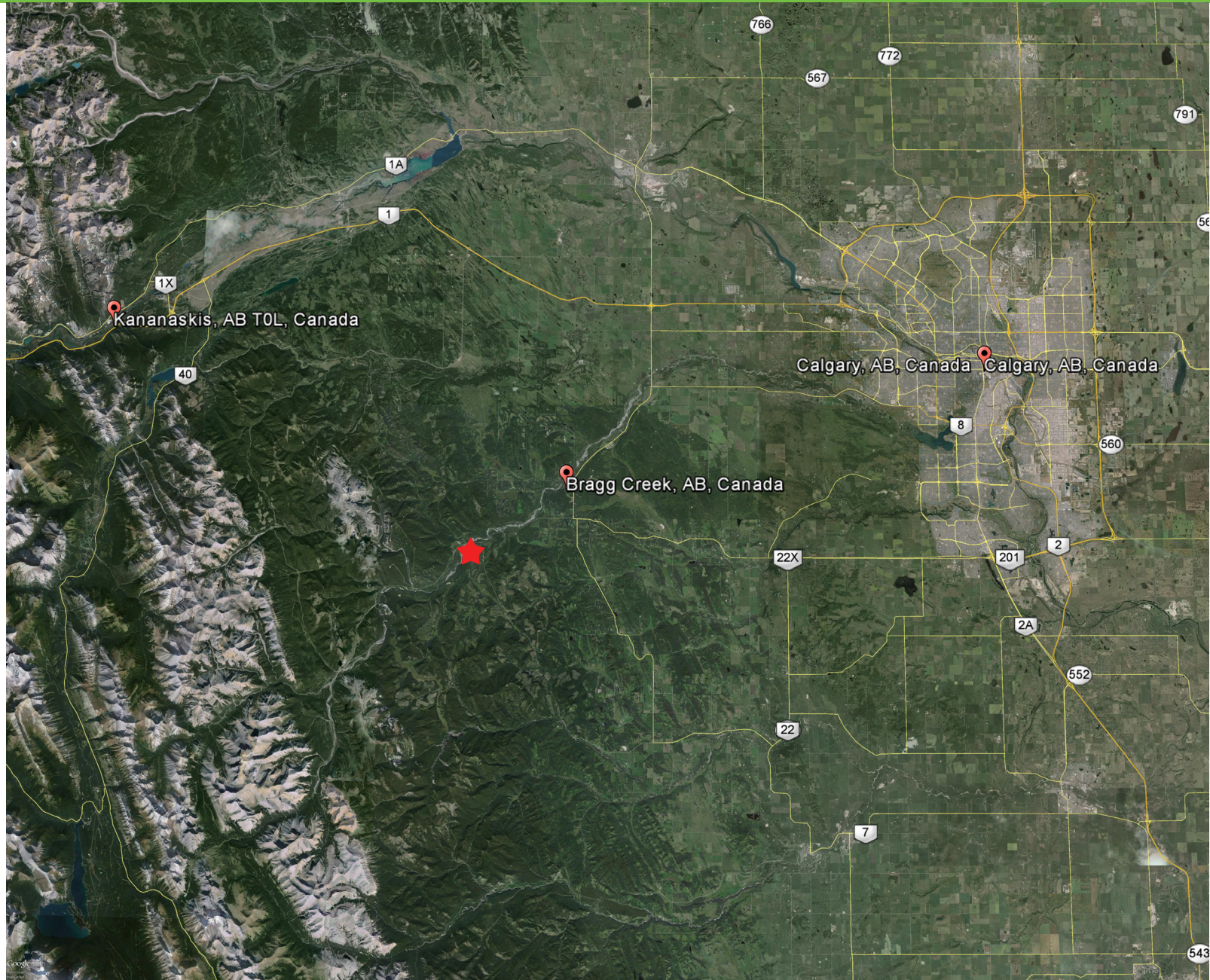
1.3 Scope

For the purposes of this study, benefits are restricted to economic benefits accruing within the study area, which is defined as the flood risk area within the City of Calgary boundaries. The study utilizes current damage estimates based on updated stage-damage curves and the Provincial Rapid Flood Damage Assessment Model. Project costs are based on the estimates prepared as part of the McLean Creek Flood Storage project submitted to the Southern Alberta Flood Recovery Task Force and dated June 2014.

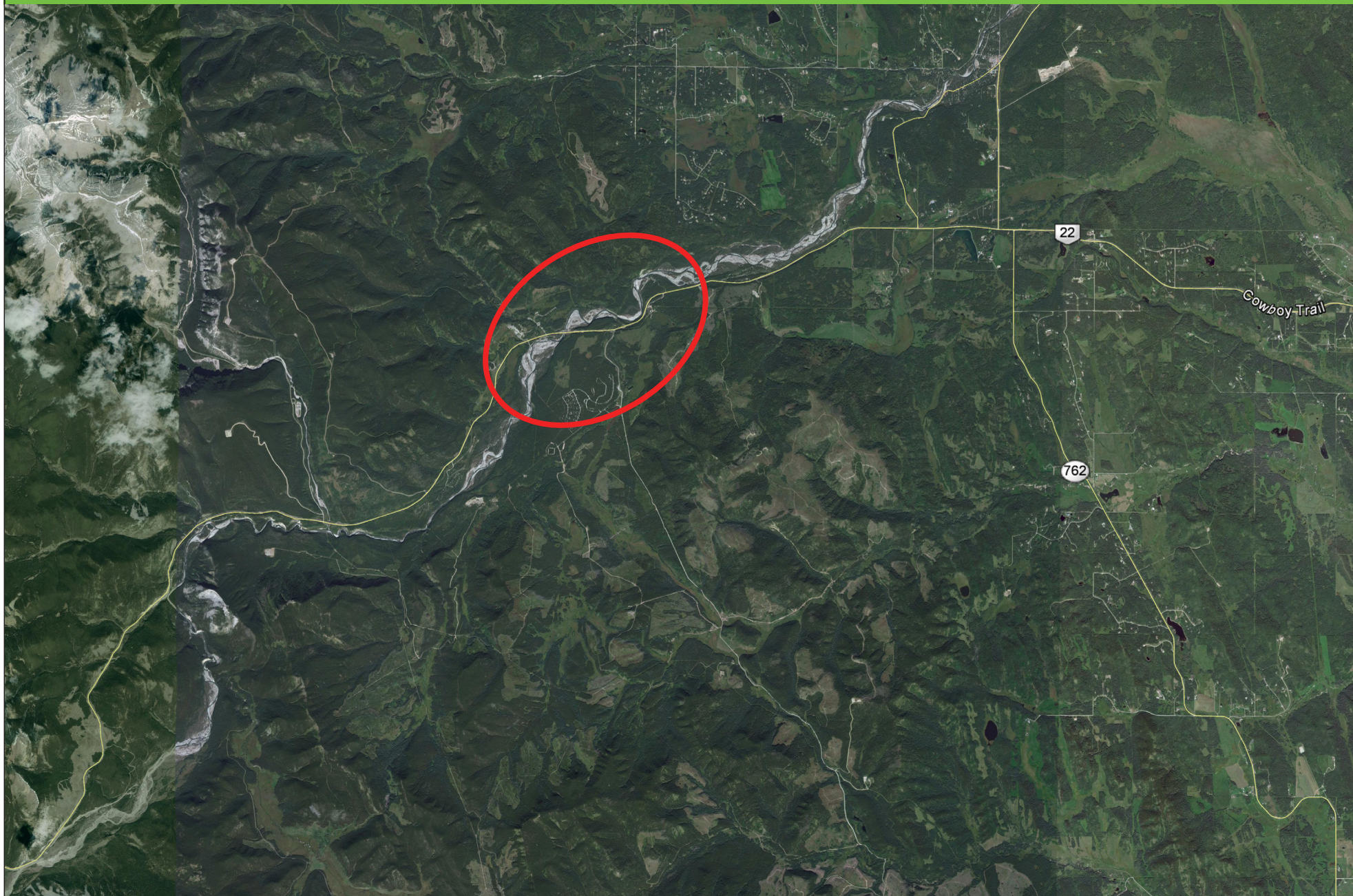
2 Context

Exhibit 2.1 illustrates the study area, while **Exhibit 2.2** illustrates the location of the proposed project.

Regional Setting



Local Setting



3 Project 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 W-E-R 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 **Exhibit 3.1**.

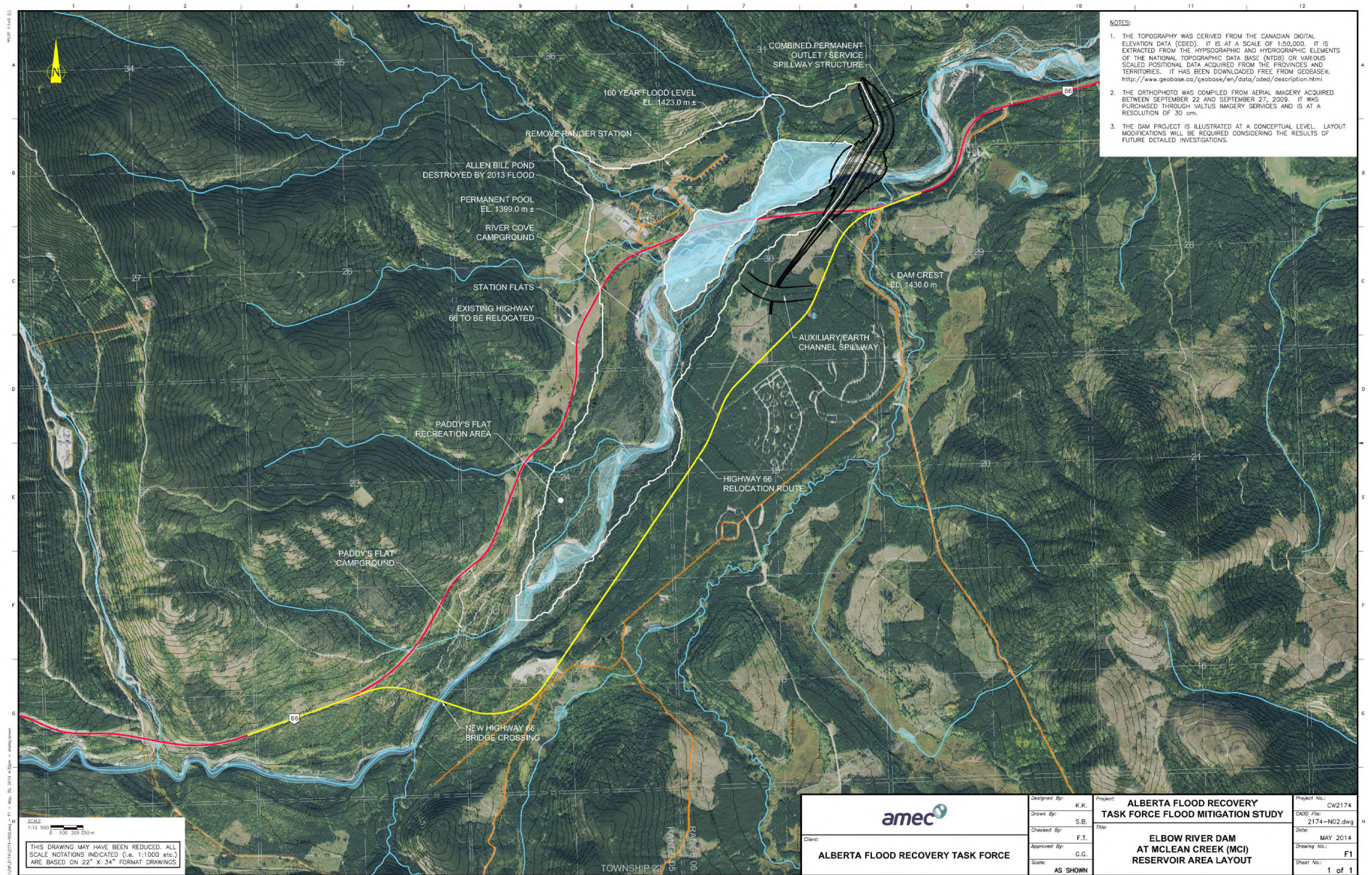
The proposed earth fill dam (main embankment) traverses a river gorge which is approximately 110 m wide at the base and is steep walled for a height of about 28 m (see **Exhibit 3.2**). The left abutment has a high knob-like feature falling away to an undulating plateau more-or-less equal to the height 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 (see **Exhibit 3.3**). 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.

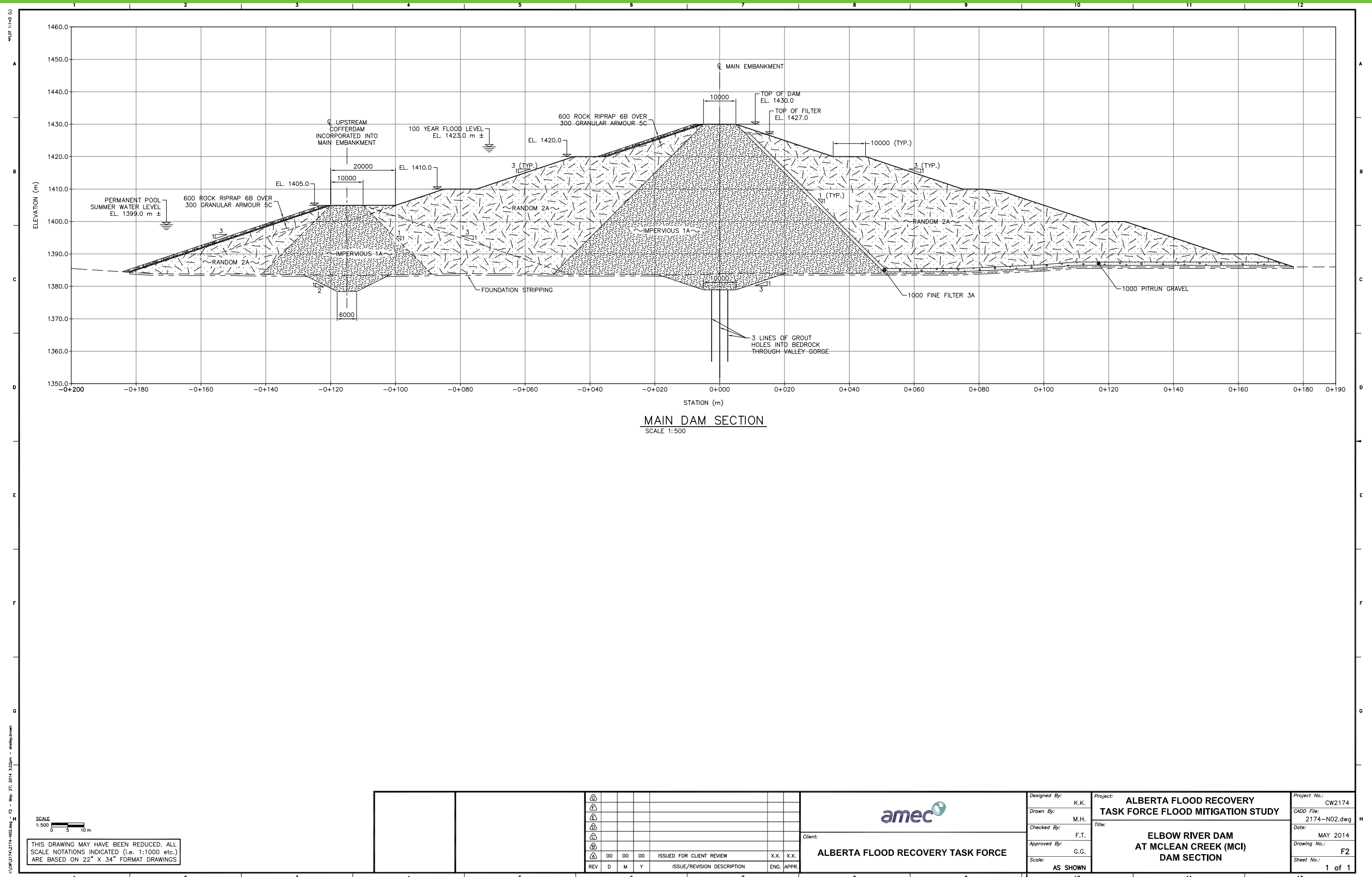
This conceptual design includes a small permanent pool in the valley bottom extending from river bottom elevation 1,379.0 m to the permanent outlet structure intake invert elevation 1,398.0 m, thereby permanently containing approximately 4,000 dam³ of water as dead storage.

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.

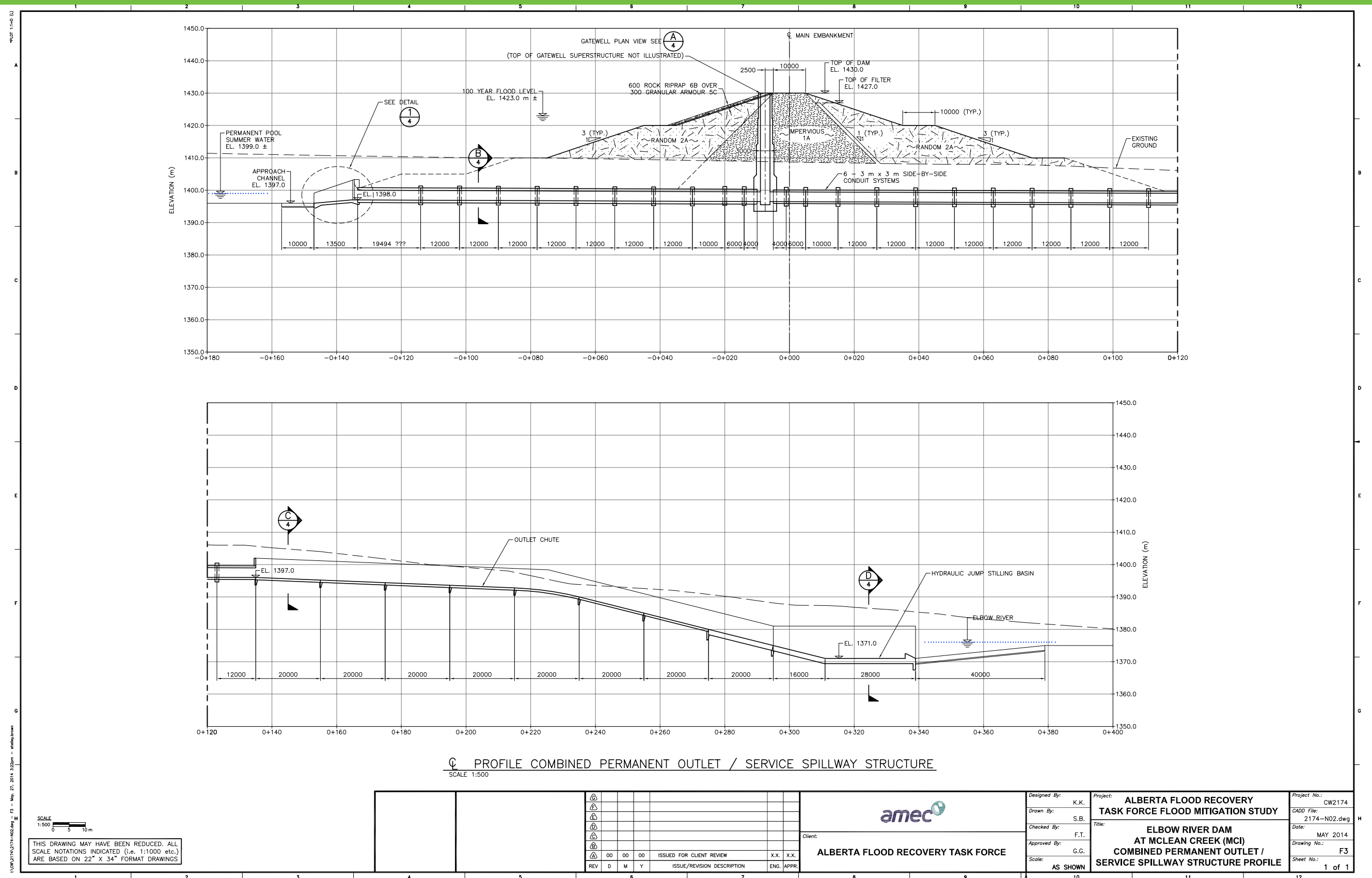
Elbow River Dam at McLean Creek (MCI) Reservoir Area Layout



Details - Elbow River Dam at McLean Creek (MCI) Dam Section



Details - Elbow River Dam at McLean Creek (MCI) Combined Permanent Outlet / Service Spillway Structure Profile



4 Cost Estimate

4.1 Project Cost Estimate

A detailed cost estimate is provided in **Exhibit 4.1**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.

4.2 Existing Infrastructure Impacts²

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 Exhibit 3.1. 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 Exhibit 3.1 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.

¹ AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Volume 4 – Flood Mitigation Measures, Appendix F – Elbow River Dam at McLean Creek*, p 21-22, May 2014

² Ibid, p 18-19.

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 ³ km	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 Spillway				
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

- 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.

Costs of replicating the aforementioned facilities within the general area and on Crown Land has been conservatively estimated at between \$40 and \$50 million³. In addition, the environmental impact assessment studies required to evaluate the project have been estimated at \$4 million⁴.

5 Flood Damages

5.1 Without Mitigation Alternative

5.1.1 City of Calgary

Flood damage estimates were generated for the City of Calgary employing updated stage-damage curves and the Provincial Rapid Flood Damage Assessment Model. Damage assessments were generated for nine return frequencies including: 1:2 year, 1:5 year, 1:10 year, 1:20 year, 1:50 year, 1:100 year, 1:200 year, 1:500 year and 1:1000 year, which allowed for the computation of average annual damages. Damage estimates were also assessed under two cases: a higher or “worst case” condition and a lower or “anticipated case” condition.

The detailed analysis of City of Calgary flood damages is contained under separate cover; however, summary tables are contained in **Appendix A**. For the 1:100 year flood under the higher damage case, total damages on the Elbow are estimated at \$741,005,000. Average annual damages for the Elbow River under the higher case equate to \$30,110,965.

For the 1:100 year flood under the lower case assumptions, total damages on the Elbow River are estimated at \$538,369,000 with average annual damages estimated at \$21,728,927.

³ Government of Alberta - Environmental and Sustainable Resource Development, Resilience & Mitigation Branch.

⁴ Ibid.

5.1.2 Other Damages

Flood damage studies, akin to the detailed assessment undertaken for the City of Calgary have not been generated for areas downstream of the McLean Creek storage project including Bragg Creek, Redwood Meadows and infrastructure within Rocky View County which would be protected by the proposed McLean Creek project. These damages constitute costs over and above those accruing to the City of Calgary and should be taken into consideration as part of the benefit/cost analysis.

A variety of secondary sources were employed to determine damages, including the damage claims submitted under the 2013 Southern Alberta Disaster Recovery Program along with a previous study of Bragg Creek completed for Alberta Environment Planning Division in 1987⁵.

In terms of the 2013 Southern Alberta Disaster Recovery Program, the total estimated amount for flood recovery projects between the McLean Creek dam site and the City of Calgary is approximately \$5.6 million. This amount is made up of \$1.084 million for recovery projects in Rocky View County (including Bragg Creek), \$2.657 million for recovery projects in the Townsite of Redwood Meadows, and \$1.901 million for recovery projects in the Tsuu T'ina First Nation. Details are contained in **Appendix B**.

5.1.2.1 1987 Bragg Creek Floodplain Management Study

The 1987 Bragg Creek Floodplain Management Study identified 37 residential units and 21 commercial units within the flood hazard area. This has increased to 51 residential units and 29 commercial units, representing an increase of 27% for residential and 28% for commercial. A very cursory assessment of potential damages employing values from the updated stage-damage curves suggests total damages in the order of \$12.7 million for the Bragg Creek flood study area for the 1:100 year event.

5.1.2.2 Cost Implications

At this juncture it is not possible to accurately calculate average annual damages for the areas downstream of MC1. Notwithstanding, in order to account for the other damages, and therefore additional costs that will be incurred by the Glenmore Reservoir Diversion and SR1 (Springbank Off-Stream Flood Storage) projects over the MC1 project, an additional \$8.9 million in total costs are proposed to be added to these other projects.

5.2 With Mitigation Alternative

Implementation of the McLean Creek Flood Storage project results in a reduction of average annual damages under the four cases as follows:

- 1:100 year level of protection under the higher damage scenario = \$19,461,291
- 1:200 year level of protection under the higher damage scenario = \$26,114,777
- 1:100 year level of protection under the lower damage scenario = \$13,746,068
- 1:200 year level of protection under the lower damage scenario = \$16,686,439

⁵ *Bragg Creek Floodplain Management Study – Final Report*, J.N. MacKenzie Engineering Ltd. in association with W-E-R Engineering Ltd., IBI Group and Ecos Engineering Services Ltd., January 1987.

6 Benefit/Cost Analysis

6.1 Benefit/Cost Analysis for Flood Mitigation Projects

For flood mitigation projects, economic evaluation requires a comparison between the events predicted to occur if the project is built and those predicted to occur if the project is not built. This is called the “with and without principle”. For flood control one cannot directly equate an exchange in the market, however flood control benefits can be estimated by assuming they are equivalent to the flood damage prevented.

For flood mitigation projects the probabilistic approach to benefit/cost estimates is used. To reiterate, within the defined flood risk area, flood damages were estimated with the application of depth-damage curves applied to the various return flood events (probability). The flood damage probability distribution was then plotted and the average annual damage (AAD) estimated for project evaluation purposes.

With the updated average annual damages and cost estimates of the diversion alternative, an economic efficiency evaluation was performed. This evaluation is based upon the net present value (NPV) of respective benefits and costs. The net present value of any project is governed by three variables: the average annual cost or benefit, discount rate, and discount period. To provide a consistent economic evaluation of flood mitigation projects across the Province, a common discount rate of 4% was agreed upon and applied. The discount period is the estimate of the alternative’s project life.

The benefit/cost (B/C) ratio of a project is the ratio of net present value of the benefits (average annual damages) over the net present value of the costs. This value is the indicator of economic efficiency. Where the benefits exceed costs, the ratio would be greater than 1.0, and where benefits are less than costs then the ratio would be less than 1.0. An economically-efficient project would have a B/C ratio greater than 1.0. At a B/C ratio of 1.0, the project is at a breakeven point.

6.2 Assumptions/Methodology

The following assumptions were employed in the benefit/cost analysis:

- Costs are based on the estimated capital and operational/maintenance costs presented in Section 4.
- \$8.9 million in capital costs was added to the Glenmore Reservoir Diversion and Springbank Off-Stream Storage projects to account for required mitigation measures upstream thereby taking into account the benefits accruing to the McLean Creek Flood Storage project.
- \$45 million in costs was added for relocating existing infrastructure.
- \$4 million in costs was added for environmental impact studies.
- Benefits are based on the quantification of flood damages averted as outlined in Section 5.
- The benefit/cost analysis has been carried out using a net present value analysis.
- A 100 year economic analysis.
- Annual operating and maintenance costs of \$1.8 million.

6.2.1 MC1 (McLean Creek Flood Storage Project) and SR1 (Springbank Off-Stream Flood Storage Project)

Net benefits for MC1 and SR1 were computed on the basis that the projects will provide protection downstream of Glenmore Dam to the 1:100 and 1:200 year flood events. When these events are exceeded, the damages will start to increase rapidly as the peak discharge passes through the flood hazard area within the City of Calgary. Without additional hydrologic routing, it was assumed that once the design event is exceeded, full damages are incurred. With additional hydrologic routing it is possible that the benefit/cost ratios of these schemes will improve somewhat.

6.2.2 Glenmore Reservoir Diversion

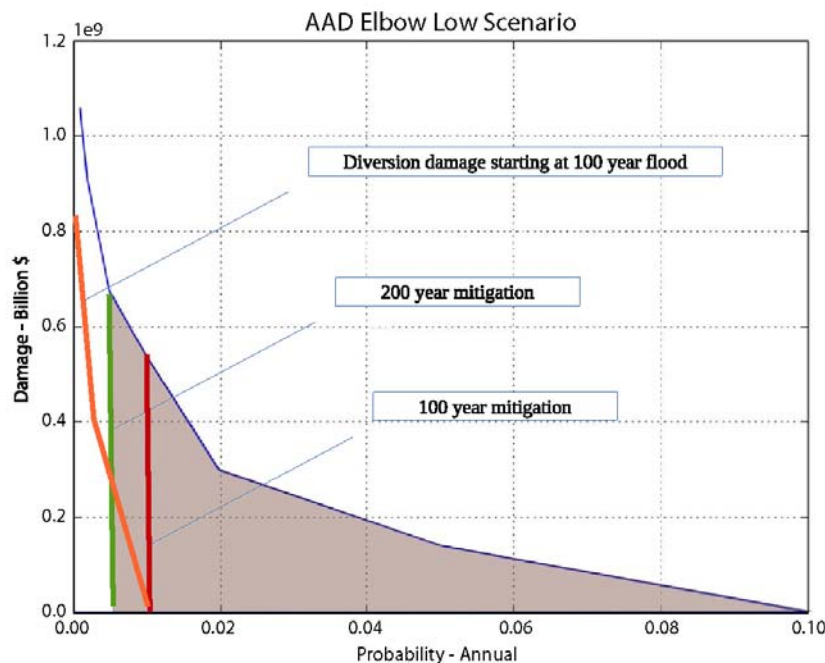
With respect to the Glenmore Reservoir Diversion it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 CMS diversion. The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, a higher benefit can be attributed to the diversion scheme based on this higher level of analysis. Notwithstanding the higher overall benefits, the actual benefit/cost ratio as illustrated in the next section is lower than the MC1 and SR1 schemes due to the much higher cost base of the Glenmore Reservoir Diversion.

Exhibit 6.1 illustrates this principle considering the average annual damage on the Elbow under the low damage scenario. If all flood damage can be eliminated then the average annual damage is equal to the area under the curve from the Y to the X axis. This is the total average annual damage.

If a dyke is constructed to a 100 year flood protection, the area right of the red line is subtracted from the total average annual damage. This is the value of the average annual damage averted. However, when the 100 year flood is exceeded then all the properties are flooded instantaneously (area to the left of the red line). Similarly, for a dyke built to the 200 year level of protection.

Conversely, in the case of the diversion tunnel, the mitigation is the area right of the orange line. In this case, when the diverted flow is exceeded, then the damage occurs gradually (slope of the orange curve) rather than vertically, like the dyke situation.

Exhibit 6.1: Affect of Mitigation on Average Annual Damage



6.3 Discussion of Results

Exhibit 6.2 highlights the key results of the benefit/cost analysis for the McLean Creek Flood Storage project considering the four cases as discussed.

For the 1:100 year level of protection under the high damage scenario, the present value of benefits is \$477 million versus the present value of costs at \$333 million, rendering a positive benefit/cost ratio of 1.43.

At the 1:200 year level of protection, the benefit/cost ratio increases slightly to 1.65, proving both alternatives to be economically viable projects.

For the low damage scenario, the 1:100 year present value of benefits is \$337 million versus \$333 million in costs, rendering a benefit/cost ratio of 1.01. Once again, for the 1:200 year level of protection the benefit/cost ratio increases slightly to 1.05.

Exhibit 6.2: Benefit/Cost Analysis

Indicator	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
PV Benefits (average annual damages)	\$476,899,000	\$639,943,000	\$336,847,000	\$408,901,000
PV Costs (development & operating total cost)	\$332,708,000	\$387,699,000	\$332,708,000	\$387,699,000
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Average Annual Damages	\$19,461,291	\$26,114,777	\$13,746,068	\$16,686,439

6.4 Benefits Beyond the Study Area

Of the three mitigation projects under consideration, only one – the McLean Creek Flood Storage project (MC1) – provides benefits beyond the primary study area, the City of Calgary. An analysis of any potential benefits downstream of the City was outside the scope of this analysis. Needless to say, it is anticipated that benefits downstream of the City would be marginal in any event.

6.5 Triple Bottom Line Considerations

Traditional economic analyses of flood mitigation alternatives have generally assumed a straightforward objective of maximizing the net benefits (total benefits minus total costs) that accrue to a project. Society however, has other goals besides economic efficiency. These goals or objectives are the results of outcomes that society desires and have more recently been described as triple bottom line objectives which include, in addition to economic objectives, considerations of environmental and social impacts. In relation to flood mitigation projects, the following criteria are often considered in the evaluation process:

- Disaster prevention:
 - reduces current losses
 - reduces future losses
 - potential residential loss of life
 - potential non-residential loss of life
- Environmental impact:
 - biophysical impacts
 - social impacts
 - aesthetic impacts
- Implementation:
 - complexity
 - flexibility of integration with other measures
- Incidental benefits:
 - recreation
 - drought mitigation
 - other

This study was concerned solely with economic efficiency and consequently does not include analysis of the aforementioned non-commensurable criteria.

6.6 Summary and Conclusions

Exhibit 6.3 below illustrates the relative ranking of the flood mitigation projects.

Exhibit 6.3: Benefit/Cost Ratio

Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

The McLean Creek Flood Storage project achieves a positive benefit/cost ratio in all four scenarios and ranks second behind the SR1 project.⁶

⁶ Refer to IBI Group Reports: *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage (February 2015)* and *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion (February 2015)*.

Appendix A – City of Calgary Flood Damage Estimates

Total Damages, Bow and Elbow Rivers, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$268,753,000	\$414,798,000	\$686,791,000	\$947,786,000	\$1,329,201,000	\$1,496,364,000
	Indirect 15%	\$0	\$0	\$0	\$40,313,000	\$62,220,000	\$103,019,000	\$142,168,000	\$199,380,000	\$224,455,000
	Total	\$0	\$0	\$0	\$309,066,000	\$477,018,000	\$789,810,000	\$1,089,954,000	\$1,528,581,000	\$1,720,819,000
Commercial	Direct	\$0	\$0	\$0	\$15,210,000	\$37,446,000	\$111,079,000	\$271,990,000	\$493,824,000	\$572,607,000
	Indirect 323%	\$0	\$0	\$0	\$49,128,000	\$120,951,000	\$358,785,000	\$878,528,000	\$1,595,052,000	\$1,849,521,000
	Total	\$0	\$0	\$0	\$64,338,000	\$158,397,000	\$469,864,000	\$1,150,518,000	\$2,088,876,000	\$2,422,128,000
Infrastructure	Direct	\$0	\$0	\$0	\$101,508,000	\$170,620,000	\$299,100,000	\$452,626,000	\$686,656,000	\$780,711,000
	Indirect 20%	\$0	\$0	\$0	\$20,302,000	\$34,124,000	\$59,820,000	\$90,525,000	\$137,331,000	\$156,142,000
	Total	\$0	\$0	\$0	\$121,810,000	\$204,744,000	\$358,920,000	\$543,151,000	\$823,987,000	\$936,853,000
Stampede	Direct	\$0	\$0	\$0	\$10,200,000	\$42,200,000	\$68,900,000	\$91,900,000	\$166,853,000	\$193,472,000
	Indirect 185%	\$0	\$0	\$0	\$18,860,000	\$78,030,000	\$127,400,000	\$169,928,000	\$308,521,000	\$357,741,000
	Total	\$0	\$0	\$0	\$29,060,000	\$120,230,000	\$196,300,000	\$261,828,000	\$475,374,000	\$551,213,000
Total	Direct	\$0	\$0	\$0	\$395,671,000	\$665,064,000	\$1,165,870,000	\$1,764,302,000	\$2,676,534,000	\$3,043,154,000
	Indirect 73%	\$0	\$0	\$0	\$128,603,000	\$295,325,000	\$649,024,000	\$1,281,149,000	\$2,240,284,000	\$2,587,859,000
	Total	\$0	\$0	\$0	\$524,274,000	\$960,389,000	\$1,814,894,000	\$3,045,451,000	\$4,916,818,000	\$5,631,013,000

* No Actual damages occur at these flow levels

** Flood Flow primarily contained within the river

Total Damages, Bow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$167,738,000	\$247,549,000	\$387,075,000	\$582,482,000	\$891,235,000	\$991,311,000
	Indirect 15%	\$0	\$0	\$0	\$25,161,000	\$37,133,000	\$58,062,000	\$87,372,000	\$133,685,000	\$148,697,000
	Total	\$0	\$0	\$0	\$192,899,000	\$284,682,000	\$445,137,000	\$669,854,000	\$1,024,920,000	\$1,140,008,000
Commercial	Direct	\$0	\$0	\$0	\$15,128,000	\$36,965,000	\$100,874,000	\$256,774,000	\$471,284,000	\$539,790,000
	Indirect 323%	\$0	\$0	\$0	\$48,863,000	\$119,397,000	\$325,823,000	\$829,380,000	\$1,522,248,000	\$1,743,522,000
	Total	\$0	\$0	\$0	\$63,991,000	\$156,362,000	\$426,697,000	\$1,086,154,000	\$1,993,532,000	\$2,283,312,000
Infrastructure	Direct	\$0	\$0	\$0	\$63,102,000	\$98,179,000	\$168,379,000	\$289,606,000	\$470,170,000	\$528,344,000
	Indirect 20%	\$0	\$0	\$0	\$12,621,000	\$19,636,000	\$33,676,000	\$57,921,000	\$94,034,000	\$105,669,000
	Total	\$0	\$0	\$0	\$75,723,000	\$117,815,000	\$202,055,000	\$347,527,000	\$564,204,000	\$634,013,000
Stampede	Direct	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Indirect 185%	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Total	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Total	Direct	\$0	\$0	\$0	\$245,968,000	\$382,693,000	\$656,328,000	\$1,128,862,000	\$1,832,689,000	\$2,059,445,000
	Indirect 84%	\$0	\$0	\$0	\$86,645,000	\$176,166,000	\$417,561,000	\$974,673,000	\$1,749,967,000	\$1,997,888,000
	Total	\$0	\$0	\$0	\$332,613,000	\$558,859,000	\$1,073,889,000	\$2,103,535,000	\$3,582,656,000	\$4,057,333,000

* No Actual damages occur at these flow levels

** Flood Flow primarily contained within the river

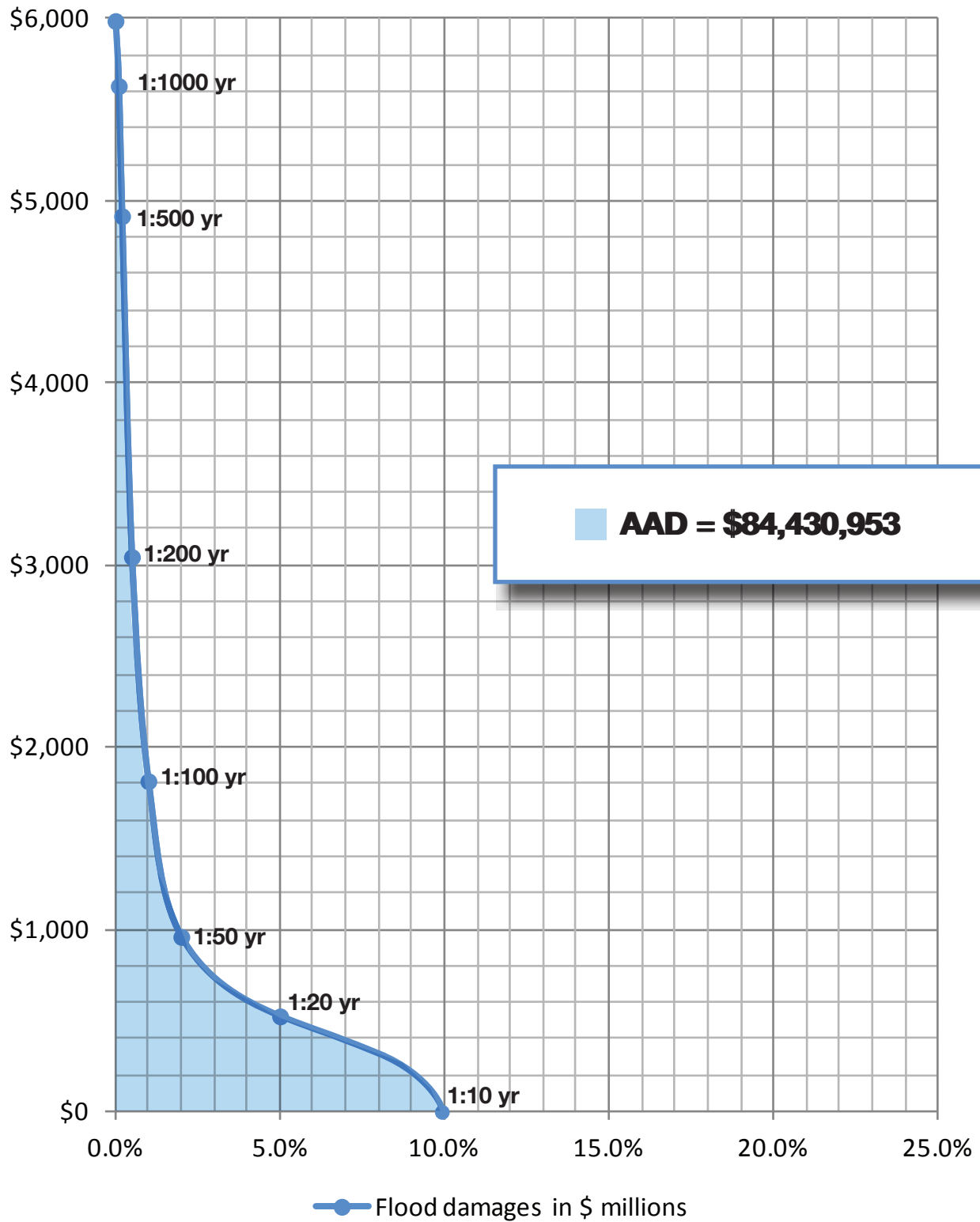
Total Damages, Elbow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$101,015,000	\$167,249,000	\$299,716,000	\$365,304,000	\$437,966,000	\$505,053,000
	Indirect 15%	\$0	\$0	\$0	\$15,152,000	\$25,087,000	\$44,957,000	\$54,796,000	\$65,695,000	\$75,758,000
	Total	\$0	\$0	\$0	\$116,167,000	\$192,336,000	\$344,673,000	\$420,100,000	\$503,661,000	\$580,811,000
Commercial	Direct	\$0	\$0	\$0	\$82,000	\$481,000	\$10,205,000	\$15,216,000	\$22,540,000	\$32,817,000
	Indirect 323%	\$0	\$0	\$0	\$265,000	\$1,554,000	\$32,962,000	\$49,148,000	\$72,804,000	\$105,999,000
	Total	\$0	\$0	\$0	\$347,000	\$2,035,000	\$43,167,000	\$64,364,000	\$95,344,000	\$138,816,000
Infrastructure	Direct	\$0	\$0	\$0	\$38,406,000	\$72,441,000	\$130,721,000	\$163,020,000	\$216,486,000	\$252,367,000
	Indirect 20%	\$0	\$0	\$0	\$7,681,000	\$14,488,000	\$26,144,000	\$32,604,000	\$43,297,000	\$50,473,000
	Total	\$0	\$0	\$0	\$46,087,000	\$86,929,000	\$156,865,000	\$195,624,000	\$259,783,000	\$302,840,000
Stampede	Direct	\$0	\$0	\$0	\$10,200,000	\$42,200,000	\$68,900,000	\$91,900,000	\$166,853,000	\$193,472,000
	Indirect 185%	\$0	\$0	\$0	\$18,860,000	\$78,030,000	\$127,400,000	\$169,928,000	\$308,521,000	\$357,741,000
	Total	\$0	\$0	\$0	\$29,060,000	\$120,230,000	\$196,300,000	\$261,828,000	\$475,374,000	\$551,213,000
Total	Direct	\$0	\$0	\$0	\$149,703,000	\$282,371,000	\$509,542,000	\$635,440,000	\$843,845,000	\$983,709,000
	Indirect 52%	\$0	\$0	\$0	\$41,958,000	\$119,159,000	\$231,463,000	\$306,476,000	\$490,317,000	\$589,971,000
	Total	\$0	\$0	\$0	\$191,661,000	\$401,530,000	\$741,005,000	\$941,916,000	\$1,334,162,000	\$1,573,680,000

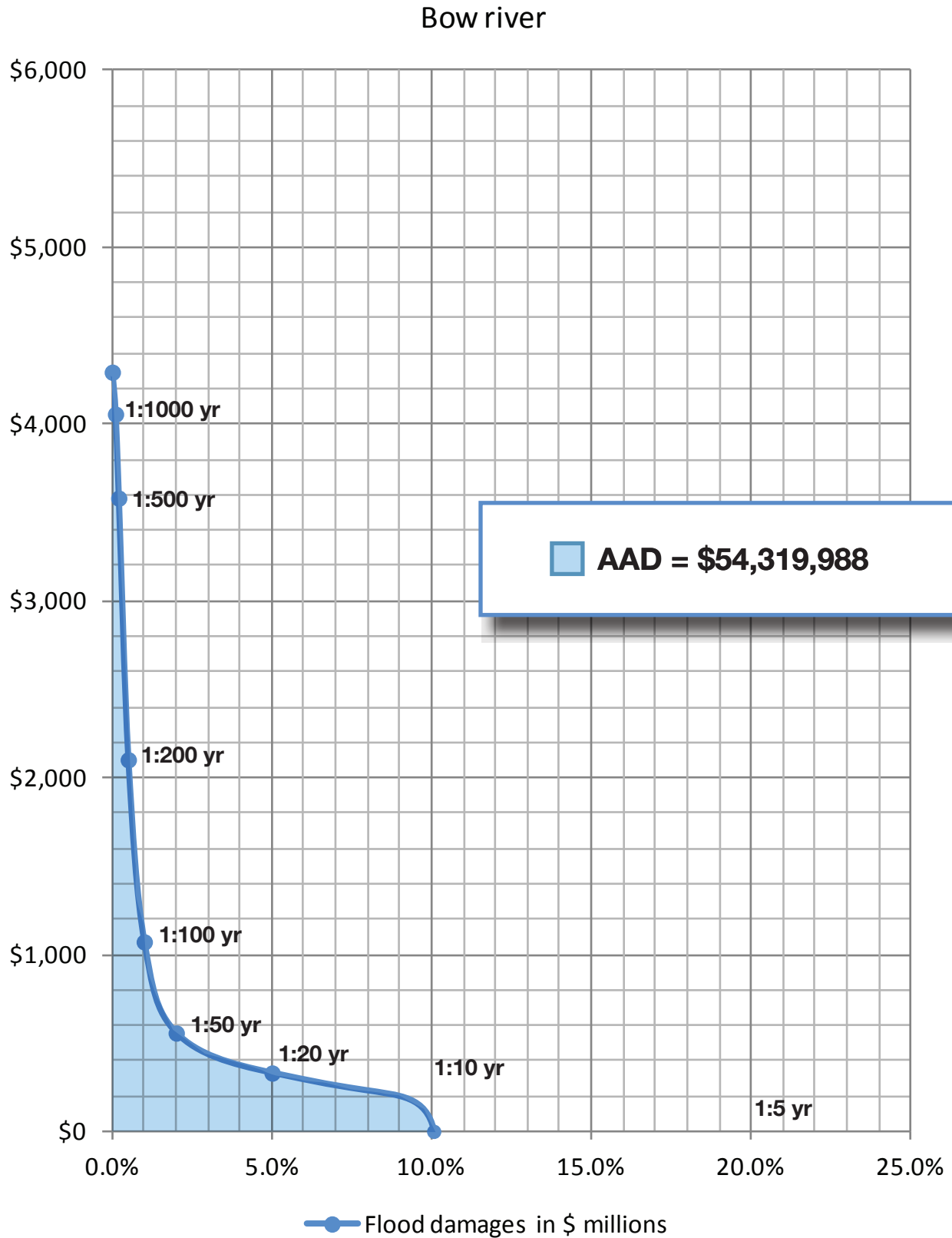
* No Actual damages occur at these flow levels

** Flood Flow primarily contained within the river

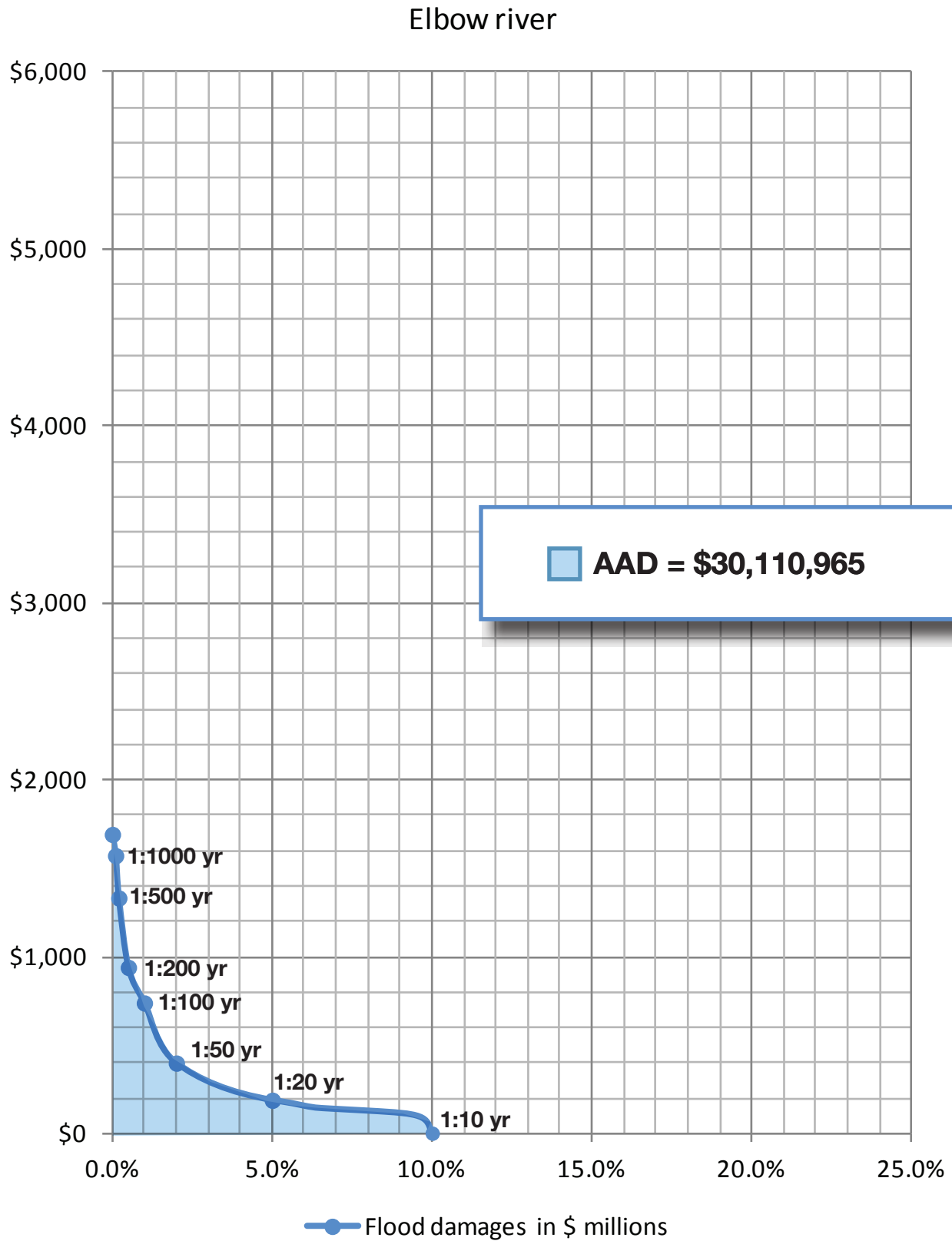
Flood Damages Probability Distribution, Bow and Elbow Rivers



Flood Damages Probability Distribution, Bow River



Flood Damages Probability Distribution, Elbow River



Alternative Damage Scenario - Total Damages, Bow and Elbow Rivers, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$268,753,000	\$414,798,000	\$686,791,000	\$947,786,000	\$1,329,201,000	\$1,496,364,000
	Indirect 15%	\$0	\$0	\$0	\$40,313,000	\$62,220,000	\$103,019,000	\$142,168,000	\$199,380,000	\$224,455,000
	Total	\$0	\$0	\$0	\$309,066,000	\$477,018,000	\$789,810,000	\$1,089,954,000	\$1,528,581,000	\$1,720,819,000
Commercial	Direct	\$0	\$0	\$0	\$15,210,000	\$37,446,000	\$111,079,000	\$271,990,000	\$493,824,000	\$572,607,000
	Indirect 45%	\$0	\$0	\$0	\$0	\$16,851,000	\$49,986,000	\$122,396,000	\$222,221,000	\$257,673,000
	Total	\$0	\$0	\$0	\$15,210,000	\$54,297,000	\$161,065,000	\$394,386,000	\$716,045,000	\$830,280,000
Infrastructure	Direct	\$0	\$0	\$0	\$21,639,000	\$90,929,000	\$159,400,000	\$241,219,000	\$365,941,000	\$416,066,000
	Indirect 20%	\$0	\$0	\$0	\$4,328,000	\$18,186,000	\$31,880,000	\$48,244,000	\$73,188,000	\$83,213,000
	Total	\$0	\$0	\$0	\$25,967,000	\$109,115,000	\$191,280,000	\$289,463,000	\$439,129,000	\$499,279,000
Stampede	Direct	\$0	\$0	\$0	\$10,200,000	\$42,200,000	\$68,900,000	\$91,900,000	\$166,853,000	\$193,472,000
	Indirect 38%	\$0	\$0	\$0	\$3,908,000	\$16,170,000	\$26,400,000	\$35,213,000	\$63,932,000	\$74,132,000
	Total	\$0	\$0	\$0	\$14,108,000	\$58,370,000	\$95,300,000	\$127,113,000	\$230,785,000	\$267,604,000
Total	Direct	\$0	\$0	\$0	\$315,802,000	\$585,373,000	\$1,026,170,000	\$1,552,895,000	\$2,355,819,000	\$2,678,509,000
	Indirect 22%	\$0	\$0	\$0	\$48,549,000	\$113,427,000	\$211,285,000	\$348,021,000	\$558,721,000	\$639,473,000
	Total	\$0	\$0	\$0	\$364,351,000	\$698,800,000	\$1,237,455,000	\$1,900,916,000	\$2,914,540,000	\$3,317,982,000

* No Actual damages occur at these flow levels

** Flood Flow primarily contained within the river

Alternative Damage Scenario - Total Damages, Bow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$167,738,000	\$247,549,000	\$387,075,000	\$582,482,000	\$891,235,000	\$991,311,000
	Indirect 15%	\$0	\$0	\$0	\$25,161,000	\$37,133,000	\$58,062,000	\$87,372,000	\$133,685,000	\$148,697,000
	Total	\$0	\$0	\$0	\$192,899,000	\$284,682,000	\$445,137,000	\$669,854,000	\$1,024,920,000	\$1,140,008,000
Commercial	Direct	\$0	\$0	\$0	\$15,128,000	\$36,965,000	\$100,874,000	\$256,774,000	\$471,284,000	\$539,790,000
	Indirect 45%	\$0	\$0	\$0	\$0	\$16,635,000	\$45,394,000	\$115,549,000	\$212,078,000	\$242,905,000
	Total	\$0	\$0	\$0	\$15,128,000	\$53,600,000	\$146,268,000	\$372,323,000	\$683,362,000	\$782,695,000
Infrastructure	Direct	\$0	\$0	\$0	\$13,452,000	\$52,323,000	\$89,734,000	\$154,340,000	\$250,569,000	\$281,571,000
	Indirect 20%	\$0	\$0	\$0	\$2,691,000	\$10,465,000	\$17,947,000	\$30,868,000	\$50,114,000	\$56,314,000
	Total	\$0	\$0	\$0	\$16,143,000	\$62,788,000	\$107,681,000	\$185,208,000	\$300,683,000	\$337,885,000
Stampede	Direct	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Indirect 38%	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Total	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Total	Direct	\$0	\$0	\$0	\$196,318,000	\$336,837,000	\$577,683,000	\$993,596,000	\$1,613,088,000	\$1,812,672,000
	Indirect 23%	\$0	\$0	\$0	\$27,852,000	\$64,233,000	\$121,403,000	\$233,789,000	\$395,877,000	\$447,916,000
	Total	\$0	\$0	\$0	\$224,170,000	\$401,070,000	\$699,086,000	\$1,227,385,000	\$2,008,965,000	\$2,260,588,000

* No Actual damages occur at these flow levels

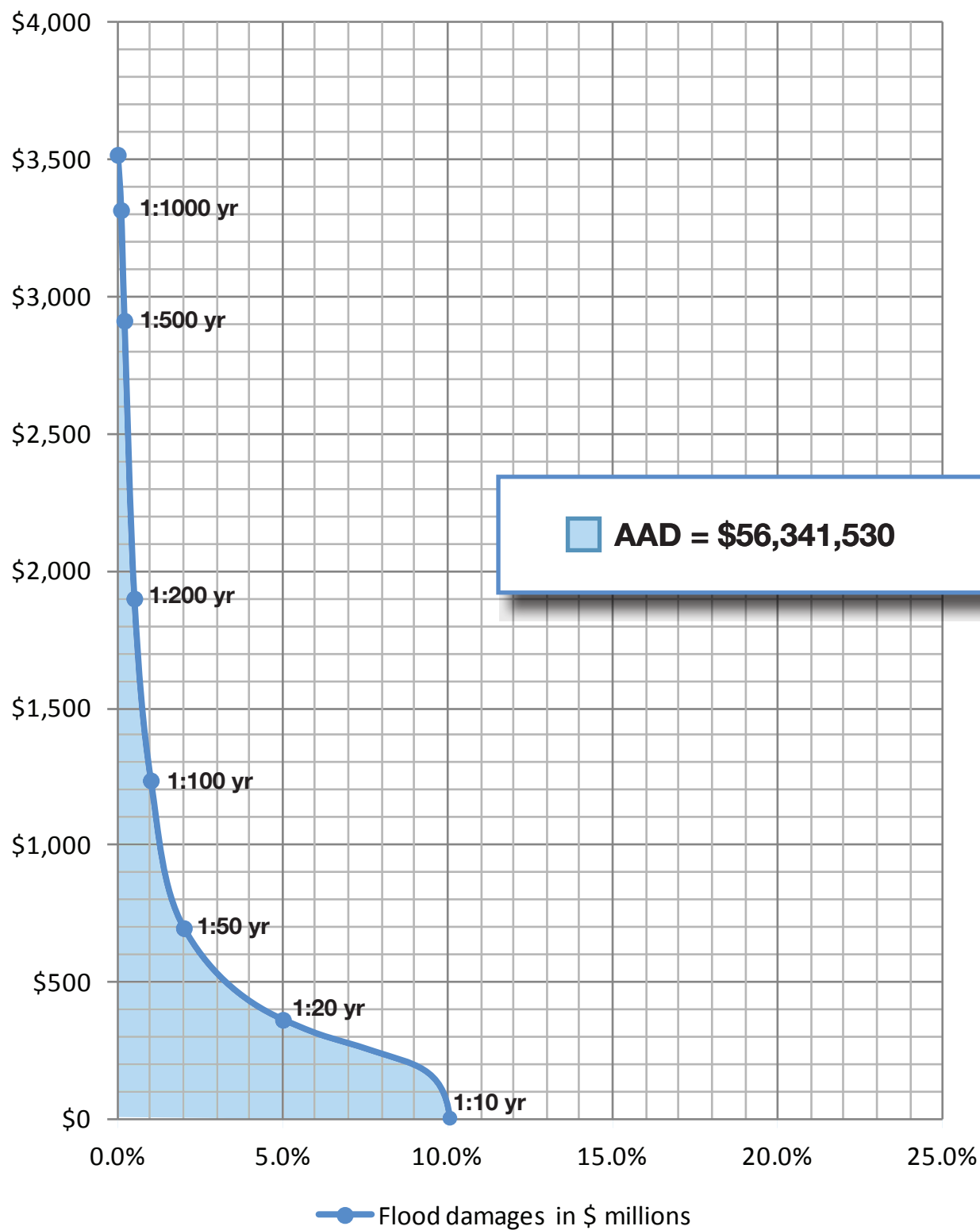
** Flood Flow primarily contained within the river

Alternative Damage Scenario - Total Damages, Elbow River, With Sewer Backup

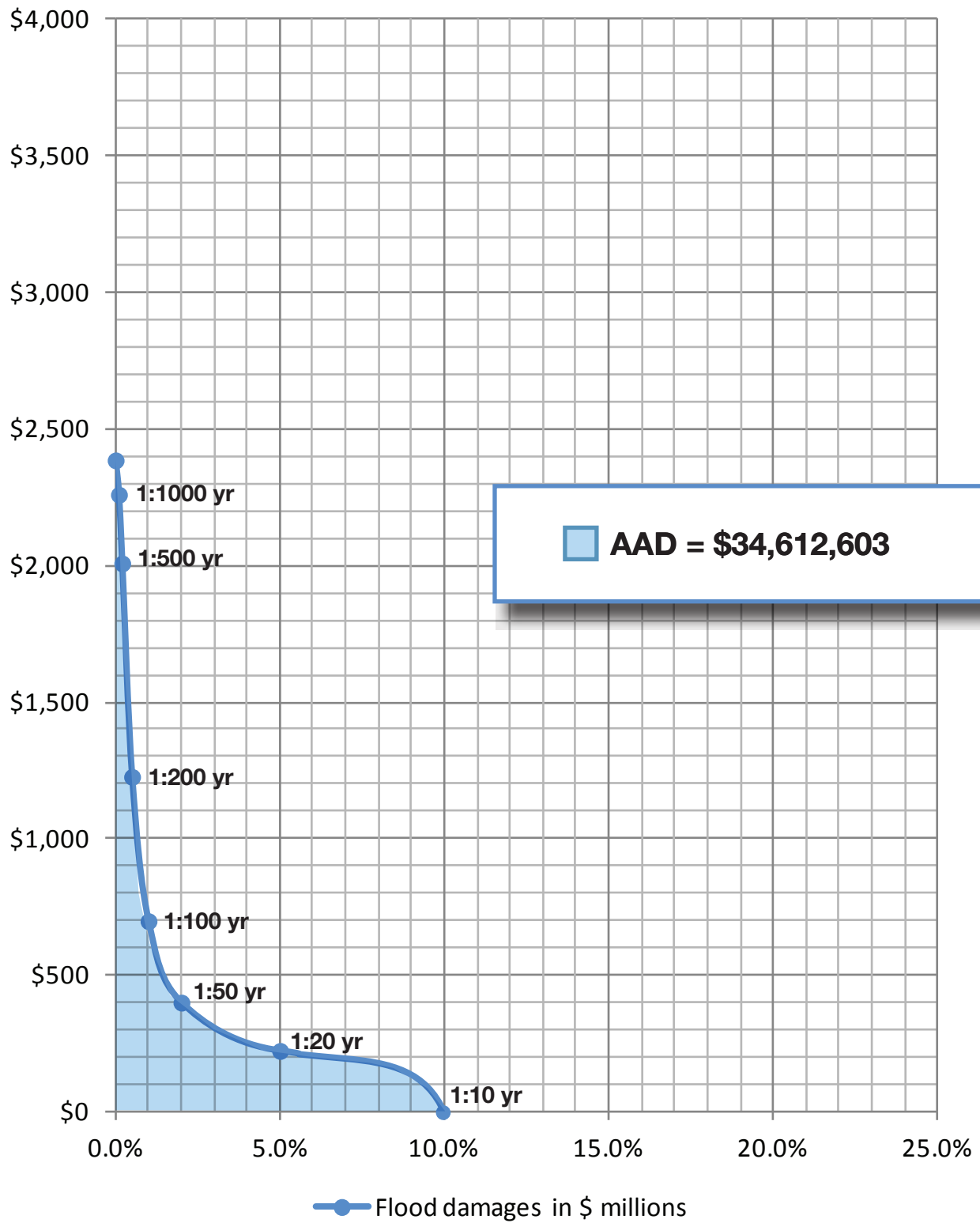
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	\$0	\$0	\$0	\$101,015,000	\$167,249,000	\$299,716,000	\$365,304,000	\$437,966,000	\$505,053,000
	Indirect 15%	\$0	\$0	\$0	\$15,152,000	\$25,087,000	\$44,957,000	\$54,796,000	\$65,695,000	\$75,758,000
	Total	\$0	\$0	\$0	\$116,167,000	\$192,336,000	\$344,673,000	\$420,100,000	\$503,661,000	\$580,811,000
Commercial	Direct	\$0	\$0	\$0	\$82,000	\$481,000	\$10,205,000	\$15,216,000	\$22,540,000	\$32,817,000
	Indirect 45%	\$0	\$0	\$0	\$0	\$216,000	\$4,592,000	\$6,847,000	\$10,143,000	\$14,768,000
	Total	\$0	\$0	\$0	\$82,000	\$697,000	\$14,797,000	\$22,063,000	\$32,683,000	\$47,585,000
Infrastructure	Direct	\$0	\$0	\$0	\$8,187,000	\$38,606,000	\$69,666,000	\$86,879,000	\$115,372,000	\$134,495,000
	Indirect 20%	\$0	\$0	\$0	\$1,637,000	\$7,721,000	\$13,933,000	\$17,376,000	\$23,074,000	\$26,899,000
	Total	\$0	\$0	\$0	\$9,824,000	\$46,327,000	\$83,599,000	\$104,255,000	\$138,446,000	\$161,394,000
Stampede	Direct	\$0	\$0	\$0	\$10,200,000	\$42,200,000	\$68,900,000	\$91,900,000	\$166,853,000	\$193,472,000
	Indirect 38%	\$0	\$0	\$0	\$3,908,000	\$16,170,000	\$26,400,000	\$35,213,000	\$63,932,000	\$74,132,000
	Total	\$0	\$0	\$0	\$14,108,000	\$58,370,000	\$95,300,000	\$127,113,000	\$230,785,000	\$267,604,000
Total	Direct	\$0	\$0	\$0	\$119,484,000	\$248,536,000	\$448,487,000	\$559,299,000	\$742,731,000	\$865,837,000
	Indirect 21%	\$0	\$0	\$0	\$20,697,000	\$49,194,000	\$89,882,000	\$114,232,000	\$162,844,000	\$191,557,000
	Total	\$0	\$0	\$0	\$140,181,000	\$297,730,000	\$538,369,000	\$673,531,000	\$905,575,000	\$1,057,394,000

* No Actual damages occur at these flow levels

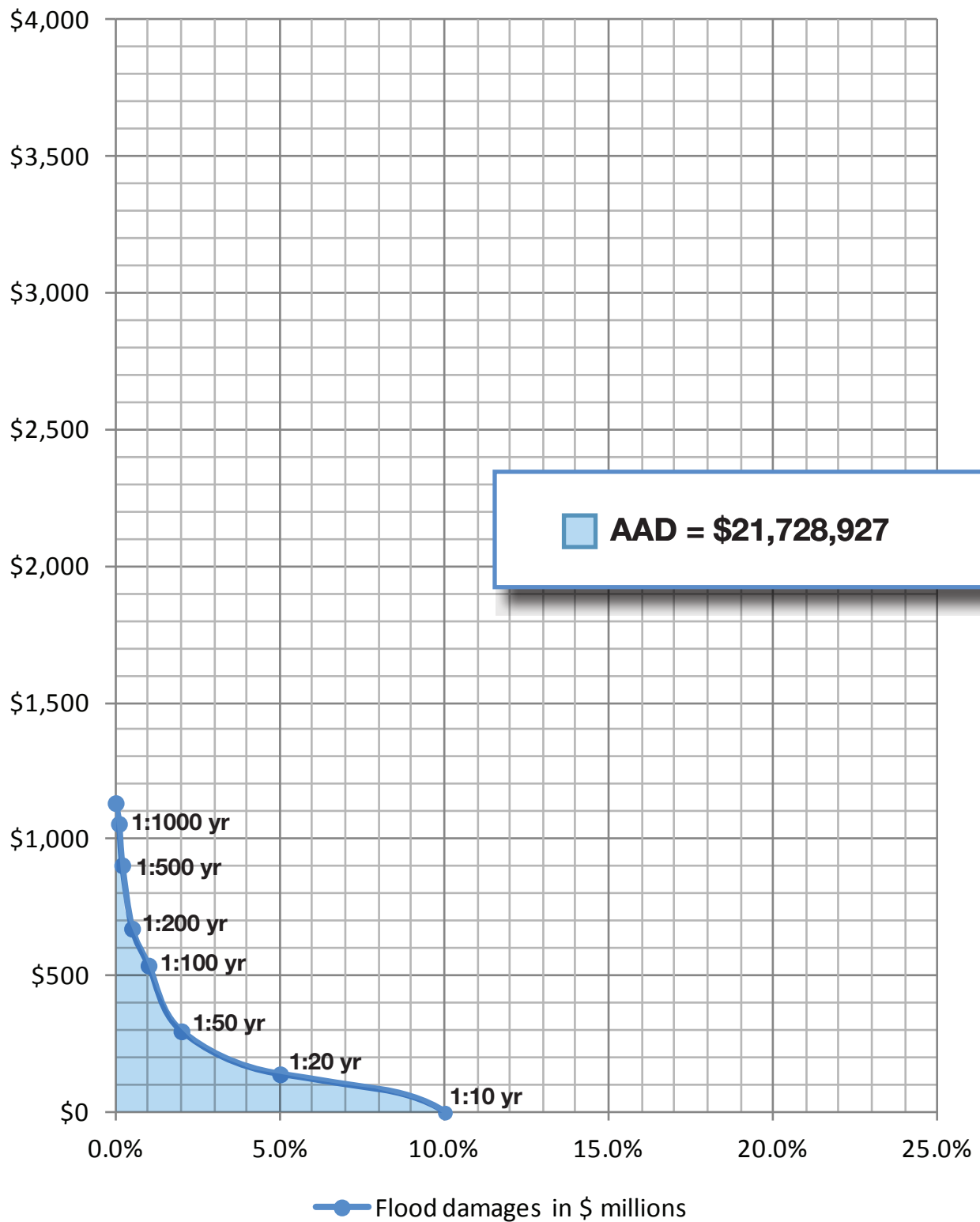
** Flood Flow primarily contained within the river



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River



Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



Appendix B – 2013 Southern Alberta Disaster Recovery Program

2013 Southern Alberta Disaster Recovery Program - Ongoing Project Estimate Tracking - As of February 4, 2014

Rocky View County Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate (\$)	Comments
1	Emergency Operations	Ongoing	Y	Sept. 19, 2013	450000.00	Approved inspection estimate
2	Hamlet of Bragg Creek water intake	Ongoing	Y	Sept. 19, 2013	110000.00	Approved inspection estimate
3	Hamlet of Bragg Creek road damage	Ongoing	Y	Sept. 19, 2013	20000.00	Approved inspection estimate
4	Balsam Ave Erosion	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
5	Access to Hamlet of Bragg Creek Snowbirds Chalet	Ongoing	Y	Sept. 19, 2013	5000.00	Approved inspection estimate
6	Hamlet of Bragg Creek Community Centre	Ongoing	Y	Sept. 19, 2013	35000.00	Approved inspection estimate
7	Wood debris site	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
8	Wintergreen road	Ongoing	Y	Sept. 19, 2013	10000.00	Approved inspection estimate
9	Slapping Tail Pond	Ongoing	Y	Sept. 19, 2013	75000.00	Approved inspection estimate
12	RR 54, S of TWP road 234	Ongoing	Y	Sept. 19, 2013	10000.00	Approved inspection estimate
14	Bracken Road gate and spillway	Ongoing	Y	Sept. 19, 2013	15000.00	Approved inspection estimate
15	Bracken Road	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
16	Bracken Road S TWP Rd 232, Bragg Creek BF72292	Ongoing	Y	Sept. 19, 2013	29000.00	Approved inspection estimate
18	RR 41, S of Springbank Road, Gross Creek BF74057	Ongoing	Y	Sept. 19, 2013	15000.00	Approved inspection estimate
19	Springbank road W of RR 35, Springbank Creek BF9024	Ongoing	Y	Sept. 19, 2013	20770.00	Approved inspection estimate
33	Bragg Creek Municipal Park	Ongoing	Y	Sept. 19, 2013	20000.00	Approved inspection estimate
34	Springbank Park for All Seasons	Ongoing	N	Dec. 9, 2013	194000.00	Applicant initial estimate only
TOTAL BUDGET ESTIMATES FOR ROCKY VIEW COUNTY ONGOING PROJECTS					<u>\$1,083,770.00</u>	

Townsite of Redwood Meadows Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate (\$)	Comments
1	Northern berm breach	Ongoing	Y	Sept. 10, 2013	838000.00	Approved inspection estimate
2	Sleigh Drive berm breach	Ongoing	Y	Sept. 10, 2013	75000.00	Approved inspection estimate
3	Use of existing rip rap for flood protection	Ongoing	Y	Sept. 10, 2013	465000.00	Approved inspection estimate
4	Water treatment plant	Ongoing	Y	Sept. 10, 2013	75000.00	Approved inspection estimate
5	Playground berm breach	Ongoing	Y	Sept. 10, 2013	690000.00	Approved inspection estimate
6	Berm breach, #18 Redwood Meadows Drive	Ongoing	Y	Sept. 10, 2013	444000.00	Approved inspection estimate
7	Sanitary sewer pumping station	Ongoing	Y	Sept. 10, 2013	70000.00	Approved inspection estimate
TOTAL BUDGET ESTIMATES FOR TOWNSITE OF REDWOOD MEADOWS ONGOING PROJECTS					\$2,657,000.00	

Tsuu T'ina Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate (\$)	Comments
1	Emergency Operations	Ongoing	N	Sept. 25, 2013	60384.22	Applicant initial estimate only
2	Infrastructure Damage	Ongoing	N	Sept. 25, 2013	211611.26	Applicant initial estimate only
3	Housing	Ongoing	N	Sept. 25, 2013	29914.77	Applicant initial estimate only
4	Band Works	Ongoing	Y	Nov. 11, 2013	800000.00	Approved inspection estimate
5	Redwood Meadows Golf Course	Ongoing	Y	Nov. 11, 2013	800000.00	Approved inspection estimate
TOTAL BUDGET ESTIMATES FOR TSUU T'INA FIRST NATION ONGOING PROJECTS					\$1,901,910.25	

TOTAL ESTIMATE OF ONGOING PROJECTS

\$5,642,680.25